THE UNIVERSITY OF MANITOBA

THE EFFECT OF AFFECT:
ASYMMETRICAL HEMISPHERIC ACTIVATION AS A FUNCTION OF EMOTION, LOBE AND DEPRESSION

by

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Abstract

Research on the asymmetry of the structure and operation of the cerebral hemispheres has established that there are a variety of functional differences between them. Of the numerous topics investigated, emotion is perhaps the most pertinent to experimental psychopathology. Evidence from this literature suggests that there are hemispheric differences in activation and subjective experience as a function of type of emotion. Two hypotheses were developed from this literature. Frist, the right frontal lobe was expected to be more activated during emotionally negative stimulation, relative to the left frontal lobe. Correspondingly, the left frontal lobe was expected to be more activated during emotionally positive stimulation. The second hypothesis was that depressed subjects would show an increase in the amount of right hemispheric activation to emotional stimulation in general, as compared to the left hemisphere.

A pretest using 5 female college students was first conducted in order to find 30 auditory stimuli that subjects agreed on as being emotionally negative, neutral, or positive. An experiment was then performed using 57 females to examine asymmetrical cortical activation as a function of three within-subjects factors: emotion (positive, negative and neutral); lobe (frontal, temporal and parietal) and hemisphere. The CES-D Scale was administered to subjects just prior to EEG recording to assess their level of depression.

A three-way repeated measures ANOVA found the effects of Emotion, Lobe and Hemisphere by Lobe to be significant. As emotional stimuli became more negative, greater cortical activation was found. Anterior

areas of the brain produced greater activation relative to other areas, with each hemisphere appearing to differentially reflect this pattern as a function of lobe. This data did not support the hypothesized greater right frontal activation with negative stimuli, but did implicate the frontal lobe, in general, in emotional processing. The second hypothesis was tested by correlating mean hemispheric proportions of activation with depression scores. An increase in depression was found to be significantly associated with a relative decrease in right hemispheric activation, opposite to the predicted direction. These results have several implications for the development of neuropsychological models of emotion and depression.

Table of Contents

List of Figures

List of Tables

The Effect of Affect:

Asymmetrical Hemispheric Activation as a function of

Emotion, Lobe and Depression

Daryl D. Gill

Research on the asymmetry of the structure and function of the cerebral hemispheres, begun at least as early as Wigan (1844), has established that there are functional differences between them. Of the numerous topics investigated, "emotion" is perhaps the most pertinent to experimental psychopathology. The majority of studies on this function, using both normal and clinical populations, have concluded that emotional processing is localized to the right hemisphere (e.g., Flor-Henry, 1979; Ley & Bryden, 1979a, 1979b). This conclusion is generally based on evidence that suggests that the right hemisphere is "superior" to the left in its speed and accuracy of recognizing emotions in others.

Although many of these studies found evidence that each hemisphere reacts differentially to certain kinds, or levels, of emotion, this was usually subordinated in light of the overall conclusion of the right hemisphere's superiority (e.g., Dimond & Farrington, 1977). These interesting findings, however, together with a few studies on the individual's own experience of emotion (not that of judging others') reveal that each hemisphere appears to "feel" or regard emotional stimuli differently. The left hemisphere seems to be differentially biased towards experiencing the same stimuli as being more affectively positive than the right hemisphere, and vice versa (cf. Tucker, 1981).

In light of what is presently known about the nature of hemispheric asymmetries, these recent findings involve two relevant implications. First, they infer that the localization of emotion to the right hemisphere could be an oversimplication. A few investigators have proposed that instead of one hemisphere being "dominant" for emotion, each hemisphere's involvement would be dependent upon the type of emotion being experienced by the individual (e.g., Schwartz, Ahern & Brown, 1979). Negative emotions, such as fear or disgust, would be dealt with more by the right hemisphere, while positive emotions, such as happiness or excitement, would be dealt with more by the left hemisphere. This is consistent with the different emotional biases of each hemisphere. Such an hypothesis could be supported through the use of electrophysiological measures (e.g., EEG or ERP) or cerebral blood flow indices. Currently, only a few studies have directly investigated (and found some support for) this hypothesis, using widely differing EEG measures, electrode locations and stimuli: Harmon & Ray (1977), Davidson, Schwartz, Saron,Bennett and Goleman (Note 3) and Tucker, Stenslie, Roth and Shearer (1981). It was one of the purposes of the present study to further test this hypothesis. This was done through using only nonverbal auditory stimuli with the subjects' eyes closed, to control for artifacts in alpha wave activity due to eye movements, and to control for the well-documented biases of the left hemisphere for verbal stimuli.(Both of these studies used visual and verbal auditory stimuli, but failed to separate their effects to look for any differences due to sensory mode).

The second relevant implication is concerned with the clinical significance that seems to follow from the finding of hemispheric biases in emotional experience. It was hypothesized by this author (Gill, Note 1) that if the right hemisphere has a more negative emotional bias than the left, then depressed populations should typically show an abnormal increase in the amount of right hemispheric emotional processing reaching awareness. The other purpose of this study, then, was to provide one way of testing this hypothesized change in the "balance" of hemispheric processing. The specific prediction that was advanced was that more depressed subjects should, in general, show a greater right hemispheric activation to emotional stimuli compared to more "normal" subjects (relative to the left hemisphere).

The following review will serve to trace the empirical and theoretical basis of these hypotheses. A review of the early history of the study of cerebral laterality, including its dependent measures, will lead into an outline of localized cognitive functions. Emotional hemispheric asymmetries will then be discussed, and evidence supporting hemispheric biases in emotional experiencing will be presented. These emotional asymmetries in hemispheric involvement will then be applied to depressed populations. Finally, some of the history and rationale behind using the alpha band of an electroencephalograph (EEG) as a dependent measure, and the exclusive use of females as subjects will be discussed.

Development of Research in Hemispheric Asymmetries

Herman Ebbinghaus, a nineteenth century pioneer in the study of mental processes, once remarked that while psychology has a short history, it has had a long past (Halpert, 1977). This is perhaps most appropriate to man's early belief in a duality in his personality or conscious self. A part of long-dead civilizations' religion and philosophy, the "scientific" study of this subject dates back to at least Hippocrates of Croton who, in the fifth century B.C., pointed out the duality in the structure of men's (and animals') brains. However, it has only been during the past century that investigators have discovered that this duality is not symmetrical. Increasingly, various mental styles and capacities have been found to be lateralized within the cerebral cortex of the brain. Using procedures that present information to only one of the two hemispheres (e.g., Hines, 1978; Murray & Richards, 1978) and evidence from patients who have had the tract of brain tissues that enjoins them (the corpus callosum) severed (e.g., Gazzaniga, 1970; Sperry, 1968), researchers have found that each side of the brain seems to be specialized, or able to do a faster and/or more accurate job of "processing" certain kinds of stimuli than the other. In addition, neurologists, through human cortical stimulation (e.g., Penfield & Roberts, 1959), the carotid amytal test (e.g., Wada & Rasmussen, 1960), electrophysiological measures (e.g., Molfese, Freeman & Palermo, 1975) and gross anatomical measurements (Galaburda, Le May, Kempa & Geschwind, 1978) support the idea of cerebral hemispheric asymmetries, or inequalities, in both structure and function.

A pioneer in this research was Wigan (1844), who believed that he was able to prove that "a separate and distinct process of thinking or ratiocination may be carried on in each cerebrum simultaneously" (Dimond, 1972, p. 179). He based his theory partly on the discovery of patients who, upon autopsy, were missing or had had destroyed an entire cerebral hemisphere, apparently with no noticeable effect while alive. Wigan may also have been the first author to have believed that the hemispheres are not always functionally complimentary, when he stated that "however intimate and perfect their unison in their neutral state, they must occasionally be discrepant when influenced by disease, either direct, sympathetic or reflex" (Dimond, 1972, p. 179). Jackson (1864) expanded upon this discrepancy, stating that the two cerebral hemispheres had different abilities, with the left hemisphere being the "faculty of expression" (Ornstein, 1972, p. 2) and the right dealing with knowledge of people, places, and things. Brown-Sequard (1877) went even further and claimed that man had two brains, completely different from one another and corresponding to the left and right hemispheres. In support of this, Fernier (1886) claimed that while the brain was a unitary organ made up of two halves when it dealt with motion and sensation, it was a dual organ when it dealt with ideation, with each hemisphere working autonomously from the other.

Beyond these attempts at simply advancing the idea of the existence of two separate "minds", research was also done on the relative specializations of each brain. Although the mapping of various cerebral faculties was initiated by L.C. Meyer (1779) it was not until Paul Broca (1861a, 1861b) that clinical evidence was presented. Upon the discovery that two of his patients with a similar impediment of articulated speech both had a lesion in what is now known as Broca's area (the posterior third of the inferior frontal convolution of the left hemisphere), he concluded that he had found the "center of motor forms of speech" (1861b). Following this, a profusion of "centers" were found by experimenters by examining the location of a lesion and correlating it with the type of mental disturbance that arose as a result. Bastian (1869) found the "centers of visual memory"; Wernicke (1874), the center of "sensory images of speech", now known as Wernicke's area (the posterior third of the superior temporal gyrus of the left hemisphere); Broadbent (1872 & 1879), Charcot (1887), and Grasset (1907) the "centers of ideation"; and Exner (1881), the "writing centers".

With these beginnings, the neuropsychological literature continued, for the next fifty years, to "map out" various areas of the brain using post-mortem examination and clinical observation. For these investigators, the left hemisphere developed great significance, for it was this half of the cerebral cortex that appeared most involved with talking, writing and speech comprehension.

Then, during the 1930's and '40's, three new procedures were developed which advanced the study of brain function in live human beings. First, in cooperation with others, Penfield (e.g., Penfield & Boldrey, 1937) began using electrical stimulation of different cerebral areas with an electrode on conscious patients during brain surgery. What the patient reported perceiving as a result not only prevented the unnecessary removal of certain tissues (by avoiding speech areas when removing a tumour, for example) but also mapped out new locations of various mental functions on the brain's topography. (For example, Penfield and Roberts (1959) reported a "new" speech area found in the supplementary motor area.) Secondly, Wada (1949) made it possible to study one hemisphere at a time, with the development of the intracarotid sodium amytal test. This effective barbituation of one or the other hemispheres has been used since by a number of investigators, including Branch, Milner and Rasmussen's (1964) extensive study of speech and handedness, and Rossi and Rosadini (1967) and other investigators' studies of "emotional" reactions following contralateral inactivation. Third, during the early 1940's, the "relations" between the hemispheres unexpectedly came under systematic observation for the first time with the beginnings of the use of commissurotomy. (This surgical operation involves the sectioning of the corpus callosum -- the tissue that spans the midline of the brain, connecting the two cerebral hemispheres -- and the smaller anterior commissure.) At the time, this procedure, first performed by von Wagenen and Herren (1940), was designed to limit the interhemispheric spread of chronic uncontrollable epileptic seizures. Case studies of patients who had undergone commissurotomy led Akelaitis and his collaborators to some surprising conclusions (Akelaitis, 1940, 1941a, 1941b, 1942a, 1942b, 1944; Smith & Akelaitis, 1942). With each hemisphere not able to communicate directly with the other, a stimulus could be presented to only one or the other side of the brain, with the almost certain knowledge that the ensuing reaction was only due to that particular hemisphere's having processed it. In contrast to previous work, the localization of verbal processing exclusively to the left hemisphere was not supported, for the right hemisphere was found to be capable of taking on speech functions and of certain aspects of visual perception (Akelaitis, 1942a, 1942b). This work was later elaborated on by Sperry and his associates, who also found a surprising amount of involvement of the right hemisphere in normal functioning, especially visuo-spatial tasks (Sperry, 1966, 1967, 1968, 1973); Sperry & Gazzaniga, 1966; Sperry, Gazzaniga & Bogen, 1969).

The results of all this research on (usually) medical patients stimulated the investigation of cerebral asymmetries using normal populations, as well. The study of hemispheric differences in receiving visual information in normals first began to appear in the early 1950's. Forgays (1953), Mishkin and Forgays (1952), and Orbach (1953) all found that their subjects recognized letters and words of their own language better when they were flashed to the right of the fixation point in a tachistoscope. Kimura (1961) was one of the first researchers to attribute this as a function of the opposite, or left, hemisphere. Since this time, the tachistoscope has become the most frequently used instrument to selectively present information first to either the right or left hemisphere. The rationale for its use is as follows: since objects in an individual's left visual field are reduced to nerve impulses originating at the right side of the retina of both eyes, they are then transmitted to be integrated at the calcarine fissure of the occipital lobe of the right hemisphere (Clark, 1975). The opposite would hold true for objects in the right visual field. This effectively means that stimuli that are presented to one side of a central fixation point will be seen first by that same side/hemifield of the eyes, and then be transferred to be processed first at the opposite, or contralateral, hemisphere. To ensure that the hemisphere of interest receives the input first, the stimuli are presented for a shorter duration of time than that necessary for the eyeball to move from looking straight ahead (where only the relevant hemifields would receive the visual information) to looking more directly at the target stimulus (where both hemifields would be receiving the visual information).

Studies of hemispheric differences in dealing with auditory stimuli present more of a complex problem to investigators. Whereas visual input goes from one field of vision to the contralateral hemisphere, the central auditory pathway consists of both contralateral and ipsilateral connections. Both ears are "represented" bilaterally in several areas of the brain stem through to the medial geniculate body. The majority of the fibers, however, are contralateral (Clark, 1975) and the weight of empirical evidence has shown that with simultaneous input to both ears, a similar contralateral relationship exists between an ear and its opposite side hemisphere as exists between a field of vision and its opposite side hemisphere. Studies of auditory asymmetries in normals began in earnest in the early 1960's (e.g., Kimura, 1963) using a procedure first devised by Broadbent (1954). Now commonly referred to as a dichotic listening procedure, Broadbent simultaneously presented auditory input to each ear using a two-channel tape recorder and a pair of stereo headphones. Since only one ear/hemisphere is of interest at a time, white noise (or a similar distractor) is typically used in the ear not receiving the "target" stimulus.

As a result of the propogation of these research procedures during the past two decades, an increasing amount of information on hemispheric differences is based on them. Since a knowledge of "cognitive" differences is helpful in the interpretation of "emotional" ones, they will be discussed first. A general survey of these differences is outlined below.

Cognitive Hemispheric Asymmetries

The right hemisphere, long regarded as the inferior half-brain, has of recent been attributed with superiority in a number of wide-ranging cognitive activities. Dimond and Beaumont (1972) found that it was more accurate in calculation and numerical functions, and this was to some extent supported by Sperry (1968) and Levy-Agresti (1968) and confirmed by other researchers (Dimond & Beaumont, 1974). Perhaps the best substantiated superiority of the right hemisphere is in spatial thought discrimination, found for example by Hécaen and Angelerques (1963), Milner (1968, 1971), James et al (1967), Sperry (1968) and Gazzaniga (1965). Teuber and Diamond (1956) found it to play a disproportionate part in binaural localization. Perception of musical melodies and tunes (musical ability) has also been well identified with the right hemisphere by Kimura (1964), Shankweiler (1966), Spellacy (1970), Spreen, Spellacy and Reid (1970); and by Gordon (1970) and Kallman and Corballis (1975). Dimond and Beaumont (1974) also suggest that the right has the capacity for creative thought and associative thought. As well, the right is superior in controlling manual tasks involving the arms, hands, legs and feet on the left side of the body (e.g. Corballis and Beale, 1976, for an extensive review). The right half-brain is apparently superior in tactile abilities, too, such as tactile memory (Milner & Taylor, 1972). In addition, Geffen, Bradshaw and Wallace (1971), Rizolatti, Vmilta and Berlucci (1971), Bradshaw, Geffen, and Nettleton (1972), Patterson and Bradshaw (1975) and Ley and Bryden (1979b) all found the right hemisphere to be better at facial recognition. It is also possible (though more hypothesis than fact) that this hemisphere is the center of talent/artistic abilities (such as dance or sculpture) and creativity (fantasy, etc.) (de Bliek & Quinn, 1979). One capacity that is substantiated that may have a critical effect in our behavior is the right hemisphere's more prominent ability for imagery (Seamon & Gazzaniga, 1973). This becomes an especially interesting capacity if one accepts Paivio's (1971) assertion that imagery is a key part of communication, long regarded as the domain of the left hemisphere.

The left hemisphere, long regarded as the dominant half-brain, is specialized for at least as many activities as the right. One of the reasons for its dominant status has been, of course, its superiority for the production and perception of speech and language. This capacity has been well documented by several authors, such as Studdert-Kennedy and Shankweiler (1970), Springer (1971) and Gott (1973). As well, Meyer and Yates (1955) and Milner (1958, 1962) advance the view that the left hemisphere is also superior in verbal memory, while others have found it to have a better sequential memory. There is also considerable evidence that the two hemispheres differ in their experience of time, with the left superior in the perception of passing time and sequence (Carmon & Nachson, 1971; Efron, 1963a, 1963b, 1963c, 1963d; Swischer & Hirsch, 1972).

In consideration of these different cognitive abilities, it appears worthwhile to consider three cautionary remarks. First, the mere listing of tasks that are assigned to a particular hemisphere has been interpreted by some authors not as a mapping of the brain according to specializations, but rather as processing styles. Ornstein (1972, 1976, 1977), for example, regards these specialized abilities as a "function" or product of each hemisphere's unique processing style, the left being verbal/rational, the right being spatial/paralogical. Secondly, all investigators seem to implicitly assume that if a hemisphere is specialized for a task, then it will necessarily be better or faster at recognition. While such an assumption may be logical for a left hemisphere style that is more concerned with reality, survival and environmental demands, this may not be applicable to the less "reality oriented" right hemisphere (Ornstein, 1977). Third, most of the studies are attempting to show only a degree (not type) of difference between each hemisphere, and often the degree may be small. (For a recent example, Buchtel, Ruzzulatti, Anzola, and Bertoloni (1978) found a right hemisphere superiority for an audio-discriminative reaction time experiment. The largest difference amongst subjects was 29 msec -- 573 msec at the left ear and 602 msec at the right ear.)

Emotional Hemispheric Asymmetries

Localizing Emotion to the Right Hemisphere

Although the proposal that the right hemisphere is "dominant" for emotion has been prevalent in the literature for less than ten years, it was first hypothesized over a century ago by Hughlings-Jackson (1879). Discovering that individuals who were not able to use "propositional" speech because of left hemisphere lesions were still able to express emotions through the tone and pitch of their utterances, he concluded that the (intact) right hemisphere must be responsible for mediating affective language. In the past decade, Hughlings-Jackson's (1879) example of using brain damaged patients as subjects in hemispheric investigations has become fairly common. Wechsler (1973) found in patients with organic brain diseases that their recall of "emotionally charged" verbal stimuli was better in patients with intact right hemispheres as compared to intact left hemispheres. Heilman, Scholes and Watson (1975), in examining patients with lesions of the right hemisphere, found that they could not comprehend the emotional meaning in verbal material because of this damage. This finding was extended by Tucker, Watson, and Heilman (1977) who found that right hemisphere lesions led to an impaired ability to discriminate emotional verbal material, in addition to a deficit in comprehension.

Work on hemispheric asymmetries in auditory processing in normals may have began in a study by Haggard and Parkinson (1971) (although they themselves did not conceive of their study in hemispheric terms). Six different kinds of sentences that varied in emotional tone (angry or happy, for example) were presented to one ear of the subjects, while white noise was given to the other. The task of the subjects was to identify the sentence content and the tone of voice used. It was found that although there were no differences in recognizing the content, there were differences for the emotional tone, with the subjects being superior at identifying tones presented to the left ear (right hemisphere) as compared to the right ear (left hemisphere). A similar left ear (right hemisphere) superiority was found by King and Kimura (1972), in the identification of non-verbal human sounds such as crying or laughing. Carmon and Nachson (1973) followed up these studies by an effort to minimize confounding due to left hemisphere influences by removing all verbal components from both the experimental stimuli and the subjects' task. This was attempted by having subjects match three types of dichotically presented "emotional" voices (laughter, shrieking and crying) with the appropriate facial drawing on a pictorial display in front of them. Finding a small but significant left ear (right hemisphere) advantage, they were among the first in the literature to conclude that this implicated the right hemisphere "in perception of emotional stimuli" (p. 356). Safer and Leventhal (1977), in reporting two experiments, made predictions based on this previous work but argued against the necessity of the dichotic listening procedure. In the first study, they had subjects rate monaurally presented passages that differed in emotional tone and content as being positive, negative or neutral. They found that most of the subjects who were given the stimuli to the left ear (right hemisphere) used the voice tone to rate the passage, while those receiving stimuli to the right ear (left hemisphere) used the content of the passage. These results were taken as support for the hypothesis "that the right hemisphere is critically involved in the perception and evaluation of emotional stimuli" (p. 78). In the second experiment, in which subjects were specifically told to use both tone and content to rate the passages, a right ear (left hemisphere) superiority in "accuracy" was found.

Similar support for a right hemisphere superiority in emotional comprehension has been claimed in studies using visual stimuli. Suberi and Mc Keever (1977) may have been the first to do so, drawing upon some of the previously discussed studies in audition, as well as evidence from the literature on facial recognition, as bases for their hypothesis. Their female subjects were presented with two photographed "target" faces to memorize, and later to discriminate, from a pair of "non-target" faces presented tachistoscopically. One of the findings was that subjects who had to learn "emotional" faces were faster in discriminating faces shown to the left visual field (right hemisphere) compared to the right visual field (left hemisphere). Although subjects who memorized "nonemotional" faces also showed a left visual field superiority, this was significantly smaller than that found for subjects with "emotional" faces. In another study involving reaction time, Landis, Assal and Perret (1979, Experiment 1) presented their subjects with a drawing of a face at the point of fixation, and a photograph of a face either to the left or right of fixation. Their task was to stop a timer whenever the facial expression of the drawing and photograph matched (either happy, astonished or angry). Results showed, as expected, that photos presented to the left visual field (right hemisphere) were correctly matched faster than those shown to the right visual field (left hemisphere).

In a similar experiment using accuracy rather than reaction time as a dependent measure, Ley and Bryden (1979b) presented cartoon faces expressing one of five emotional expressions to either the left or right visual field. Subjects were then presented with another facial drawing presented at the fixation point, and asked to judge whether the type of emotion and the cartoon figure itself were the same as the face previously shown. They found a left visual field (right hemisphere) superiority for both tasks. Further, each task was claimed to be independent of the other: accuracy in recognizing the cartoon figures was not related to the type of emotion expressed, while the discrimination of the emotional expression was found to be related.

Another dependent measure that has been used has been emotional "intensity". Sackheim and Gur (1975) had their subjects rank order the four emotions (out of seven listed on their rating sheet) that were most prevalent in each of a series of slides of faces presented up on a screen. Subjects were also instructed at the same time to rate the intensity of the emotion that was present for each slide. Some of these slides were "composites", in which a photograph of the left facial side was joined with its "mirrored" opposite, and then rephotographed, so that the final slide was completely symmetrical (actually consisting of two left-sided halves). This was also done for the right facial side. Each subject received several left side, and right side composites, as well as originals, displaying one of seven types of emotions. Their finding of interest here was that left side composites were seen as being more emotionally "intense" than the right side composites. They concluded that their results "point to greater right hemispheric involvement in the production of emotional expression" (p. 478). Borod and Caron (1980) also used "facedness" and intensity ratings, but in a somewhat different mannner, to obtain "more natural expression" (p. 237). Subjects were asked to imagine themselves in various realistic situations, in order to produce nine different facial expressions (for example, "toughness", "flirtation", or "greeting"), and then filmed as they produced the appropriate gestures. For each expression of each subject, the film frame believed to be the most expressive was given to three raters who (independently) rated them on a 15-point scale as to which side of the face was most intense. Their findings indicated that overall, the left side of the face was judged as the most intense, although when the nine expressions were analyzed separately, only "disgust", "disapproval" and "grief" were significantly left-sided. They concluded that they had found support for the prediction "that facial expression would be primarily related to the emotion and thus mainly innovated by the right hemisphere" (p. 240).

The general conclusion that has been drawn from all of these visual and auditory studies of hemispheric asymmetries is that, in the least, the right hemisphere is superior in speed and accuracy of emotional processing. (At most, the right hemisphere has overall responsibility for emotions, being "dominant" over the left hemisphere for any functions involving emotional stimuli). Most recently, however, there have been a few indications that evidence for even this first conclusion is far from equivocal. With regard to auditory asymmetries, Megibow and DeJamaer (1979) failed to find the expected left ear (right hemisphere) superiority, or for that matter, any differences at all between ears of presentation. Presenting their subjects with various four-letter nouns given to either the right or left ears, they had them discriminate between the emotional and non-emotional words. The former were to be responded to by stopping a timer with the middle finger of either the left or right hand; the latter were stopped by using the index finger of the same hand. Although they found a significant practice effect, and a difference in reaction times between emotional and non-emotional words, they failed to find a difference for ear of presentation. In attempting to account for these results, they interpret the previously found right hemisphere superiority as not being due to its natural, or innate qualifications, but to its being less "disrupted" by arousal than the left hemisphere. Their own study, however, was seen as unarousing, so the left hemisphere was not disrupted, and thus the right hemisphere failed to gain an "advantage". As for visual asymmetries, Hansch and Pirozzolo (1980), also failed to find a right hemisphere superiority in a task dealing with emotional stimuli. There were four categories of stimuli very briefly presented to either the left or right visual field: emotional faces, neutral faces (both were photographs), emotional words, and neutral words. Prior to their presentation, the subjects were verbally given a "cue word". For the two emotional conditions, this word was one of their emotions, while for the two neutral conditions, the word was one of three female names. After both the cue word and the visual stimulus had been presented, the subject's task was to judge whether or not the two were in the same category ("same" or "different"). Although the left visual field (right hemisphere) had faster reaction times with emotional faces, the times did not differ from those found with neutral faces. In addition, other results of the study led the authors to conclude that emotional processing and facial recognition/processing cannot be regarded as independent. (This is in contrast to Ley and Bryden's, 1979b, assertion.) In accounting for their results, Hansch and Pirozollo (1980) emphasize the importance of the task requirements, noting that the processing of emotional faces, unlike that of facial recognition, "does not lead to enhanced right hemisphere superiority" (p. 58).

The possible effects of the subject's experimental task have also been mentioned elsewhere (Gill, Note 1). First, the division between "cognitive" and "emotional" tasks or stimuli is imperfect, at best, for all "emotional" studies require some cognitive processing on the part of the subject, and some "cognitive" studies may evoke unexpected, covert emotional reactions. The right hemisphere superiority "found" by many researchers using "emotional" stimuli (and/or an "emotional" task) may not have been due to the emotional component, but to the cognitive components of the experimental tasks. The effect of task is easily demonstrated by the findings of certain investigators who have even found a reversal of predicted performance in dealing with certain classes of stimuli (verbal or pictorial, depending upon the task involved. Klatzky and Atkinson (1971), for example, presented their subjects with pictures of objects (right hemispheric stimuli) but gave them the task of comparing the first letter of each new object with those already viewed (a left hemisphere task). As a result, a left hemisphere superiority was obtained. Alternately, Gibson, Dimond and Gazzaniga (1972) found a right hemisphere superiority for subjects given a word-matching task (left hemisphere stimuli) when they could only respond to the physical nature of the verbal material (a right hemisphere task).

The choice of task leads into the second reason for viewing these "emotional" studies with caution. Although tasks involving speed and/or accuracy measures may be relevant for more "cognitive" abilities such as mathematical skills or spatial coordination, it should be questionable as to what extent they apply to emotional processing. As with more "cognitively" oriented research, these differences in speed or accuracy may be small. In addition, they seem to ignore the fact that such an experimental design dictates that one or the other (or neither) hemisphere will be superior (Colbourn, 1978) and fail to allow for evidence that both may be equally involved. Moreover, once a superiority is found, it is difficult to interpret what it means. Since the emotional side to human behavior may be far from rational, (especially the less reality oriented right hemisphere: Galin, 1977) all that can be said is that the right hemisphere appears to be more oriented towards gauging others' emotions, and not the subject's own. As Tucker et al (1977) recognized in their accuracy study (of the ability to discriminate affective speech and reproduce certain emotional tones in patients with right parietal disease) nothing can be claimed about what or how the subjects "feel" themselves (p. 950).

Asymmetries in the Subjective Experience of Emotion

Unfortunately, there are very few studies which have, indeed, looked at asymmetries in what the subjects are "feeling". In terms of the value of such research in clinical psychology and psychiatry, it is believed that any approach that concentrates more on delineating the hemispheric parameters of subjective experience may be more fruitful than a simple phrenological approach that localizes all of emotional processing to one or the other hemisphere.

The possibility that each hemisphere may react to stimuli in an emotionally different manner was first suggested by observations on individuals with various unilateral brain disorders. Goldstein (1939,

1948) in commenting on patients with lesions to the left hemisphere, noted they shared a similar emotional state which he termed a "catastrophic reaction". Thus, when only the right hemisphere was intact, the individuals evidenced a pronounced negative emotional reaction. Correspondingly, Denny-Brown, Meyer and Horenstein (1952) and Hécaen, Ajuriaguerra and Massonet (1951) have found that patients with right hemisphere lesions shared a relaxed, unpreturbed mood which was referred to as an "indifference reaction". Gainotti (1972), in a study of patients with damage to either the left or right hemisphere, confirmed these findings: right hemisphere-intact patients were anxious, crying and hostile, while left hemisphere-intact patients were jocular and indifferent.

Evidence of this pattern of "positive reactions" from the left hemisphere and "negative reactions" from the right has also been found in commissurotomized individuals. Sperry (1968), for example, found that these "split-brain" patients were more likely to react negatively, or be displeased, when a stimulus was presented to the right hemisphere than when it was presented to the left hemisphere.

These differential emotional states were stimulated in normal subjects in a series of studies by Hécaen and Ajuriguerra (1963), Perria, Rosadini and Rossi (1961), Terzian (1964), Terzian and Cecutto (1959) and Rossi and Rosadini (1967). They all used a well-documented procedure (cf. Rossi et al, 1967) termed the "sodium amytal procedure" in which this barbiturate is injected into either the left or right carotid arteries, resulting in the pharmacologic inactivation of the corresponding cerebral hemisphere. All studies found similar results: when the right hemisphere was inactivated, the patient exhibited a cheerful or euphoric response, while left hemisphere inactivation led to a catastrophic-depressive reaction.

Thus, in all of these studies in which one hemisphere's functioning is interrupted, destroyed, or paralyzed, we are able to observe that individual's emotional state, and attribute it as being at least partly a function of the emotional bias of the intact hemisphere. Inferences about normal functioning from these populations certainly need testing on normals themselves. However, this is a point which, judging by the paucity of emotional "experiences" studies on normals, appears to have been overlooked in the literature.

Sackheim and Gur (1978) (in their previously discussed study on the emotional intensity of facial composites), found that while sadness, disgust, fear and anger intensity ratings (all negative emotions) were higher for left side (right hemisphere) face composites, happiness (a positive emotion) was rated higher for right side (left hemisphere) composites. Although this offers some support for hemsipheric differences in emotional bias, at present there may have only been the three studies outlined below which have specifically tested for these differences.

Dimond, Farrington and Johnson (1976) used specially designed contact lenses (Dimond, Bures, Farrington and Brouwers, 1975) to project visual input from three silent films to either the left hemifields (right hemisphere) or right hemifield (left hemisphere) of both eyes. The films consisted of a surgical operation (emotionally negative), a travel sequence of Lucerne, Switzerland (emotionally neutral) and a "Tom and Jerry" cartoon (emotionally positive). The subject's task was to rate each film on a 1 - 9 scale on dimensions of humor, pleasantness, unpleasantness and horror. They found that the right hemisphere group of subjects rated all three films as being more unpleasant, and all but the "neutral" travel film as being more horrific, than the left hemisphere group. (Differences between type of film and hemisphere group failed to be found for the other two dimensions.) Based on these results, they concluded "that the two hemispheres of the brain of man possess an essentially different emotional vision of the world" (p. 691) with the right hemisphere regarding events in a more unpleasant and horrific light than the left hemisphere.

Beaton (1979) also found hemispheric asymmetries in subject's experience of emotion, but in the direction opposite to that of Dimond et al (1976). He used a dichotic listening paradigm to present three selections of instrumentals and three poems to either the left or right ear of the subjects with the other ear receiving white noise. After each presentation, subjects rated the stimuli on a 1 - 9 scale on three dimensions: "Pleasant-Unpleasant", "Cheerful-Depression" and "Soothing-Irritating". Results of these ratings showed a significant effect for ear of presentation, with the left ear (right hemisphere) judging both music and poetry to be more "pleasant", and the music (but not poetry) as also more "soothing". (The "Cheerful-Depressing" dimension failed to show any significant effects or interactions.) Beaton, like Dimond et al (1976), interpreted the results in terms of differences in hemispheric emotional outlook, but in the opposite direction, with the right hemisphere "more disposed towards seeing the bright side of life than is the left hemisphere" (p. 108).

In an effort to resolve this marked discrepancy in the literature, Gill (Note 2) explored hemispheric differences in subjective emotions using both visual stimuli (as Dimond et al, 1976 used) and auditory stimuli (as Beaton, 1979, used) to test for differences due to this aspect of methodology. To control for well-documented biases of the left hemisphere for language (e.g., Studdert-Kennedy & Shankweile, 1970) and the right hemisphere for tones and melodies (e.g., Gordon, 1970), spatial discrimination (e.g., Gazzaniga, Bogen & Sperry, 1964) and facial recognition (Hansch & Pirozzolo, 1980), the stimuli were different from any used previously: non-numeric, non-verbal "traffic" lights, signs and sounds. To examine a possible interaction effect involving the type of emotion, these stimuli were classified in a pretest as being either very negative, mildly negative, neutral, mildly positive or very positive. Subjects were presented the auditory and visual stimuli to either one ear/visual field or the other using a dichotic listening paradigm and a tachistoscope. (The visual and auditory stimuli were interspersed in a random order.) They were then asked to rate on a 1 - 15 scale their emotional reaction to each stimulus upon its conclusion, in the context of a simulated driving experience. It was found that the effects of Hemisphere and Emotion were significant, with subjects in the left hemisphere group experiencing both the visual and auditory stimuli as more "positive" than right hemisphere subjects. Differences between each hemisphere groups' ratings appeared greatest with the mildly and very negative, and the mildly positive emotions. It was concluded that the left hemisphere, in comparison to the right, attaches a more positive emotional value to its input.

Hemispheric Involvement as a function of Type of Emotion

The findings of Dimond et al (1976) and Gill (Note 2) are not inconsistent with another body of literature which suggests that the localization of emotion to the right hemisphere is an over generalization -- studies indicating that each hemisphere is neurophysiologically more active with different emotions. It would seem logical and certainly worthy of investigation that the right hemisphere, having more of a negative emotional bias, may have a greater involvement with negative emotions, with the left hemisphere having more involvement with positive emotions. Evidence of this biological relationship has been found using a vareity of measures of hemispheric involvement.

Dimond and Farrington (1977), presented their subjects with the same series of three films as in their Dimond et al (1976) study (a "neutral" travel film, a "negative" surgical operation and a "positive" Tom and Jerry cartoon). While subjects viewed these films through special contact lenses that transmitted the visual input (first) to either the left or right hemisphere, the experimenters recorded their heart rate throughout the film's duration. They found that the mean heart rate (or "affective response") to the emotionally negative medical film was greater when presented to the right hemisphere. Correspondingly, the mean heart rate to the emotionally positive cartoon film was greater when presented to the left hemisphere. Interestingly, they failed to find any hemispheric differences for the "neutral" travel film.

Lateralized hemispheric involvement has also been found using facial electromyography (EMG) as the dependent measure. Schwartz, Ahern and Brown (1979) measured bilateral EMG from the zygomatic and corrigator muscle regions under two conditions: In (involuntary) response to various emotionally positive, negative and neutral questions and under instructions from the experimenter to (voluntarily) produce four different facial expressions (two "positive" and two "negative"). For the involuntary condition, emotionally positive questions were found to elicit greater right zygomatic muscle activity (left hemisphere involvement) than left muscle activity (right hemisphere involvement) while negative questions elicited greater left zygomatic muscle activity (right hemisphere involvement) than right muscle activity (left hemisphere involvement). It was also found that this effect was greater for the more "intense" emotional questions (fear and happiness) than for the less intense questions (sadness and excitement) in both the zygomatic and corrigator muscle groups. This effect was also found for both muscle groups in the voluntary condition. (They failed, however, to find any lateralization for type of emotion in the corrigator muscles in the involuntary condition, and for both muscle groups in the voluntary condition).

Further evidence for these hemispheric differences has been found in several studies using conjugate lateral eye movements (LEM). This has previously found wide use as an indicator of hemispheric activation (e.g., Galin & Ornstein, 1974; Gur, 1975; Gur, Gur & Harris, 1975; Weiten & Etaugh, 1974), although the procedure has not gone uncriticized (Ehrlichman & Weinberger, 1978). Tucker, Roth, Arneson, and Buckingham (1977) tested the hypothesis that putting a subject under stress would increase the right hemispheric activation. In the emotionally "neutral" condition, subjects were asked a series of questions varying in two dimensions (verbal-spatial and emotional-nonemotional) and told that this was simply to calibrate a "dummy" electroencephalograph. In the "stress" condition, the subjects were told their responses to the questions were indicative of the quality of their intellect and personality. They found that across the verbal-spatial dimension, there were more eye movements to the left (indicative of greater right hemispheric activation) to emotional questions in the stress condition than in the non-stress condition. Although they concluded that these results demonstrated the "importance of the right half of the brain in affective experience" (p. 699) it is suggested here that, more specifically, this provides support (only) for greater right hemispheric activation with negative emotion, with "stress" (or anxiety or fear) in this case being the negative emotion. Neutral and positive stimuli were studied, as well, by Schwartz, Ahern, Davidson and Pusar (Note 6). They asked subjects a series of emotionally positive, negative, and neutral questions, and then measured any movements of the eyes to either the subject's right or left side. These investigators found that positive questions evoked more eye movements to the right than to the left (greater left hemispheric involvement) while negative questions evoked more eye movements to the left than to the right (greater right hemispheric involvement). Neutral questions failed to lead to any hemispheric differences. In a similar experiment which added a verbal-spatial dimension to the positive (happiness and excitement) and negative (sadness and fear) emotional questions, Ahern and Schwartz (1979) again found more eye movements to the right (left hemispheric involvement) to positive questions and more movements to the left (right hemispheric involvement) to negative questions. They also found the effect of type of emotion to be more robust than the effect of the verbal-spatial manipulation, leading them to "suggest that lateralization for positive and negative emotion may be a more fundamental aspect of [human] neural organization than lateralization for verbal/spatial processing" (p. 696). In light of the fact that hemispheric differences in verbal and spatial processes are probably the best documented of all asymmetrical functions (as previously outlined in this paper) this is certainly a significant statement in support of hemispheric emotional biases.

Although these studies certainly support a lateralization of hemispheric involvement with different emotions, the most direct means of assessing this would be with instruments that measure either subtle changes in cerebral blood flow (CBF) or electrocortical activity (EEG). Although the study of cerebral blood flow has been valuable in crudely mapping out areas of the brain involved in cognitive tasks (e.g., Lassen, Ingvar & Skinhøj, 1978) and in establishing that electroencephalographic (alpha band) and lateral eye movement measures are valid indices of hemispheric activation, in comparison (Gur & Reivich, 1980) there have been no investigations of bilateral differences with varying emotions. (Although Shakhnovich, Serbinenko, Razumovsky, Rodionov & Oskolok, 1980, claimed to have examined the "emotional state", no manipulations of emotionally arousing stimuli were performed, nor were any bilateral differences looked for.)

A similar lack of research has been done using electroencephalographic measures. At present there are only a few studies which have examined hemispheric asymmetries in activation with emotional stimuli, with each using different means of analyzing the EEG output. In light of its potential value in testing for, and defining the parameters of, this emotional lateralization, this is indeed frustrating.

Harman and Ray (1977) were among the first to bilaterally record the emotional responsivity of normals. Their experiment began by having the subjects verbally recall events from their past in which they had felt distinctly happy, sad, fearful or angry. The experimenter then decided which of the three negative emotional memories contained the most "meaningfulness, concern and anxiety" (p. 458), using this as the "negative" emotional stimulus and the happy memory as the "positive" stimulus. He then literally "replayed" these experiences back to subjects for 35 seconds on the pretext of coaching them on how to "self-generate" the emotions involved. During this time, and EEG was recording hemispheric activity between 3 and 30 Hz from monopolar electrodes on the temporal lobes (T_3 and T_4) referenced to the center of the scalp (Cz). Analyzing the data in terms of power (voltage x time) they found that the total left hemispheric power was greater than that for the right hemisphere during the positive emotional stimulation, while the total right hemispheric power was greater than that for the left hemisphere during the negative emotional stimulation. (However, since the left hemisphere, but not the right, evidenced a significant effect for time and treatment, Harmon and Ray concluded that the left hemisphere is more reflective of emotional changes.)

Davidson, Schwartz, Saron, Bennett and Goleman (Note 3) also found evidence for a lateralization of hemispheric affective response. In one experiment, subjects were presented with segments of a television show that varied in emotional content, and were instructed to press up or down on a pressure-sensitive knob in accordance with how much they liked or disliked the selection, respectively. During the presentation, an EEG recorded and digitized activity between 8 - 13 Hz (alpha band) from the frontal (F_3 and F_4) and parietal lobes (P_3 and P_4) referenced to Cz. Both the readings from the pressure-sensitive knob and the EEG measures were taken every 30 seconds. Those values of EEG that corresponded to the most liked and disliked segments, as per the pressures readings, were used to form the ratio of $\frac{R - L}{R + L}$ alpha amplitude. It was found that for the frontal lobe area, the left hemisphere was more activated than the right with the positive emotional segments, while the right hemisphere was more activated than the left with the negative emotional segments. (EEG from the parietal lobe area failed to show significant hemispheric differences.) In another experiment, subjects were simply asked to self-generate emotionally negative and positive imagery, during which time frontal and parietal alpha activity was recorded by the EEG. The results basically replicated the first experiment, with the finding of greater left hemispheric activity with positive emotions and greater right hemispheric activity with negative emotions, in the frontal lobes.

Similar results were found in one of two experiments by Tucker, Stenslie, Roth and Shearer (1981). After giving subjects descriptions of "manic" (or "euphoric") and "depressive" mood states, subjects (with eyes closed) were asked to evoke similar emotions within themselves, using one minute of reflecting upon relevant personal experiences to enhance the mood intensity. (For each mood state, subjects also performed an arithmetic and an imagery task, representing left or right-hemispheric-specific activity.) Tucker et al suggested from this data that compared to the "euphoric" state, the "depressive" state showed the right frontal lobe to be more activated, and the left frontal lobe to be less activated.

In interpreting the results of these EEG studies, certain methodological criticisms can be made which may prove important. First, it is often unclear what sensory mode is influencing the results. In Harmon and Ray's (1977) study, verbal input appears as the principal medium, but since the subjects' eyes are presumably open, the facial expression of the experimenter as he "acted out" the subjects' experiences must have also contributed to an unknown amount of variance in the EEG readings. In Davidson et al's study (Note 3), the use of TV segments also makes it difficult to assess whether there may have been any hemispheric differences due to sensory modality. Since this last study used alpha wave activity as a dependent measure, and since these frequencies are (empirically) most abundant when the eyes are closed (e.g., Thompson, 1975) one wonders whether there may have been even more differentiation between the hemispheres as a function of type of emotion if the eyes had been able to be closed. The present experiment attempted to control for visual stimulation (with all subjects having their eyes closed), thus specifically investigating these effects with just one sensory modality, and concurrently decreasing artifacts in alpha wave readings due to visual activity and distractions. A second and related point is the frequent lack of control of the imagery associated with the various stimuli used. Since the right hemisphere's bias for imagery-related tasks is established in the literature (e.g., Morgan et al, 1971), the experimental (or statistical) control of this variable would seem integral to a methodology assessing often small differences in hemispheric alpha asymmetry. For Tucker et al, who in the same publication speculate on the association between decreased imagery and depressive affect, this may have been an especially valuable factor to have controlled for. The present experiment attempted to equate the three emotional conditions or the mean "imagery" that pretest subjects associated with their respective stimuli (as well as the mean "familiarity", which is seen as a covariate of imagery).

Application of Emotional Asymmetries to Psychopathology

These results have interesting implications for psychopathology, especially for such obviously mood-related states as severe depression. It has been suggested by this author (Gill, Note 2) that given the right hemisphere's hypothesized emotionally negative bias, it would be predicted that depressed populations may have an abnormal relative increase in the amount of right hemispheric emotional processing reaching awareness. One method of testing this prediction would be to compare normals with depressed populations in the amount of right hemispheric involvement they show with emotional stimuli. If the depressed populations were found to have greater right hemispheric electrophysiological involvement in processing (certain) emotional stimuli, this prediction would be supported.

Other than the literature on emotional asymmetries in normals, there is also some support for this right hemispheric "increase" from studies on depressed populations. d'Elia and Perris (1973) compared the mean integrated amplitude (MIA) from eight channels of an EEG of indivisuals with "psychotic depression" before and after a series of bilateral electroconvulsive and Indoklon therapy sessions. Before treatment, the right hemisphere appeared to have greater amplitude than the left hemisphere. After treatment, they found that the average left/right ratio of MIA had increased, with a correspondingly smaller percentage of patients showing a ratio below 1.0. While both the left and right MIA increased with treatment, the left hemisphere appeared to increase the most -- consistent with its role in more positive emotions. This author would interpret this to mean that during depression, there is more right hemispheric emotional processing than left hemispheric processing. As a result of treatment, the balance between the hemispheres is equalized (the mean left/right ratio after treatment was found to be 0.99). This phenomena was also seen by Flor-Henry, Koles, Bo-Lassen and Yeudall (1975). They had a group of normals and unmedicated psychotic depressives (in addition to other groups with various diagnoses) perform visuospatial and verbal tasks, as well as just rest with eyes open, while bilateral recordings on several frequencies were taken on an EEG. In the resting condition, they found an increase in power (voltage x time) in the temporal lobe of the right hemisphere (13 - 20 and 20 - 50 Hz) and decreased power in the right parietal lobe (alpha band) as compared to normals. Thus, an overall increase in hemispheric activity in these two lobes was found. (For the verbal and visuospatial conditions, a complex shift of changes in power occured for both lobes of both hemispheres, for various frequencies, making interpretation difficult. In general, however, there was an increase in the variability of the power of the right parietal lobes.)

Apart from EEG work with depressives, there are also some analogous studies using electrodermal activity (EDA) as a dependent measure of hemispheric involvement. Gruzelier and Venables (1974) presented a group of depressives with a series of 1000 Hz tones. They were then required to discriminate these tones from other tones at 2000 Hz by pushing a button whenver the 1000 Hz tones were heard. The bilateral skin conductance recordings that were taken throughout the experiment indicated that their mean response amplitudes were lower on the right hand compared with the left irregardless of the time or task involved. Myslobodsky and Horesh (1978), assuming that normals do not have asymmetrical recordings (Gruzelier, 1973) and arguing that the skin conductance response is contralaterally controlled, would interpret this finding within a hemispheric framework (i.e. greater right hemispheric activity in depressives). They attempted to replicate Gruzelier and Venables' (1974) results, using a group of hospitalized, endogenous and reactive depressives and adding a "normal" control group. These subjects were presented with three experimental conditions: a tone habituation task; an emotional and nonemotional verbal task; and an emotional and nonemotional visuospatial task; all during which EDA (and lateral eye movement) measures were taken. It was found that for the emotional verbal task, the subjects with endogenous depression had greater EDA on the left hand than on the right hand (increased right hemisphere activity), while for normals, the opposite held true: they had greater EDA on the right hand. These results were also found for the visual and neutral tone conditions, with the depressives again showing increased acitivity on the left side (right hemisphere). (However, there failed to be found any significant differences in any of the three conditions for the reactive depressives.) Myslobodsky and Horesh concluded that "a relatively higher amount of EDA on the left side of the body in endogenous depression could probably suggest a higher excitability of the right half of the brain" (p. 117).

Methodological Rationale

The EEG and Alpha Waves

Apart from simple observation, or gross anatomical measurements, the EEG has probably been in existence longer than any other instruments used in research on hemispheric asymmetries. It was first used to gauge electrical activity in humans by Hans Berger (1929), (appropriately) a psychiatrist. It exicted the imaginations of clinicians and researchers alike as a noninvasive tool to find out what was going on (or not going on) inside the skull. Various attempts were made at this time to use the EEG in a wide range of diagnostic applications, including personality analysis (Gottlober, 1938), psychological organization (Saul, Davis, & Davis, 1937; Williams, 1939), obsessive compulsive states (Pacella, Polatin & Wagler, 1944) and psychoneurosis (Strauss, 1945), as well as neurological disorders such as cerebral tumours (Walter, 1936) and epileptic seizures (Gibbs, Lennox & Gibbs, 1936). Although there has been little change in technique used with the EEG since 1940 (Cooper, Osselton & Shawn, 1969), the following decades have certainly seen gradual improvements in the sophistication of data analysis and its application to various fields of human health practice and research. Instead of being faced with a boggling array of electrical signs at various frequencies, electrophysiologists are now able, if desired, to "filter" the output from an EEG to receive data from only selected frequencies. Such an approach can somewhat reduce the complexity of the accompanying data analysis and the amount of biological artifacts in the output, and provide the experimenter with greater specificity in certain areas of investigation. One of the frequencies which has seen well documented use in psychophysiology is the "alpha" band.

This set of frequencies was first noted in the literature by Berger (1930), who also assigned it its current name (Berger, 1938). Alpha waves refer to the frequencies which fall between 8 and 13 Hz (or cycles per second). They may vary in amplitude anywhere from a couple of microvolts to a few hundred microvolts (Thompson, 1975). Found in most individuals over 12 years of age, they constitute the "main activity seen in the EEG of the alert adult" (Scott, 1976, p. 19). Alpha waves appear most prominently when the individual is conscious and relaxed, with the eyes closed and the amount of external stimulation fairly low and constant. If the individual is aroused, however, (especially visually), this leads to "alpha blocking" in which these waves are attenuated, and replaced by faster waves (greater frequency) that are associated with more activity in the brain, such as beta (18 - 30 Hz) and gamma (30 - 50 Hz) waves (Thompson, 1975).

This apparently inverse relationship between alpha wave activity and mental "effort" is probably the main reason (apart from its abundance in adults) for its regular use as the dependent measure in EEG research. Thus, the rationale behind its use dictates that the cerebral hemisphere that demonstrates the least alpha wave activity (or greatest reduction in alpha) is the one which is more involved with the task at that moment. However, since for right-handed individuals, the right hemisphere has alpha waves of slightly greater magnitude (Kiloh, McComas & Osselton, 1972; Cabral & Scott, 1975) especially in the occipital lobes (Morgan, McDonald & MacDonald, 1971), this must be taken into consideration. This has been most frequently done through the calculation of a ratio of right/left or $\frac{R - L}{R + L}$ activity (e.g., Mc Kee, Humphrey & McAdam, 1973). Although intuitively it may strike the observer as questionable as to why the higher frequency waves are not just used as an index of activation, it has been found that changing an experimental task has not led to distinct hemispheric changes in the delta band while only small differences occur in the beta band (cf. Gardiner & Walter, 1977). The alpha band, on the contrary, has been found to show the greatest amount of hemispheric change as a function of task demands (Doyle, Ornstein & Galin, 1974). In addition to these advantages, alpha waves are also easily identified (especially with paper output) in that they are found in well defined bursts, with reliably rhythmical waves of high amplitude in comparison to other bands (Marsh, 1978).

Although the inverse relationship between mental effort and alpha wave activity has been known since Berger (1930) and Adrian and Matthews (1934), its use with laterality research really did not start until studies using it with handedness appeared (e.g., Glanville & Antonitis, 1955). Since that time, EEG measures using the alpha band have been used to assess hemispheric asymmetries in a wide variety of topics. Some of these have included learning ability (e.g., Chartock, Glassman, Poon, & Marsh, 1975), motor and nonmotor tasks (e.g., Doyle et al, 1974), musical and lingiustic tasks (e.g., McKee et al, 1973; Schwartz, Davidson, Maer & Bromfield (1974), mental arithmetic and hypnotizability (Morgan, MacDonald & Hilgard, 1974) and visuospatial tasks (e.g., Morgan et al, 1971). Generally, the results of this literature on cognitive differences using the alpha band (and using other EEG measures, as well) have supported the hemispheric differences found so far with other measures such as dichotic listening or the tachistoscope (Galin, Johnstone & Herron, 1978). This support, it should be realized, is not so much in the replication of these other studies but in showing that there is a corresponding neurophysiological basis for these hemispheric asymmetries. In this regard, it is seen here that the application of alpha wave measures to emotion is a logical extension and expansion of this earlier cognitive work.

Alpha Wave Activity and Sex of Subjects

In the past two decades, it has become increasingly evident that there are differences between the sexes in the degree of hemispheric asymmetries that have been found. Bryden (1978), in a comprehensive review of the literature on cognitive functions, concluded that males are generally more lateralized than females. Whether these differences have a neurophysiological basis, however, appears to be a different question. At least with regard to the alpha band on the EEG, at least three studies have found a higher proportion of this type of activity in females. Selldén (1964) was perhaps the first to notice this asymmetry in his EEG study of normal subjects given megimide (a stimulant), finding that females had a higher mean frequency of alpha waves than males. This was also found by Deakin and Exley (1979) who compared the alpha wave activity in small groups of males and females, at rest. Davidson and Schwartz (1976), in their study of cardiac self-regulation, found this difference to be lateralized. When the subjects were given auditory feedback on their performance, females were found to have greater alpha wave activity than males in the right hemisphere.

There are also sex differences in hemispheric involvement with emotion. Tucker et al (1977), in their study of conjugate lateral eye movements as a function of neutral and stressful question periods, found that only females exhibited significantly increased eye movements to the left (right hemisphere involvement) for emotional questions (while only males significantly increased their left eye movements for the stressful condition). Schwartz et al (Note 6) found a similar effect in their study of facial EMG in response to emotional questions and to voluntary face mimicking sessions. In the question condition, they found that "females accounted for most of the right-side superiority in excitement" (one of the types of emotion) and went on to state that this "supports the prediction that females would show greater degrees of lateralization than males" (p. 570). In addition, for the corrigator muscles in the voluntary facial expression condition, only the females showed increased left muscle output (right hemispheric involvement) over right muscle output, and "any significant emotion-related lability" (p. 570). Further evidence of these sex differences comes from Borod et al (1980) in their study of the relationship between facial asymmetry ("facedness") and type of emotion. They found that females were more lateralized (left-faced) for emotionally pleasant facial expression (similar to the finding of Schwartz et al, 1979, for a positive emotion) while males were more lateralized for negative expressions.

Taken together, these studies suggest two conclusions relevant to the present study. The first is that females produce more alpha wave activity than males, especially in the right hemisphere. Secondly, females appear to be more lateralized in their electrophysiological involvement with emotions, especially and perhaps exclusively for "positive" emotions. It would thus appear more appropriate to use females as the subjects for the present study, in light of the slightly greater probability of finding asymmetries in hemispheric involvement as a function of type of emotion.

Hemispheric Activity and Location of Electrodes

The EEG studies discussed above have used a variety of electrode locations utilizing all four lobes. Harmon and Ray's (1977) study found hemispheric differences in the temporal lobe while Davidson et al (Note 3) and Tucker et al (1981) found their differences occuring in the frontal lobe. The parietal lobe may also reflect hemispheric asymmetries in activation: Flor-Henry (1976a, 1979) in reviewing some of his previous studies, noted the differences in the parietal and temporal lobes of normals and depressives as a function of spatial or visual tasks. In a "cognitively neutral situation", depressives showed an increase in right and left parietal power, while during a visuospatial task, depressives had decreased right parietal power and increased left parietal power. (Heilman (Note 4) has also implicated the right temporoparietal lobe in the comprehension and location of affective speech, and in emotional "arousal".) Based on Davidson et al (Note 3) and Tucker et al's (1981) studies alone, hemispheric asymmetries in alpha activity in this study as a function of type of emotion were expected in the frontal lobe. However, since the stimuli used here were technically neither verbal nor visual/spatial (as Flor-Henry, 1979) and since Davidson et al (Note 3) and Tucker et al (1981) used the two other lobes reflecting previous hemispheric differences -- the temporal and parietal -- these regions were also examined.

Hypotheses

First, a three-way interaction between hemisphere, lobe and type of emotion was predicted. For the frontal lobe, greater alpha activity was expected in the left hemisphere (greater right hemispheric activation) with negative emotions, and greater alpha activity in the right hemisphere (greater left hemispheric activation) than in the left hemisphere was expected with positive emotions. This pattern of hemispheric alpha asymmetry is possible, but not explicitly predicted, with the parietal and temporal lobes (in which case a hemisphere x emotion interaction may result). Second, an association between depression and hemisphere was expected, using the $\frac{L - R}{L + R}$ ratio. As depression increases, greater right hemispheric activation was expected to be seen across emotions. This was to be reflected in a significant positive relationship between depression and the ratio. No predictions were made as to whether this pattern would be reflected in all lobes, or just the frontal lobe.

Method

Subjects

A total of 62 female Introductory Psychology students registered in the Intersession and Regular enrollment periods at the University of Manitoba were used in this study. All subjects participated in order to satisfy the experimental requirements of their psychology course.

Of these subjects, 5 were utilized for the pretest, and were selected in the following manner: the entire Intersession Introductory Psychology class was first administered a three part questionnaire. This consisted of: a handedness survey designed by Raczkewski, Kalat and Nebes (1974); a series of two items inquiring as to any hearing deficits the subject may have; and a series of two items asking what was the first language the subject learned (see Appendix A). From this sample, all females were selected who met the criteria of English as first language, adequate hearing, and right handedness (assigned on the basis of using that side of the body for at least 12 of the 14 activities listed on the questionnaire, with the constraint that writing, kicking and throwing must be right-sided). Five of these subjects were then randomly chosen for the pretest, and were contracted to participate through the class instructor.

Subjects for the experiment proper were acquired through the use of experimental sign-up booklets. The booklets had three requirements of subjects: that they were female; right handed; and had English as their first language. (Upon arrival at the experimental chambers, subjects completed the three-part questionnaire to check that the conditions were actually met.) Of the 57 experimental subjects, two were eliminated from analysis because of having first learned a language other than English. Twenty-one subjects were also eliminated from the analysis because of artifactual signals found in 5 out of 6 EEG recording channels. Another 14 subjects were not included in the analysis because of computer failure occuring at various trials, terminating the storing of EEG data for any tirals yet to be presented. Thus, there were a total of 20 subjects whose depression scores and EEG data were analyzed. Age ranged from 18 to 54 years, with a mean of 21.9.

Apparatus

This study utilized two rooms. A sound-proofed equipment room housed an 8-channel Beckman multifrequency electroencephalograph linked through an interface box to an S-100 Vector Graphic microcomputer and terminal. A power score (which is a function of amplitude and time) was used as a dependent measure. From each subject, 256 signals per second per channel, for a total of 150 seconds, were stored on 5¼ inch magnetic disks. Also in this room was the auditory equipment consisting of a Sansui G-2000 stereo receiver/amplifier and a Toshiba PC-3460 stereo cassette recorder-player. These instruments transmitted the stimuli across a hall to a pair of stereo headphones in a sound-proofed electrically shielded "EEG chamber". The chamber consisted of: a reclining "EEG chair", a table, an electrode terminal, into which the monopolar silver cup electrodes were connected, and an intercom linked to the equipment room.

Stimuli

The auditory stimuli used in the pretest were 54 samples of instrumentals and (nonverbal) sound effects, prerecorded on cassette from a selection of 33 rpm records. (These were chosen over "live" recordings to allow for the possibility of a replication of this study.) The specific sounds used are given in Appendix B.

Each auditory sample, or stimulus, was of approximately 6 seconds duration. The interstimulus interval was the time needed by a subject to perform a series of ratings on each sound, with an average range between 10 and 20 seconds.

From the pretest stimuli, 30 sounds were selected for use in the experiment. There were 10 stimuli, or trials, for each of the three emotional categories (negative, neutral and positive). The specific sounds used in the experiment are given in Appendix C. The duration of each sound was approximately 6 seconds with an interstimulus interval of approximately 30 seconds (of silence). This interval was seen as a compromise between sufficient length to minimize "carry-over" effects from a previous stimulus, and yet short enough to also minimize the subject's fatigue, boredom and/or distraction.

For both the pretest and the experimental subjects, the order of the stimulu was random and constant within each of these two subject groups. (The pretest order was, of course, different from that used in the experiment). The sound level of all sounds, on the average, ranged between 54 and 61 db.

Procedure

All subjects in this study were individually tested. A pretest was first performed in order to select the specific stimuli to be used in the experiment. Prior to this point, the experimenter had chosen equal numbers of sounds that in his judgement, were classifiable as emotionally negative, neutral and positive, for a total of 54 sounds. The pretest subjects' tasks were then to give their own opinion as to whether they felt emotionally negative, neutral, or positive about each stimulus. From the group data, the stimuli that had the highest agreement in falling into each classification were then chosen for the experiment. The pretest was also used to evaluate any potential difficulties in the use of the stereo equipment or the questionnaire used to measure depression -- the CES-Depression Scale (Radloff, 1977; See Appendix D).

Pretest subjects first reported to the equipment room, where they were briefed on their task and administered the CES-Depression Scale. The pretest was explained to them as an evaluation of people's emotional reactions to a variety of sounds. Reassurances that this was not a test of logic, but rather a survey of subjective experience were given to the subjects. Subjects were then taken to the EEG chamber and seated at a table from which they rated the stimuli on a 54 section questionnaire (See Appendix E). Each section had 3 questions. The first asked the subject which category a particular sound fit into, giving 4 choices: emotionally positive; emotionally neutral; emotionally negative; or "don't know". The second question asked the subject how familiar they were with each sound, while the third asked them how much imagery they associated with that sound. Both of these questions used a 5 point Lickert-type scale, with possible responses ranging from "not at all" or "none" (respectively) to "very familiar" or "a large amount" (respectively). After explaining the questionnaire to the subject, and emphasizing that she was not required to place an equal number of sounds in any category, she was then asked to close her eyes once the experimenter had left the room, opening them only for performing the rating for each sound. (Both this instruction and the use of the EEG chamber itself were done to increase similarities between the pretest and experimental procedures.) The subject was then fitted with the headphones, and the experimenter left for the equipment room, from which the sounds were transmitted. The intercom was used by the experimenter to alert the subject just before the first sound began, and used by the subject to indicate when she had finished each rating. After all 54 sounds had been rated, the subject was informally questionned by the experimenter as to how emotionally arousing the sounds were, in general, and as to any sounds which were particularly arousing. Subjects were then debriefed, with the purpose of the depression scale (pretesting) and stimulus rating sheets (stimulus selection for the experiment) explained to them.

The strategy used to choose the 30 experimental stimuli from the 54 stimuli presented to the pretest subjects was dictated by the preconditions of each emotional category having relative equality in: the familiarity of its stimuli; the imagery of its stimuli; and in their proportion of instrumentals and sound effects. This involved the following general procedure: first, for each stimulus a tally was made of the number of subjects placing it in each emotional category (or the category of "don't know"). The pretest stimuli were then chosen as experimental stimuli on the basis of the proportion of agreement on their emotional classification. Sounds having 100% agreement on their classification were chosen first, followed by those with 80% agreement, and in some cases, those with 60% agreement. Third, an attempt was made to approximately equate the three emotional categories in the number of stimuli that were instrumentals and sound effects. Last, stimuli that were alike in both instrumental/sound effect status and percentage agreement were chosen or eliminated upon the basis of their mean familiarity and imagery scores. In this way, 10 stimuli for each of 3 categories were chosen from the original group of stimuli.

Subjects in the next stage of the study (the "experiment") reported to the equipment room, where it was explained that they were participating in an investigation of the effect of different sounds on "brain wave activity". The subject was also administered two questionnaires in this room: the three part survey used to check for the handedness/hearing/language requirement; and the CES-Depression Scale.

Subjects were then taken into the EEG chamber and introduced as to how the electrodes were attached. Each subject was then fitted by the experimenter and an assistant with a ground electrode (placed behind the left ear), a reference electrode, and six active electrodes. Place conformed to the "Ten-Twenty" or "International" system (Jasper, 1958), with P_3 and P_4 sampling the left and right parietal lobe; T_3 and T_4 sampling the left and right temporal lobe; and F_3 and F_4 sampling the left and right frontal lobe, respectively (all referenced to Cz). The subject's task was to simply reflect upon how they "felt" during each sound they heard, to be able to discuss the stimuli in general with the experimenter afterward. These instructions were designed to minimize the amount of mental activity the subject had to perform (and thus maintain a high amount of alpha activity) while at the same time providing some certainty that the subject's attention was focused primarily on the stimuli. Alpha activity was also enhanced (and the chance of artifacts reduced) by having subjects keep their eyes closed throughout the stimulus presentation procedures. (The lights in the EEG chamber were also turned off prior to the stimulus presentation with the door partly closed, to facilitate this.) After answering any questions that the subjects had, the experimenter carefully fitted them with the headphones, and left for the equipment room to begin transmission of the stimuli. There, the experimenter gave the subject notice through the intercom of when the first stimulus would commence for a continuous period of approximately 18 minutes. Once the audio equipment was operational, the experimenter at the beginning of each trial manually activated the computer to begin EEG data storage for a standard 5 second period. After each 5 second period, the computer automatically terminated storage.

After all 30 stimuli had been presented, the electrodes were removed from the subject, and she was informally questionned as to how emotionally arousing the stimuli were, and asked which stimuli affected her most.

Experimental Design

The EEG data was collected for this study using a within-subjects design. There were three repeated measures factors: Hemisphere (left or right), Emotion (negative, neutral or positive) and Lobe (frontal, temporal or parietal). Since all three variables were discrete, a 2 x 3 x 3 repeated measures analysis of variance was able to be performed. As for the depression variable, reduction in the numer of subjects with complete EEG data precluded dichotomizing scores into "depressed" or "nondepressed" groups. As a continuous variable, depression was able to be analyzed using a correlation technique.

Results

Pretest

The results of the stimuli selection procedure of the pretest can be seen in the context of each emotional category. For the negative category, 5 of the stimuli chosen had 100% agreement that the sound was emotionally negative while the other 5 stimuli had 80% agreement. Eight of the stimuli were sound effects, while the other two were instrumentals. The mean familiarity and imagery scores were 3.36 and 3.84 respectively. For the neutral category, 5 of the stimuli chosen had 80% agreement, and 5 stimuli had 60% agreement. As with the negative category, 8 stimuli were sounds effects and 2 were instrumentals. The mean familiarity and imagery scores (across the 10 stimuli) were 3.42 and 3.38, respectively. For the positive category, 5 stimuli had 100% agreement and 5 stimuli had 80% agreement, having the same proportions as the negative category. Five of the stimuli were sound effects, while the other 5 were instrumentals. The mean familiarity and imagery scores were 3.92 and 4.00, respectively.

To assess whether the three emotional categories differed significantly in the familiarity and imagery associated with their stimuli, a repeated measures analysis of variance (ANOVA) was performed. Using emotional category as the independent variable, separate ANOVA's were done for each of the dependent variables. Given the small sample size for each, the tests were made more liberal through the use of an error rate of 0.10. A (sphericity) test for violation of the assumption of compound symmetry was computed for each ANOVA.

The assumption was not found to be significantly violated for either familiarity ($p > 0.08$) or imagery $p > 0.55$). The effect of emotional category on familiarity failed to be found significant ($\underline{F}$ (2,8) = 1.97, $p > 0.20$) as was its effect on imagery ($\underline{F}$ (2,8) = 2.38, $p > 0.15$) indicating that the stimuli chosen for the three emotions did not significantly differ along these dimensions. After this point, no further modifications were made to the thirty sounds to be used as experimental stimuli.

In comparing the experimenter's original emotional classification of stimuli with the pretest subjects', several differences appeared. Two originally neutral stimuli were classified by subjects as positive, with 80% agreement, and another neutral stimulus was classified by subjects as negative, with 100% agreement. In addition, ten of the original 54 stimuli were classified by at least one subject as "don't know". Of these stimuli, four sounds had the most agreement as a negative stimulus, three had the most agreement as a neutral stimulus, one had the most agreement relatively evenly spready across all four categories, and two sounds had the most agreement as a "don't know".

EEG Data

Each subject's magnetic disk had stored on it a total of 230,400 separate data points (256 samples/second x 5 seconds/trial x 30 trials x 6 channels). With 20 subjects, this amounted to over 4½ million data points for this dependent variable alone. Clearly, much of the handling of the data was involved in its reduction.

An off-line scoring program in BASIC performed Fast Fourier Transforms to get a powerscore for all frequencies. Those between 8 and 13 Hz were then analyzed further. Selecting seconds two, three, and four for each trial, the program averaged over each second, to produce a mean alpha level in a second-by-second basis for each of 6 channels for each of 30 trials, resulting in 540 data points per subject. This data was then output to a printer as each of the data points was computed. After each subject's data was printed, a second program was used to average over trials and seconds, to yield a value of alpha for each emotional condition of each lobe of each hemisphere.

A 3 (Emotion) x 3 (Lobe) x 2 (Hemisphere) repeated measures analysis of variance was then applied to this data. Sphericity tests that were conducted along with the analysis indicated that the assymption of compound symmetry was significantly violated for the effect of Lobe ($p < 0.00001$), and Lobe x Emotion ($p < 0.007$). As a result, the Greenhouse-Geisser (1958) correction was applied to the p value of the F test to make it more conservative (reflected in Table 1). The assumption failed to be found significantly violated for the effects of Emotion ($p > 0.15$), Emotion x Hemisphere ($p > 0.61$), Hemisphere x Lobe ($p > 0.07$) and Hemisphere x Emotion x Lobe ($p > 0.35$).

Insert Table 1 about here

Table 1 reveals that three effects were found to have a significant impact upon alpha activity; Emotion ($F(2,38) = 2.51$, $p < 0.04$),

Table 1

Repeated Measures Analysis of Variance for Hemisphere x Emotion x Lobe

Source	df	MS	F	p	p(adj)[a]
Hem	1	0.01792	0.21	0.6500	-
Error	19	0.08428			
Emot	2	0.11145	3.51	0.0400	-
Error	38	0.03177			
Hem x Emot	2	0.00160	0.68	0.5116	-
Error	38	0.00235			
Lobe	2	1.32690	8.26	0.0010	0.0070
Error	38	0.16061			
Hem x Lobe	2	0.16466	3.36	0.0453	-
Error	38	0.04898			
Emot x Lobe	4	0.00386	1.29	0.2814	0.2872
Error	76	0.00299			
Hem x Emot x Lobe	4	0.00186	0.86	0.4945	-
Error	76	0.00218			

Note. Hem: Hemisphere. Emot: Emotion.

[a]Greenhouse-Geisser adjusted probability for effects having significantly violated the assumption of compound assymetry.

Lobe (F (2,38) = 8.26, $p < 0.007$) and Hemisphere x Lobe (F (2,38) = 3.51, $p < 0.045$). The effects of Hemisphere (F (1,19) = 0.21, $p > 0.65$); Emotion x Lobe (F (4,76) = 1.29, $p > 0.28$) and Hemisphere x Emotion x Lobe (F (4,76) = 0.86, $p > 0.49$) failed to be found statistically significant.

The main affect for Emotion is presented in Figure 1, indicating that alpha activity across hemispheres and lobes appeared to increase as emotional stimuli became more positive. Visual inspection reveals that the least alpha is produced in response to emotionally negative stimuli (M = 0.73498; SD = 0.28544), with a moderate amount of response to emotionally neutral stimuli (M = 0.77706, SD = 0.32570) and the greatest amount of alpha in response to emotionally positive stimuli (M =0.79421; SD = 0.34145).

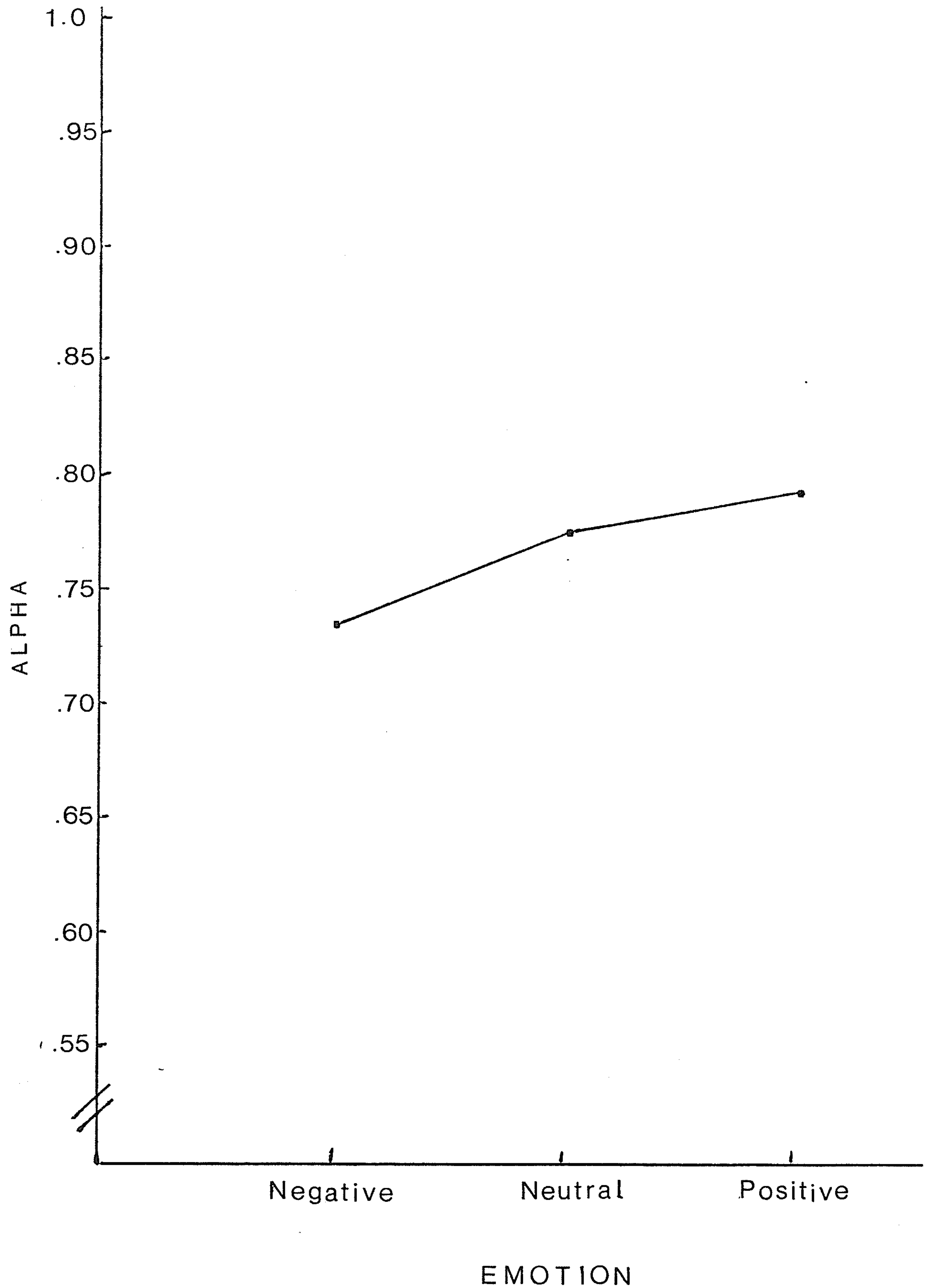
Insert Figure 1 about here

Although the main effect for Emotion was significant, post hoc Tukey multiple (pairwise) comparisons that were later performed on the data failed to reflect significant differences in alpha activity between the negative and neutral emotions (q (3,38) = 1.06, $p > 0.05$) the neutral and positive emotions (q (3,38) = 0.43, $p > 0.05$) or the negative and neutral emotions (q (3,38) = 1.49, $p > 0.05$).

As for the other significant factor, Lobe, it was found that across emotions and hemispheres, alpha activity was significantly affected by the location of the electrodes. Inspection of the means suggests that the parietal lobe produces the greatest amount of

Figure 1.

Alpha activity as a function of type of emotion.



1.0
.95
.90
.85
.80
.75
.70
.65
.60
.55
ALPHA
Negative
Neutral
Positive
EMOTION

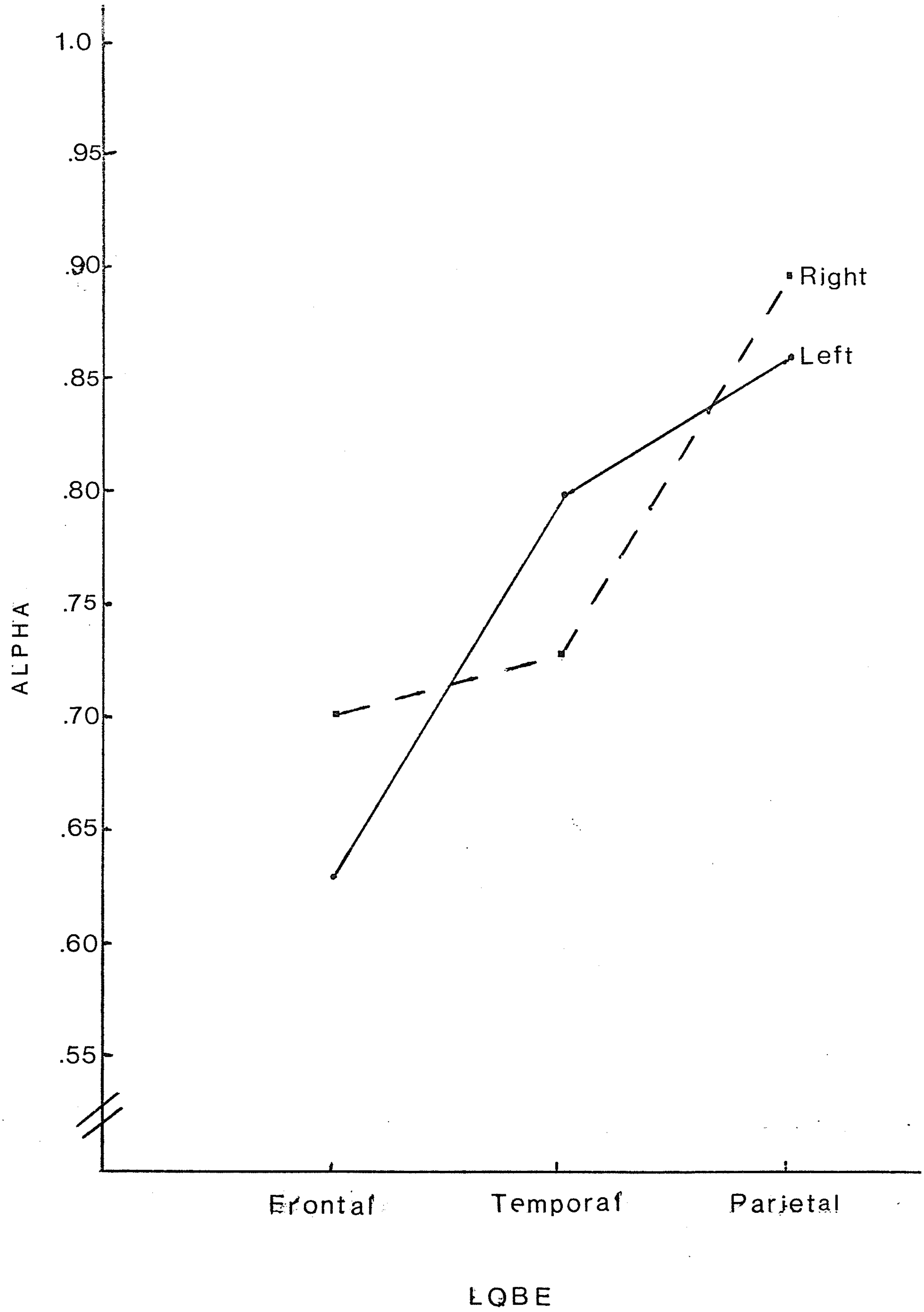
alpha activity ($\underline{M}$ = 0.87696; $\underline{SD}$ = 0.23473) with alpha activity appearing to decrease in the anterior lobes. The temporal lobe has an intermediate amount of alpha ($\underline{M}$ = 0.76233; $\underline{SD}$ = 0.27648), with the frontal lobe seeming to have the least amount of alpha activity ($\underline{M}$ =0.79421; $\underline{SD}$ = 0.34145). This interpretation, however, must be tempered by the significant Lobe x Hemisphere interaction displayed in Figure 2.

Insert Figure 2 about here

Although the same general statement of apparently greater alpha activity being produced in the posterior lobes still holds, the left and right hemispheres seem to have different patterns in reflecting this. The frontal and parietal lobes appear to have greater right hemispheric alpha activity relative to the left hemisphere, while the temporal lobe appears to have greater left hemispheric activity relative to the right hemisphere. Hemispheric differences appear to be greatest in the frontal lobe, with a mean right hemispheric alpha of 0.70530 ($\underline{SD}$ = 0.26254) as compared to 0.62860 ($\underline{SD}$ =0.20692) for the left hemisphere (See Table 2). However, post hoc Scheffe multiple comparisons failed to evidence a significant difference in alpha activity between the hemispheres at the frontal lobe ($\underline{F}$ (2,38) = 0.547, $p > 0.05$), temporal lobe ($\underline{F}$ (2,38) = 0.484, $p > 0.05$) or parietal lobe ($\underline{F}$ (2,38) = 0.238, $p > 0.05$). Moreover, significant differences in alpha activity failed to be found between the three lobes in either the left or right hemispheres (all $\underline{F}$'s < 1.7, $p > 0.05$).

Figure 2.

Alpha activity as a function of lobe and hemisphere.



1.0
.95
.90
.85
.80
.75
.70
.65
.60
.55
ALPHA
Right
Left
Frontal
Temporal
Parietal
LOBE

Insert Table 2 about here

To obtain an overall score representing lateral balance of alpha, the left and right hemisphere scores for each subject were then converted to the ratio of the difference score between the left and right hemispheres, divided by their sum ($\frac{L - R}{L + R}$ alpha). This ratio represents the size of the left hemisphere's abundance of alpha activity, relative to the right hemisphere (proportionate to the total alpha activity). A negative value would thus represent a right hemispheric abundance of alpha activity relative to the left hemisphere. These ratios were then used to examine the relationship between alpha activity and a subject's level of depression.

Depression Data

A subject's total score on the CES-Depression Scale was used as the index of depression. Each of 20 items had a possible value of 0 to 3, with summed scores ranging from 0 to 60. Higher scores on the scale represented greater amounts of depression. It was found that subjects' scores in this study ranged from 0 to 25. The mean score was 11.80, with a standard deviation of 6.93. Five subjects were found to have scores higher than 16, which Radloff (1977) uses as an arbitrary critical value for "depression".

When the depression scores were correlated with the mean alpha activity ratio, a moderately sized inverse relationship was found

Table 2

Mean Alpha Activity as a function of Hemisphere and Lobe

		Statistic	
Hemisphere	Lobe	M	SD
Left	Frontal	0.62860	0.20692
	Temporal	0.79617	0.28787
	Parietal	0.86030	0.42687
Right	Frontal	0.70530	0.26254
	Temporal	0.72849	0.26509
	Parietal	0.89362	0.45587

between the two variables ($r = 0.445$). This accounted for approximately 19.8% of the variance in their scores. A two-tailed t-test used to assess this relationship found it to be statisfically significant ($df = 18$, $p < 0.049$). Thus, across conditions, a significant increase in left (compared to right) superiority in alpha production is associated with a decrease in depression. Since the $\frac{R - L}{R + L}$ ratio is the inverse of the $\frac{L - R}{L + R}$ ratio, this result can be stated in terms of the right hemisphere, with a significant increase in right (relative to left) hemispheric alpha production being associated with an increase in depressed mood.

Informal Comments

During the informal questioning of subjects after the pretest and experiment, two similarities were seen in their reports. First, subjects claimed that, in general, the sounds had either an emotional effect upon them at some point, or had emotionally "aroused" them in some way. Secondly, subjects felt at least two different strong emotional reponses, corresonding to the categories of "positive" and "negative" feelings. Reports of the duration of these feelings (not asked of all subjects) were typically "a few seconds". (The longest duration was reported by a pretest subject, who claimed that the sound of a woman screaming disturbed her throughout the next few sounds.) Although no consistent similarities were found in the specific stimuli subjects had been most aroused by, they seemed to have little variation in their general degree of arousal (low to moderate).

Discussion

The results of this study were not found to support either of the experimental hypotheses, using alpha activity as an inverse index of cortical activation. Nonetheless, the results associated with each hypothesis provided an opportunity for speculating on variables that may prove of importance in developing neuropsychological models of emotion and depression.

Three significant effects emerged from the data analysis. The main effect of emotion will be discussed both as a possible methodological artifact, and as having possible theoretical relevance in defining the reference points of an emotional continuum. Interpretation of the main effect of lobe will be mitigated by its interaction with hemisphere. This interaction will be seen as providing some support for the importance of the frontal lobe in emotional processing. Each of these significant effects, and the experimental hypotheses, are discussed below.

Cortical Activation and Emotion

The effect of emotion was found to influence activation across regions of the cerebral cortex. The pattern of the results suggested that as emotions become more negative, activation increases. It was particularly difficult to interpret whether this finding had theoretical importance, or whether it was an artifact of the methodology used. Several factors contributed to this: no post hoc pairwise comparisons between emotions were found significant; no interactions involving emotion were found significant; no experimental hypotheses on the main effect of emotion were made; and no previous EEG literature appears to have discussed emotion in isolation from other variables (such as lobe or hemisphere). Hence, consideration must be given to both methodological and theoretical issues.

One aspect of methodology that may be related to the emotion effect is the difference in the number of instrumentals and sound effects used in each category. In contrast to the negative and neutral emotions, the positive category had three more instrumentals amongst its stimuli. Whether the possibly more "soothing" nature of the instrumentals led to apparently less cortical activity is difficult to assess, since no literature on the subject could be found. Another methodological issue may be the sound level and/or frequency of the sounds used in each emotional category. The negative sounds, apparently evoking the greatest amount of activity, may have done so due to greater frequency or sound levels. However, no detailed records of these variables were made. Like the first methodological issue, then, the importance of these differences remains difficult to assess. Given that the two experimental hypotheses were not confirmed, any possible methodological differences may have served to obscure expected findings.

Alternately, the emotion effect may be of theoretical importance. Although it is not seen as theoretically significant in relation to the hypotheses, it may have implications for the study of emotions in general. It is interesting to note that few laterality studies of emotion include a "neutral" emotional condition. Indeed, with respect to the EEG literature on emotion, no studies were found that examined "neutral" emotion. This practice may reflect the belief that "neutral" emotion is at the bottom of an emotional continuum. The results of this study suggest, however, that "neutral" emotion occupies an intermediate position on an emotional continuum, at least with regard to cortical activation. The neutral category appeared to elicit greater activation in relation to positive emotions, but less activation to negative emotions. Moreover, responses from pretest subjects are seen as indicative that neutral emotion is a phenomenological entity as well as a psychophysical one. Of the ten stimuli categorized by at least one subject as "don't know", only three stimuli has the most agreement as a neutral stimulus. (Nor were subjects reluctant to use the category of "don't know", with a proportion of 10/54.) It would seem, then, that the neutral condition was not regarded by subjects as equivalent to a "don't know", or an undefined category. Instead, it appeared to have as valid a phenomenological existence as the positive and negative emotions.

Apart from the issue of neutral emotion, the pretest and experimental results above may also have a related theoretical implication, in the formulation of a model of an emotional scale. This scale would be seen here as a continuum of negativity. At one end of the continuum would be a negative state that is phenomenologically unpleasant and electrophysiologically arousing. The finding of apparently greatest cortical activity with the negative stimuli in this study is consistent with theories of affect that associate highly activated or arousal states with phenomenological pain or unpleasantness, such as "drive" states (cf. Gray, 1971). At the other end of the continuum would be a positive state that is experienced phenomenologically as the absence of "negativity". The apparently intermediate position in cortical activity of neutral emotion (relative to the two end points) that was found in this study is consistent with this conception. Logically, neutral emotion would have an intermediate amount of "negativity", and a corresponding intermediate level of activation. While this kind of model has been constructed out of speculation, the association between negative emotion and apparently greater cortical activation may be of use in testing current theories of emotion and motivation, and in developing new models.

Asymmetrical Hemispheric Activation and Lobe

The effect of lobe was found to influence activation across hemispheres. Examined in isolation from other significant effects, it appeared that cortical activation was greatest in the anterior regions of the brain. Any interpretation, however, must be tempered by the significant interaction between lobe and hemisphere. Examination of this effect suggested a similar pattern of apparently greater activation in the anterior regions, but with each side of the lobes reflecting the pattern differently. For the frontal and parietal lobes, the left hemisphere appeared more activated than the right hemisphere, while this asymmetry was reversed in the temporal lobe.

Interpretation of this effect was largely speculative in light of the nonsignificant post hoc differences and cautious in light of less alpha activity typically being found in the anterior lobes

(Stern, Ray & Davis, 1980). It was, however, seen as valuable to draw parallels between this finding and two areas of research.

First, the apparently greater activation of the frontal lobe is consistent with the importance to emotional processing that the EEG studies on normals have assigned this region (e.g., Tucker et al, 1981; Davidson et al, Note 3). Tucker et al (1981) also interpret studies on clinical populations such as Flor-Henry (1976b) as implicating the "anterior" area of the brain in "psychiatric depression". However, these studies further specify the right frontal lobe as important to emotional processing, while the present study found a trend for greater left frontal activation. This suggests that further research is necessary before such specificity is supported.

Secondly, certain anatomical studies and investigations of brain-damaged subjects have implicated the frontal lobe with emotional processing. In their review of this subject, Heilman and Valenstein (1980) comment on the "strong reciprocal connections" (p. 78) between the frontal lobe and the limbic system, which is highly involved with emotional arousal (e.g. Daube & Sandok, 1978). Heilman and Valenstein (1980) then outline the psychological effects of frontal lobe lesions. Individuals with dorsolateral frontal lesions appear emotionally "flat", despite having appropriate cognitive abilities. (Certain limbic system lesions produce a similar blunted affect.) Alternately, orbitofrontal lesions seem to exaggerate affect, with inappropriate anger, sexual behavior and irritability being found as common affects.

It would appear then, that the trend for greater frontal activation in response to emotional stimuli found in this study is consistent with a variety of evidence that suggests it has an important role in affective processing. Directions for future research are twofold. First, investigators should try to integrate the literature on normals and clinical populations by more often including samples of both groups in their research. Secondly, attention must be focused not only on the different hemispheres as has been done in the past, but also on the different forms of emotion. These may include comprehension, subjective experience, evocation, and/or arousal thresholds. As will be seen in the discussion of the hypotheses below, the importance of the form of the emotion has yet to become clear.

Cortical Activation: Emotion and Hemisphere

The first hypothesis predicted greater activation of the right frontal lobe relative to the left in response to emotionally negative stimuli and a greater activation of the left frontal lobe relative to the right in its response to emotionally positive stimuli. This was not supported when the three-way interaction between hemisphere, emotion and lobe failed to be found statistically significant. Thus, the results of both Davidson et al (Note 3) and Tucker et al (1981) were not replicated in this regard. In attempting to account for this difference, methodological issues are of obvious importance. Two major differences in procedure are evident between these two studies and the present one: the subject's mental activity level; and the type of "emotional" stimuli used. In the other studies, subjects were given specific tasks to complete while being subjected to the emotional stimulation. Tucker et al's (1981) subjects were required to either silently add numbers, or maintain a visual image of a butterfly, or fireworks, while Davidson et al's (Note 3) subjects manipulated a pressure-sensitive knob to indicate their dis/like of a television segment. In contrast, subjects of this study were simply asked to reflect upon how each stimulus affected them, without having to make a quantitative judgement, or to engage in any other task-related activity. The importance of this difference, however, is difficult to assess. Since the combination of memory, intellectual and emotional tasks given to subjects in these studies would specifically implicate the prefrontal area (Daube & Sandok, 1978) it is possible that the frontal lobe must be more activated than other cortical areas to reflect asymmetrical alpha activity as a function of emotional stimulation. This is consistent with this study's finding of only a trend towards greater (relative) frontal lobe activation. Whether or not the frontal lobe was, indeed, relatively more activated in the other studies is difficult to assess. Tucker et al (1981) did not compare lobes, but performed, instead, a separate analysis for each lobe. And, although Davidson et al (Note 3) did find a significant interaction effect between lobe and emotion, they reported their data using the $\frac{R - L}{R + L}$ alpha ratio, which prohibits comparisons of hemispheric activity per se between lobes.

Implications for this issue are twofold. First, the task demands on a subject while being emotionally stimulated may prove to be an important variable in future electrophysiological studies of affect. Not only should future studies provide different tasks, as Tucker et al (1981) did, but also provide a condition without a formal task, as was used in the present study. Secondly, the question of prefrontal activity relative to other cortical areas appears an important one. Should "overactivity" in this area be found a necessary condition for greater right hemispheric activation (relative to the left) in response to emotionally negative stimuli (and vice versa for positive stimuli), this may be a very specific phenomenon, with much less theoretical importance than certain studies award it (especially in light of the possible infrequency of consistent "overactivation" of this area relative to other cortical areas; Daube & Sandok, 1978). Alternately, it may be of importance in further delineating areas that are specific to emotional processing. (For example, an "emotional processing area" within the prefrontal lobe may be defined as a region that is accounting for most of the variance in differential activation during emotional stimulation.) Certainly, an examination of prefrontal activity relative to other areas of the cortex may prove of use in future studies in better understanding the complexities of cerebral involvement with emotion. It is unfortunate that the present study appears to be alone in regarding lobe as a critical independent variable in this literature.

The other major methodological difference between this study and previous ones is their use of stimuli that are specific to each subject's personal definition of emotionally "negative" or "positive". Davidson et al's statistical analysis was based only upon the two T.V. segments that each subject judged as most negative and most positive. Not surprisingly, they found the same results when subjects self-generated their own positive and negative affective imagery. The procedure used by Tucker et al (1981) can also be seen as a modification of the self-generated emotion procedure, in that after direct, textbook descriptions of a negative and positive mood (depression and euphoria, respectively) each subject "was given one minute to reflect on a relevant personal affective memory to enhance the mood" (p. 172). This is also consistent with Harman and Ray's (1977) finding a differential hemispheric activation (in the temporal lobes) with the use of a procedure based in part upon subjects' personal recollections of very emotionally arousing situations. In contrast, the pretest procedure in the present study selected stimuli on a group basis, rather than an individual basis. Moreover, informal questioning of subjects after testing found considerable variation in the stimuli that subjects had been most affected by. It is thus possible that the pattern of results found in Davidson et al (Note 3) and Tucker et al (1981) were dependent upon having subject-specific stimuli. If so, it remains to be speculated as to why this would be of importance.

At a simplistic level, emotional stimulation that is specific to the individual implies some guarantee that the subject is, indeed, emotionally aroused. Yet, from informally gathered information after testing, all subjects in the present study appeared to have been aroused, as well. Perhaps a more important variable, then, is not arousal itself, but the level of emotional arousal. From Tucker et al (1981) and Harman and Ray's (1977) descriptions, subjects appear to have experienced a relatively intense level of arousal, while Davidson et al's (Note 3) methodology of choosing to analyze the most positive and negative stimuli for each subject suggests this. In contrast, informal questioning of subjects in the present study found them at a low to moderate level of arousal during emotional stimulation. Apart from serving an obvious purpose of providing enough affect with which to detect differences, intensity as a variable has at least two theoretical implications. First, the possibility that an atypical level of emotional experience generates hemispheric asymmetries in activation is consistent with theories that view hemispheric asymmetries in activation as an abnormality, indicative of psychopathology (cf. Gruzelier, 1981). Gainotti (1979) supports an association between high levels of depressive affect, clinical depression, and abnormalities in right hemispheric activation, with a similar association between euphoria and the left hemisphere. Flor-Henry (1979) has also proposed a model of increased left and right hemispheric "activity" in mania and depression. Secondly, Heilman (Note 4), from his work with brain-damaged subjects, has implicated the right temporoparietal region with (negative) emotional arousal. The finding by Harmon and Ray (1977) of hemispheric asymmetries in the temporal lobe using apparently highly aroused subjects indicates that asymmetrical hemispheric activation as a function of emotional stimulation is not exclusive to the frontal lobe, adding importance to Heilman's finding. It would seem,then, that the intensity of emotional arousal is another variable worthy of investigation in future studies, ideally with lobe included as another factor in the design. This would involve each subject arranging an emotional "hierarchy" prior to any EEG recording.

In attempting to integrate the two methodological differences between this study and the relevant others, a third and perhaps critical distinction becomes clear. Whereas subjects in the present study were simply experiencing emotional stimulation, subjects in the other studies were also producing emotional stimulation. Their combination of task and stimuli is seen as engaging them in the evoking of particular emotional states, basically using affective recall and imagery (to "relive" past emotional experiences). Although distinctions between emotional comprehension, evocation and subjective experience are frequently made in the literature on brain-damaged populations (e.g., Heilman, 1976; Heilman & Valenstein, 1980), this practice is not common in the literature on neurologically "intact" subjects. It would appear that the conclusions of investigators in this area need to be more specific in this regard. Whether or not Tucker et al (1981) and Davidson et al's (Note 3) findings are exclusive to self-evoked emotional states cannot be assessed from the results of the present study. Further, any study of the self-evoking of emotion would be hard pressed to separate its efforts from the simultaneous experiencing of these emotions. (Note that "evocation" is not equivalent to "expression".) It is seen as worthwhile, however, for future studies to contrast hemispheric activation in response to emotional experience alone with differential activation in response to emotional evocation/experience.

Asymmetrical Hemispheric Activation and Depression

The second hypothesis of this study predicted a significant positive relationship between depression and right hemispheric activation (relative to the left hemisphere). This was not supported when a significant negative relationship was found between these two variables. Hence, opposite to what was predicted, right hemispheric activity (relative to the left hemisphere) significantly decreases as depression increases. Alternately, left hemispheric activity (relative to the right hemisphere) significantly increases as depression increases. This finding is divergent from previously discussed studies which suggested increased relative right hemispheric activation in depressives using EEG measures (d'Elia & Perris, 1973; Flor-Henry et al, 1975) and EDA measures (Gruzelier & Venables, 1974; Myslobodsky & Horesh, 1978). It is also seen as inconsistent with the increase in right hemispheric activation as a function of negative emotion (relative to the left hemisphere) that was found by Davidson et al (Note 3) and Tucker et al (1981).

This interesting finding, however, can be seen to support studies that associate depression with a decrease in the mental "capacity" of the right hemisphere. Flor-Henry (1976b) and Goldstein, Filskov and Weaver (1977) found that depressed psychiatric patients' performance in neuropsychological tests such as the Halstead-Reitan battery were indicative of a right hemispheric dysfunction. Yozawitz and Bruder (Note 5) found that patients with affective disorders performed similar to patients with right hemisphere lesions on neuropsychological tests. Similar results have been reported with "normal" college students. In pilot work that Tucker et al (1981) did with depression and imagery questionnaires, they found that subjects with greater depression scores had poorer imagery performance. Attributing imagery functions to the right hemisphere, they suggested that "this finding suggests that mild depression in normal persons may coincide with a noticeable decrement in the information-processing capacity of the right half of the brain" (p. 170). They then pursued this possibility by comparing subjects' performance at a left and right hemisphere-specific task under negative and positive mood induction procedures. (These consisted of direct suggestions of euphoric and depressive behavior/mood to subjects under a hypnotic trance.) It was found that when subjects were given the negative mood treatment, their performance at a right hemisphere task of formulating visual images was impaired. In contrast, the left hemisphere task involving arithmetic computations and word problems was unaffected. Taken together, these results indicate the possibility of a performance decrement in the right hemispheres of depressives (compared to nondepressives). Since hemispheric asymmetries in activation have been found to reflect their relative superiority at a task (cf. Galin, Johnstone and Herron, 1978) it is also possible that any performance decrement in the right hemisphere is associated with (or can be interpreted as) a relative decrease in activation. The association between a relative right hemispheric activation and an increase in depression found in the present study is consistent with this possibility. Research that is designed to simultaneously assess hemisphere-specific performance and hemispheric activation would be of great value in understanding the complex effects of emotional stimulation.

In attempting to reconcile the literature above with the experimental hypothesis, one speculation that might be made is the possibility that investigators are tapping different aspects of depressive symptomatology. Depression surveys are typically a sum of a variety of physical complaints and emotional experiences -- potentially two subjects with different symptomatology could have the same depression "score". The results of Perris & Monakhov (1979) suggest that these differences may lead to different patterns of hemispheric activation. Collecting EEG data from depressed subjects, they found that greater depressive affect was associated with a greater level of activation in the right precentral region. However, with symptoms of anxiety and "ruminative ideation", they found an association between an increase in these complaints and an increase in left frontal activation. And Tucker (1981), in his review of literature on lateralized functioning and emotion, concludes that "a more specific understanding of brain function in emotional disorders requires greater specificity in the psychopathological phenomena examined" (p. 27). In light of the contradictory findings that have been discussed here, this recommendation should be pursued in future studies.

Summary

In discussing the results of this study, an attempt has been made to integrate different areas of investigation, and to provide directions for future research in these areas that will assist in the formulation and testing of neuropsychological models of emotion and depression. Although the role of the right hemisphere in the experience of negative emotion and depression is not yet clear, variables that may be of importance in examining this relationship have become clear. It is also apparent that the implications of this area of investigation are widespread, in light of the role that emotional experience plays in human life, especially negative emotions. Perhaps Shakespeare best expressed the urgency in studying this effect:

> "Canst thou not minister to a mind diseased;
> Pluck from the memory a rooted sorrow;
> Raze out the written troubles of the brain;
> And, with some sweet oblivious antidote,
> Cleanse the foul bosom of that perilous stuff
> Which weighs upon the heart?"

The search for the "antidote" continues.

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Appendix A.

EXPERIMENT "ECHO-ONE"

Name ______________________________ Sex M F Age ______

Telephone Number ____________________

* * *

This is a survey to discover which hand you use in the following manual tasks. Circle L if you perform the task with your left hand; circle R if you perform the task with your right hand; circle B if you perform the task equally well with both hands. Assume that your hands are empty (except as indicated) before attempting each task.

With which hand do you:

1.	draw?	L	R	B
2.	write?	L	R	B
3.	remove the top card of a deck of cards (i.e. dealing?)	L	R	B
4.	use a bottle opener?	L	R	B
5.	throw a baseball to hit a target?	L	R	B
6.	use a hammer?	L	R	B
7.	use a toothbrush?	L	R	B
8.	use a screwdriver?	L	R	B
9.	use an eraser on paper?	L	R	B
10.	use a tennis racket?	L	R	B
11.	use scissors?	L	R	B
12.	hold a match when striking it?	L	R	B
13.	stir a liquid or semi-solid?	L	R	B
14.	on which shoulder do you rest a bat before swinging?	L	R	B

* * *

15. How many of your immediate family are left-handed? ____________________
16. What is the first language that you learned? ____________________
17. At what age did you learn to speak English? ____________________
18. Do you have any problems with your hearing? ____________________
19. If so, what kind of problems are you presently experiencing?

Appendix B.

54 Sounds for Pretest

NEGATIVE

1. squad car
2. woman screaming
3. battle scene
4. "monsters" roaring
5. pigs grunting
6. hippopotamus
7. lion
8. hyrax
9. wildebeast
10. "School in flames" from Carrie
11. Dracula and victim
12. moans and groans
13. growling dog
14. banging shutter
15. creaky door
16. Frankenstein
17. "The Droid" from Alien
18. "Pup vs Adult" in Music of Wolves

NEUTRAL

1. horses galloping
2. boat whistles
3. seagulls feeding
4. geese honking
5. jackal
6. "Evening Star"
7. "Blue Danube"
8. "My Best Girl"
9. ringing tone
10. telephone ringing
11. electrical fan hum
12. Greenwich time signal
13. "The Symphony"
14. boat whistles
15. outboard motor
16. diesel train
17. swimming pool
18. traffic background

POSITIVE

1. applause
2. laughs
3. fanfare
4. surf effect
5. morning birds
6. sheep, birds
7. wild dog laughing
8. "Contest Winners" from Carrie
9. "Modern Times"
10. "A Dog's Life"
11. "March Militaire"
12. "Hungarian Dance"
13. "The Pilgrim"
14. "On the Trail"
15. "Gonna Fly Now"
16. "Marine's Hymn"
17. Theme song from Star Wars
18. "Fools Overture"

Appendix C.

30 Sounds for Experiment Proper

Negative

1. squad car
2. growling dog
3. moans and groans
4. creaky door
5. "Pup vs. Adult" from Music of Wolves
6. monsters roaring
7. woman screaming
8. banging shutter
9. "Evening Star"
10. "The Droid" from Alien

Neutral

1. telephone ringing
2. seagulls feeding
3. boat whistles
4. galloping horses
5. "Marines Hymn" from Rocky
6. Greenwich time signals
7. diesel train
8. "My Best Girl" from Silent Film Classics
9. hippopotamus
10. outboard motor

Positive

1. morning birds
2. surf effect
3. "Fools Overture" from Supertramp Breakfast in America
4. sheep, birds
5. "Gonna Fly Now" from Rocky
6. Allegro ma non troppo, Bethoven's Symphony No. 6 in F (Pastoral), Op.68
7. "A Dog's Life" from Charlie Chaplin
8. wild dog
9. swimming/splashing
10. Theme Song, from Star Wars

Appendix D.

ECHO-ONE

INSTRUCTIONS FOR QUESTIONS: Below is a list of the ways you might have felt or behaved. Please tell me how often you have felt this way during the past week.

Rarely or None of the Time (Less than 1 Day)
Some or a Little of the Time (1 - 2 Days)
Occasionally or a Moderate Amount of Time (3 - 4 Days)
Most or All of the Time (5 - 7 Days)

During the past week:

1. I was bothered by things that usually don't bother me.

( ) Less than 1 Day
( ) 1 - 2 Days
( ) 3 - 4 Days
( ) 5 - 7 Days

2. I did not feel like eating; my appetite was poor.

( ) Less than 1 Day
( ) 1 - 2 Days
( ) 3 - 4 Days
( ) 5 - 7 Days

3. I felt that I could not shake off the blues even with help from my family or friends.

( ) Less than 1 Day
( ) 1 - 2 Days
( ) 3 - 4 Days
( ) 5 - 7 Days

4. I felt that I was just as good as other people.

( ) Less than 1 Day
( ) 1 - 2 Days
( ) 3 - 4 Days
( ) 5 - 7 Days

5. I had trouble keeping my mind on what I was doing.

( ) Less than 1 Day
( ) 1 - 2 Days
( ) 3 - 4 Days
( ) 5 - 7 Days

6. I felt depressed.

( ) Less than 1 Day
( ) 1 - 2 Days
( ) 3 - 4 Days
( ) 5 - 7 Days

7. I felt that everything I did was an effort.

( ) Less than 1 Day
( ) 1 - 2 Days
( ) 3 - 4 Days
( ) 5 - 7 Days

8. I felt hopeful about the future.

( ) Less than 1 Day
( ) 1 - 2 Days
( ) 3 - 4 Days
( ) 5 - 7 Days

9. I thought my life had been a failure.

( ) Less than 1 Day
( ) 1 - 2 Days
( ) 3 - 4 Days
( ) 5 - 7 Days

10. I felt fearful.

( ) Less than 1 Day
( ) 1 - 2 Days
( ) 3 - 4 Days
( ) 5 - 7 Days

11. My sleep was restless.

( ) Less than 1 Day
( ) 1 - 2 Days
( ) 3 - 4 Days
( ) 5 - 7 Days

12. I was happy.

( ) Less than 1 Day
( ) 1 - 2 Days
( ) 3 - 4 Days
( ) 5 - 7 Days

13. I talked less than usual.

( ) Less than 1 Day
( ) 1 - 2 Days
( ) 3 - 4 Days
( ) 5 - 7 Days

14. I felt lonely.

( ) Less than 1 Day
( ) 1 - 2 Days
( ) 3 - 4 Days
( ) 5 - 7 Days

15. People were unfriendly.

( ) Less than 1 Day
( ) 1 - 2 Days
( ) 3 - 4 Days
( ) 5 - 7 Days

16. I enjoyed life.

( ) Less than 1 Day
( ) 1 - 2 Days
( ) 3 - 4 Days
( ) 5 - 7 Days

17. I had crying spells.

( ) Less than 1 Day
( ) 1 - 2 Days
( ) 3 - 4 Days
( ) 5 - 7 Days

18. I felt sad.

( ) Less than 1 Day
( ) 1 - 2 Days
( ) 3 - 4 Days
( ) 5 - 7 Days

19. I felt that people dislike me.

( ) Less than 1 Day
( ) 1 - 2 Days
( ) 3 - 4 Days
( ) 5 - 7 Days

20. I could not get "going".

( ) Less than 1 Day
( ) 1 - 2 Days
( ) 3 - 4 Days
( ) 5 - 7 Days

Appendix E.

ECHO-ONE

* * Pretest # 1 * *

1. a) Which category does this sound best fit into?

1	2	3	4
Emotionally positive	Emotionally neutral	Emotionally negative	Don't know

b) How familiar are you with this sound?

1	2	3	4	5
not at all	a little	somewhat	fairly familiar	very familiar

c) How much imagery is associated with this sound?

1	2	3	4	5
none	a little	some	a fair amount	a large amount

2. a) Which category does this sound best fit into?

1	2	3	4
Emotionally positive	Emotionally neutral	Emotionally negative	Don't know

b) How familiar are you with this sound?

1	2	3	4	5
not at all	a little	somewhat	fairly familiar	very familiar

c) How much imagery is associated with this sound?

1	2	3	4	5
none	a little	some	a fair amount	a large amount

3. a) Category?

1	2	3	4
Emotionally positive	Emotionally neutral	Emotionally negative	Don't know

3. b) Familiarity?

1	2	3	4	5
not at all	a little	somewhat	fairly familiar	very familiar

c) Imagery?

1	2	3	4	5
none	a little	some	a fair amount	a large amount

4. a) Category?

1	2	3	4
Emotionally positive	Emotionally neutral	Emotionally negative	Don't know

b) Familiarity?

1	2	3	4	5
not at all	a little	somewhat	fairly familiar	very familiar

c) Imagery?

1	2	3	4	5
none	a little	some	a fair amount	a large amount

5. a) Category?

1	2	3	4
Emotionally positive	Emotionally neutral	Emotionally negative	Don't know

b) Familiarity?

1	2	3	4	5
not at all	a little	somewhat	fairly familiar	very familiar

c) Imagery?

1	2	3	4	5
none	a little	some	a fair amount	a large amount

6. a) Category?

1	2	3	4
Emotionally positive	Emotionally neutral	Emotionally negative	Don't know

b) Familiarity?

1	2	3	4	5
not at all	a little	somewhat	fairly familiar	very familiar

c) Imagery?

1	2	3	4	5
none	a little	some	a fair amount	a large amount

7. a) Category?

1	2	3	4
Emotionally positive	Emotionally neutral	Emotionally negative	Don't know

b) Familiarity?

1	2	3	4	5
not at all	a little	somewhat	fairly familiar	very familiar

c) Imagery?

1	2	3	4	5
none	a little	some	a fair amount	a large amount