Order Number 9417496

Perception of facial emotions in brain-damaged patients: Development and validation of a task

Moss, Edward Maurice, Ph.D.

City University of New York, 1994

U·M·I
300 N. Zeeb Rd.
Ann Arbor, MI 48106

PERCEPTION OF FACIAL EMOTIONS IN BRAIN-DAMAGED PATIENTS: DEVELOPMENT AND VALIDATION OF A TASK

by

EDWARD MAURICE MOSS

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

1994

This manuscript has been read and accepted for the Graduate Faculty in Psychology in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

11/18/93
Date

Chair of Examining Committee

11/18/93
Date

Executive Officer

Ruben C. Gur, Ph.D

Wilma G. Rosen, Ph.D.

Vivian C. Tartter, Ph.D.
Supervisory Committee

The City University of New York

Abstract

PERCEPTION OF FACIAL EMOTIONS IN BRAIN-DAMAGED PATIENTS: DEVELOPMENT AND VALIDATION OF A TASK

by

Edward Maurice Moss

Adviser: Ruben C. Gur, Ph.D.

Stroke produces differing cognitive deficiencies depending upon lesion site. Left hemisphere stroke affects linguistic functions, while right hemisphere stroke disrupts visuospatial processes. Mood disturbances frequently follow stroke, and many survivors and families note persistent mood changes and difficulties perceiving nonverbal communication. Lateralized emotional disturbances are described in other clinical disorders such as epilepsy and head trauma.

Despite abundant tests for assessment of cognitive functioning, and widespread acknowledgement of an interdependent relationship between emotions and cognition, no conventional measures for evaluation of emotion perception exist. As part of a battery of emotion tests (face perception, prosody perception, and mood), two versions of a face perception test were developed to determine whether stroke affected perceptions of subtle gradations in expressions of emotions. Happiness and sadness were selected because they are polar opposites, and universally recognized in cross-cultural studies. Very high quality black-and-white photographs of actors portraying

wide ranges of happiness and sadness were created. Neutral faces were a control measure. Stimuli were balanced for the quality and intensity of emotions displayed, via group ratings and a facial muscle coding system (FACS). Separate male and female stimuli were created to avoid possible biases. Subjects nonverbally rank-ordered stimuli in pairwise comparisons (PC task), and also by simply arranging stimuli in order of increasing intensity (sorting, or ST task). Response times (RT) were also recorded.

Subjects were 16 patients with unilateral CVA (10 female, 6 male) and 18 normal elderly age-matched controls (11 female, 7 male). All CVA subjects met clinical and CT scan criteria for admission.

The CVA group differed from controls for rankings of intensity within happy and sad emotions. Comparisons of males produced many more significant differences than females, perhaps due to sex differences in emotion perception. No significant PC differences emerged among females. Male CVA's differed significantly from controls for sad and neutral face rankings, but not happy. The ST task demonstrated discrepancies between CVA's and controls across all emotion conditions for both sexes. These tasks contribute to eventual assessment batteries which augment cognitive evaluations by addressing pathologic emotion changes. Emotion assessment can guide data-based rehabilitation and provide culturally unbiased measures.

Table of Contents

TABLES

FIGURES

APPENDICES

Chapter 1

Objectives and Background

1.1 Objectives

The primary purpose of this dissertation is to examine the perception of emotion in humans. This topic is explored utilizing tests of visual and auditory emotion perception, in conjunction with tests of cognitive functioning, among a population of patients who have sustained unilateral strokes to either the left or right cerebral hemisphere. Performance on these measures is compared with that of a normal, nonbrain-damaged control population. Measures of mood at the time of testing are taken.

Though there are many tests available for the routine assessment of cognitive functioning, no standard tests of emotion perception exist. Therefore, this research required the development of specific tools with which to explore emotion perception, rather than the application of previously validated measures. It is necessary to employ these tools in the context of a conventional neuropsychological evaluation in an attempt to determine the

relationship between performance on measures of cognitive competence and measures of emotion perception. More specifically, the ability to perceive emotions expressed on the face appears dissociable from other visuospatial abilities including complex pattern perception or simple (neutral) face recognition. Similarly, the ability to perceive emotions expressed through voice appears to be distinct from the ability to comprehend nonaffective spoken language.

Selecting patients who have sustained unilateral strokes has the following theoretical advantages for the study of brain and behavior:

a) Examining patients with documented circumscribed lesions allows for more direct inference of the role of specific neural structures in regulating discrete behaviors,

b) Much information regarding the importance of particular brain regions in the performance of various cognitive tasks has been obtained through the use of this population,

c) Since several noteworthy studies on emotion have already been conducted using stroke patients, the potential for replication and extension of current findings exists,

d) Where comparison is possible, destruction of brain tissue in humans is replicable in animal models,

allowing for further elaboration of basic theoretical constructs,

e) Mood disturbances frequently follow brain injury, and a large subsample of stroke survivors and/or their families complain of persistent mood changes and difficulties perceiving and expressing nonverbal (often affectively laden) communication.

Happiness and sadness, the emotions selected for examination, have been chosen for the following specific reasons. They are considered polar opposites (Plutchik, 1984), consistently emerge as stable and robust two-dimensional factors across numerous lines of research and statistical analyses (Watson and Tellegen, 1985), and have been demonstrated through cross-cultural studies to be universally recognized via facial expression (Ekman and Friesen, 1975).

This research may ultimately have clinical implications, because it is necessary to conduct research into the mechanisms underlying these deficits before effective assessment and rehabilitation strategies can be developed.

1.2 Background and Reasons to Study Emotional Processing

Studies conducted over the past few decades have demonstrated differing cognitive capacities of the two cerebral hemispheres. For most neurologically intact

right-handed people, the left hemisphere is specialized for speech and language functions, while the right hemisphere appears to predominate in visuospatial and other nonverbal processes (Beaton, 1985; for review). Until recently, little attention was given to possible hemispheric asymmetries in the recognition and expression of emotion.

Psychologists and other investigators now devote more resources to the study of emotion, in part to discern the pervasive role of emotion in cognitive processing. Underscoring the necessity of examining emotional behavior in order to provide a context for many behaviors, Tucker (1981) wrote:

> "..the human organism is not a closed loop data processor but a creature whose cognition is subject to activation and direction by motivational processes" (p. 19).

On a parallel front, an increasing number of observations of lateralized emotional disturbances in various clinical populations such as stroke, head injury, and epilepsy patients, also led brain-behavior researchers to scrutinize this area.

Experimental techniques and paradigms developed through cognitive studies of normal samples and patients with psychiatric disorders have also produced pertinent findings. This data is reviewed in sections 1.2.3 through 1.2.7. Several investigators have attempted to define a coherent theoretical structure within which to explain this data and

direct future efforts. For example, Frijda (1988) offers a set of laws governing the experience and expression of emotion.

Psychologists and medical researchers were not the first to recognize the importance of studying emotion in relation to brain function. Darwin (1872) argued that communication about emotion had adaptive value for social species in that it helped coordinate social behavior. He employed comparative studies of the emotional expressions of man and animals to support his theory that man evolved from lower animals. He stated that emotional expression arose from the central nervous system, which also regulated the necessary motor output. He also appreciated the inter-relationship of cognition and emotion, and wrote:

> "...certain actions which we recognize as expressions of certain states of mind, are the direct result of the constitution of the nervous system, and have been from the first independent of the will, and, to a large extent, of habit" (p.66).

1.2.2 Neural Substrates of Emotion

Traditionally, neurologists have viewed emotion as a primitive function of the brain which was represented largely subcortically in the limbic system. This view originated from the work of Papez (1937), who was struck by the fact that rabies, which attacks the hippocampus, presents clinically with prominent mental changes such as fear, terror, rage, and insomnia. He proposed that emotions

were elaborated, and perhaps expressed, via a "harmonious mechanism" consisting of the hypothalamus, anterior thalamic nuclei, cingulate gyrus, hippocampus, and their interconnections.

In the late 1940's Paul MacLean expanded Papez' work, and later added an evolutionary perspective. In 1970, he introduced a schematic representation of what he called the "triune brain", consisting of three overlapping regions. The "reptilian" brain consists of the brainstem core, responsible for basic visceral functions. The "paleomammalian" brain is contained in the limbic system and is important for emotion. Finally, the "neomammalian" brain represents the neocortex, the newest and most highly developed part of the nervous system, which carries out the complex functions of higher organisms. MacLean (1950) suggested that understanding limbic functions had far-reaching implications for psychiatric and psychosomatic disorders.

Much work in the past four decades has further elucidated the neural structures involved in the limbic system, their inter-connections, and the roles they play in emotion. Essential nuclei are thought to be the septum, hypothalamus, and anterior and medial thalamic nuclei, surrounded by the hippocampus, amygdala, parahippocampal gyrus, cingulate, and orbital frontal cortices. The main fiber pathways interconnecting these structures include the

fornix, stria terminalis, stria-medullaris-fasciculus retroflexus system, and the medial forebrain bundle (Koella, 1982; Kelly and Stinus, 1984).

The role of the amygdala in emotion processing has been highlighted in work by Aggleton and Mishkin (1986). They pointed out that modality-specific cortical sensory regions project to discrete amygdalar nuclei, while polysensory cortical regions project to overlapping amygdalar nuclei. Thus, there is considerable potential for sensory convergence within the amygdala. According to their theory, the surprising lack of emotional behavior following bilateral amygdalectomy might be the consequence of a disconnection of cortically processed sensory information from affective mechanisms centered in the hypothalamus and midbrain. Reciprocal pathways carry information from the hypothalamus and midbrain back through the amygdala, and from the amygdala back to cortical sensory systems. Little is known about these ascending pathways, and Aggleton and Mishkin postulated that they may serve to allow emotions to modulate perception.

Cortical centers (phylogenetically newer) have long been viewed as exerting inhibitory control over subcortical responses to internal or external stimulation. Patients with frontal lobe lesions provide the most spectacular examples of disinhibition (Milner and Petrides, 1984). In a review of neurophysiologic mapping studies and clinical

data, Nauta (1971) wrote:

> "The frontal lobe is characterized so distinctly by its multiple associations with the limbic system, and in particular by its direct connections with the hypothalamus, that it would seem justified to view the frontal cortex as the major..neocortical representative of the limbic system. The reciprocity in the anatomical relationship suggests that the frontal cortex both monitors and modulates limbic mechanisms." (p.182)

Nauta speculated that loss of this modulatory influence may explain the oft-described inability of patients with frontal lobe lesions to respond appropriately despite their preserved ability to accurately describe the correct responses.

In addition to cortical management of subcortical responsivity, there appears to be a complex inter-hemispheric balance of activation. For example, Tucker (1981) reviewed data suggesting that the enhanced emotional responsivity of the right hemisphere is modulated by inhibitory or regulatory controls exerted by the left hemisphere. In support of this hypothesis, Tucker pointed to evidence for lateralized neurotransmitter systems.

Emotion regulation systems thus appear to be phylogenetically elaborated at each successive level to allow broader and more subtle processing, to meet the requirements of the animal. Mankind's sacrifice for developing the most intricate adaptive control system is security. This fragile network is prey to disruption by a host of traumatic events, including stroke.

1.2.3 Mood Disturbance Following Unilateral Stroke

1.2.3.1 Epidemiology

Stroke is the third leading cause of both death and disability among older Americans, and estimates of the annual incidence of all types of strokes in the United States range from 600,000 to 750,000. Eighty percent of all new strokes affect people over the age of 65, and despite an overall decrease in the incidence of stroke over the last several decades, the prevalence has remained constant due to a general increase in long-term survival. Approximately 30% of all stroke sufferers expire within 30 days (almost 170,000 in 1979 alone), but the majority survive many years with a wide range of chronic physical, cognitive and communicative disabilities. In 1984, there were estimated to be over 1.8 million stroke survivors (Wolf et al, 1986; Schulz et al, 1988).

1.2.3.2 Depression and Stroke

Several estimates suggest that the prevalence of depression among stroke survivors may approach or exceed 50% (Folstein, 1977; Price, 1987). This symptom has been shown to adversely affect prognosis (Berrios and Samuel, 1987), and to be associated with increased incidence of depression in spouse/primary caregivers (Schulz et al, 1988). Until recently, post-stroke depression was assumed to be a

secondary psychological reaction to sudden physical misfortune and disrupted communication abilities. Goldstein (1935; in Benson) termed this a 'catastrophic reaction' and interpreted it as a response to the frustrations of disability. The main source of frustration is being asked repeatedly to perform tasks that were once easy but have become impossible.

Patients with strokes are more likely to be depressed than patients with orthopaedic injuries, even when the level of functional impairment is comparable for both groups (Folstein et al, 1977). Moderate to severe depression and abnormal dexamethasone suppression test results among stroke patients, as compared to hospitalized controls, was reported by Finkelstein et al (1982). Both findings showed a nonsignificant trend toward greater prevalence among left hemisphere stroke patients. Though Folstein found that patients with right hemisphere lesions were more likely to be depressed, the majority of the literature concerning post-stroke depression reports greater frequency following left hemisphere lesions. This discrepancy may be due to differing samples of patients and definitions of depression. For example, Folstein's patients displayed behaviors characterized as irritability. Also, while appetite and sleep disturbances usually appear in patients suffering from major depressive disorder, most stroke patients in Finkelstein's study exhibited only one of these symptoms.

Depression in patients with a brain injury may differ from standard unipolar or bipolar depression. To clarify this distinction, a framework for dissociating aphasic patients from those with psychiatric disorders was first presented by Benson (1973). He also suggested that differing emotional presentations of stroke patients could provide clues to the location of the lesion along the anterior/posterior axis.

Reviewing hospital records, Gainotti (1969) reported a relationship between side of damage and emotional response. Patients with unilateral damage to the left hemisphere were more likely to show depressive/catastrophic reactions, while those with damage to the right hemisphere more often had euphoric or indifference reactions. One of the most remarkable features of this study was how infrequently the opposite reaction occurred. That is, patients with left hemisphere injuries were rarely euphoric, and those with right hemisphere injuries were rarely depressed. Examination of 160 consecutive right-handed patients with lateralized lesions (80 left, 80 right) yielded similar results (Gainotti, 1972). Etcoff (1985) also reported greater euphoria and indifference among a smaller sample of patients with right hemisphere lesions.

Supporting this data, Sackeim et al (1982) reviewed published accounts of patients with lateralized lesions, hemispherectomy, or lateralized epilepsy who exhibited

pathologic laughing or crying. They found that left-sided destructive lesions were associated with crying while right-sided destructive lesions were more likely to be associated with laughing. Right-sided cortical resection was likely to result in euphoria. Gelastic epilepsy (ictal laughter) was associated with left-sided epileptic foci, while dacrystic epilepsy (uncontrolled crying) occurred with right-sided foci. This reverse effect for epilepsy was thought to result from the irritative, or hyper-stimulating effect of an epileptogenic focus compared with the hypo-stimulating effect of a destructive lesion.

Robinson et al have reported several studies characterizing post-stroke depression and examining the effects of factors which may contribute to this disorder. Care was taken to match stroke patients with control groups having comparable impairments in their activities of daily living and global cognitive functioning. Depression was assessed with multiple measures including ratings by the patient, a close relative, and a primary nurse. Robinson and Szetela (1981a) reported that for patients with left hemispheric stroke, as compared with a head-injured control group, there was a negative correlation between the severity of depression score and the distance of the anatomic lesion from the frontal pole. Thus, the more anterior the lesion, the greater the severity of depression.

This data was re-interpreted by Robinson and Benson

(1981b), who combined the patient and control groups in order to examine the relationship of aphasia and depression. Nonfluent aphasic patients had greater frequency and severity of depression. Paradoxically, the smaller the lesion, the more severe the depression. Global aphasics showed the opposite: the larger the lesion, the greater the depression. These two studies had several limitations; 1) no patients with right hemisphere strokes were studied, 2) 50% of the stroke patients had a history of alcohol abuse, as compared with 27% of the control sample, and 3) controls consisted of eleven patients with traumatic brain injury (ten with closed head injury and one with a gunshot wound). Traumatic brain injuries are typically multifocal (due to contra-coup, axonal shearing, etc.), which restricts their comparability to single stroke lesions.

The finding of increased depression associated with left anterior lesions was replicated in a study of patients with left (n=22) or right hemisphere strokes (n=14), but patients with right posterior lesions also exhibited significant depression (Robinson et al, 1984). Due to the method used to grade the severity of depression, this finding was based largely on scores obtained from only two patients. The relationship between left anterior stroke and disturbance of mood appears to be independent of cerebral motor dominance, as a sample of 30 left-handed stroke patients (18 with left hemisphere lesions and 12 with right hemisphere lesions)

also exhibited greater depression with left hemisphere lesions (Robinson et al, 1985).

In an attempt to replicate Robinson's work, Sinyor et al (1986) also found that patients with left anterior or right posterior lesions had a greater frequency of depression. However, patients in their study with right anterior lesions were equally depressed. They suggest a linear relationship between mood and brain damage for the left hemisphere, and a curvilinear relationship between mood and brain damage for the right. As noted earlier, Folstein et al (1977) also reported a higher prevalence of depression among patients with right hemisphere strokes.

In an attempt to determine more precisely the relationship between subcortical damage and depression, Starkstein et al (1988) studied 25 patients with infarcts limited to the left or right basal ganglia or thalamus. Basal ganglia (head of the caudate nucleus) damage was associated with more frequent and severe depression in the left hemisphere (n=8) than similar damage in the right hemisphere (n=7). No patients in this study with lesions restricted to the left (n=6) or right (n=4) thalamus developed major depression. Unfortunately, four of the 25 patients included in this study had a history of alcohol abuse (3 with right-hemisphere lesions and 1 with a left-hemisphere lesion). Other data exists which supports Starkstein's findings. Sackeim et al (1982) also noted that

lesions resulting in emotional disturbance almost always included subcortical structures, frequently at the level of the internal capsule, with involvement of the basal ganglia.

Focusing their attention only on patients with left hemisphere strokes, Robinson et al (1986a) described greater cognitive impairments, as measured by the Mini-Mental State Examination (MMSE), among depressed than non-depressed patients. This suggests the possibility of potentially reversible "pseudodementia". Not surprisingly, lesion size was correlated with decreased scores on the MMSE for all subjects. When impairment was held constant, depressed subjects had significantly smaller lesions than non-depressed patients. Six months later, only the non-depressed patients showed improved MMSE scores. Of note, 55% of their depressed sample was left-handed or ambidextrous in contrast to only 8% of their non-depressed sample. This raises questions regarding the interpretation of the relationship between hemispheric dominance and depression. Despite its drawbacks, this study highlights the negative effects of post-stroke depression on overall cognitive functioning.

Follow-up studies indicate that patients may become depressed many months after hospitalization (Robinson et al, 1986b), although the relationship between lesion location and depression appears to be significant only within the first year following the stroke (Parikh et al, 1987).

Robinson (1988; personal communication) suggests that while post-stroke depression may resolve without intervention within 7-8 months, evaluation for depression and subsequent treatment may speed overall recovery by alleviating debilitating emotional symptoms which interfere with active participation in rehabilitative endeavors.

Selection bias may be operative in all the stroke studies attempting to correlate lesion location with severity of mood disturbance. Patients with receptive aphasia or severe comprehension problems, problems generally associated with left posterior lesions, were excluded. This may have led to underestimation of depression among this group due to limitations in current, language-based, diagnostic methods.

Another way to explore the correlation between brain damage and affective disturbance is to take the converse approach of examining patients with mood disorders and searching for structural lesions. In an MRI study of depressives, Krishnan et al (1988) found a high prevalence of leukoencephalopathy (patchy white matter lesions) among patients over the age of 45 with late-onset depression. This data is impossible to interpret however, as there was no control group data or postmortem studies. The relationship between subtle age-related cerebrovascular changes and the increased prevalence and severity of depression and suicide in middle and late life has yet to be meaningfully explored.

Based upon the data indicating greater frequency of depression following left rather than right hemisphere stroke, it is intriguing to speculate a correlation between depression or suicide and anterior left hemisphere cerebrovascular alterations.

1.2.3.3 Treatment of Post-Stroke Depression

Treatment of post-stroke depression remains a debated topic. Benson (1973) reported antidepressants to be ineffectual in treating post-stroke depression, and instead he recommended individual and group supportive psychotherapy. Disappointing results with pharmacologic intervention were also reported by Berrios and Samuel (1987). Alternatively, the efficacy of nortriptyline as a method of ameliorating post-stroke depression has been demonstrated by Lipsey et al (1984b). Folstein et al (1977) also recommended consideration of a clinical trial of tricyclic antidepressants. Importantly, they noted that although almost half of their stroke patients met criteria for depression, none had been referred for psychiatric consultation. In addition, the advent of several new psychopharmacologic agents for treatment of depression warrants further study of this form of treatment for alleviation of post-stroke depression.

1.2.4 Differential Affective Response to Hemi-Anesthesia

Clinical data from studies of persons with epilepsy provide another avenue for the exploration of the laterality of affective valence. Sedation of each hemisphere via carotid injection of sodium amytal (a barbiturate) is a procedure performed to localize verbal language and memory functions prior to surgical excision of epileptic foci in persons with medically intractable epilepsy. Patients undergoing this procedure were reported to react emotionally. Ross and Rosadini (1967) correlated emotional valence with side of injection. Right-sided injections (active left hemisphere) more often resulted in euphoria while left-sided injections (active right hemisphere) were followed by depression. Notably, the same reactions occurred among a subset of patients who received doses too low to produce language impairment. Thus, it is unlikely that the depression associated with left hemisphere sedation can be attributed to language loss alone.

Not all studies have found this effect. Milner (1967) reported no reliable differential affective response following lateralized injection, but the procedures used at her center differ in several important aspects from those used elsewhere. Most centers titrate the dosage of sodium amytal each patient receives, using just enough to produce flaccid contralateral hemiplegia and EEG changes which signal hemi-anesthesia (Lee et al, 1988). All of Milner's

patients received a higher, standardized dosage. Further, many of Milner's patients suffered brain dysfunction at an early age, perhaps resulting in re-organization of various cerebral functions. Finally, these patients were performing various cognitive tasks throughout the barbiturization procedure, which may have distracted them and/or resulted in competition with emotional response systems.

Lee et al (1988) reviewed 92 patients undergoing the intracarotid sodium amytal (ISA) procedure. Following right hemi-anesthesia, five of those patients (5.4%) developed behavioral disturbances which were of sufficient severity as to invalidate the procedure (four became agitated or aggressive, one became comatose). Four of these five patients had left frontal structural lesions, and the fifth had a left temporal lesion. The five patients with similar anterior lesions in the opposite hemisphere did not exhibit any behavioral disturbance. Lee et al proposed that the right hemisphere may play a role in the modulation of emotional processing, while left anterior regions inhibit emotional behavior. Thus, loss of both these controls results in an uncontrolled display of emotion.

1.2.5 Lateralization of Emotion in Depression

There is a plethora of literature illustrating lateralized cerebral asymmetries among emotionally disturbed individuals. A large portion of this work is devoted to the

effects of depression on the processing of cognitive or emotional stimuli, or to neurophysiologic or neuroanatomic measurement. A brief review of several seminal articles is included here to provide further evidence for the general hypothesis of hemispheric specialization for emotion.

Flor-Henry et al (1979a) reported right temporal EEG abnormalities among psychotically depressed patients. This effect of depression and lateralized EEG asymmetries has been replicated in a number of studies across a wide range of symptom severity. Schaffer et al (1983) found greater right frontal EEG activation in a small sample of subclinically depressed undergraduates. Using mood-induction techniques, Tucker et al (1981) found greater right frontal EEG activation among college students who were made to feel depressed. These students also displayed a decrease in visual imagery, providing further support of right hemisphere alterations.

The imbalance of cerebral activation found among depressed patients appears to be reversible. Moscovitch, Strauss, and Olds (1981) assessed dichotic listening before and after electroconvulsive therapy (ECT) in a small sample (N=6) of unipolar depressives. These patients showed abnormal lateralization prior to ECT, and normal (right-ear) lateralization following ECT. Three to four months later, they still displayed normal lateralization, and were judged to have improved clinically. A case report offered by

Freeman et al (1985) presents a woman who exhibited marked cognitive and behavioral abnormalities in addition to focal left body-side signs of neurologic impairment (hemi-facial weakness, less use of the left arm, and a right hemisphere EEG abnormality). Dramatic improvement in cognitive and behavioral status and disappearance of the focal neurologic signs followed ECT. Sackeim and Weber (1984) suggest that ECT may produce its therapeutic effects by suppressing right hemispheric hyperactivation in depression.

In a study comparing neuropsychological test performance of patients with unipolar depression, mania, or schizophrenia, Flor-Henry and Yeudall (1979b) reported right hemisphere deficits among the depressed patients. Patients diagnosed as schizophrenic exhibited left hemisphere deficits, and those with mania displayed bilateral dysfunction.

1.2.6 Emotion Processing in Normal Populations

In addition to data collected from patients with clinical disorders such as brain injury or depression, there is a substantial body of literature describing lateral specialization for emotion among normal populations.

Early attempts to uncover behaviors which might provide clues to emotion-processing mechanisms included observing the effects of affective questions on lateral eye movements (LEMs). Schwartz et al (1976) reported that questions

eliciting negative emotions resulted in leftward eye movements (indicating right hemisphere activation) while questions eliciting positive emotions resulted in rightward eye movements (indicating right hemisphere activation). Ehrlichman and Weinberger (1979) reviewed 19 published LEM studies and found that only nine of those experiments obtained significant effects in the predicted direction. Numerous methodological inadequacies were partly to blame, but Ehrlichman and Weinberger acknowledged LEMs as a potentially useful research paradigm. A significant component of eye-movement control resides in the frontal cortex (Bruce and Goldberg, 1984).

In a recognition memory study, Suberi and McKeever (1977) found a greater left visual field (LVF) advantage for the recognition of emotional versus nonemotional faces. Sad faces produced the greatest LVF (right hemisphere) advantage, whereas happy and angry faces had the least LVF superiority. Not all experiments have yielded results which discriminate between emotions. Ley and Bryden (1979), in a tachistoscopic experiment, also showed a LVF advantage for the recognition of schematic emotional faces. Unlike Suberi and McKeever,they found LVF superiority across all emotions.

Left-sided facial composite photographs are judged as expressing emotions more intensely than right-sided composites (Sackeim and Gur, 1978). Post-hoc analyses revealed that this effect was strongest for negative

emotions. Sex differences have been shown to play a role in affect intensity judgement. Borod et al (review; 1984) found females to be significantly more left-faced for expressions of sadness, but not happiness, while males showed left-sided asymmetry for all emotions.

Using tachistoscopic presentation of emotional faces to the left and right visual half-fields, Natale, Gur and Gur (1983) found evidence for both overall right hemispheric superiority for interpretation of emotion and a left hemispheric bias toward rating facial expressions as more positive.

Films projected to the right hemisphere, via specially constructed contact lenses, were judged to be significantly more unpleasant than when these films were projected to the left hemisphere (Dimond et al, 1976). Moreover, cartoons produced the greatest change in heart rate (HR) when projected to the left hemisphere, whereas surgical films evoked greater HR changes when projected to the right hemisphere (Dimond and Farrington, 1977). Thus, lateralized input appears to be capable of modulating autonomic nervous system responsivity.

Normal subjects perceive more happiness in response to facial stimuli initially presented (tachistoscopically) to the left hemisphere compared with presentations of identical faces to the right hemisphere (Davidson, Mednick, Moss, Saron, and Schaffer, 1987). This study also revealed a

similar effect for self-ratings of happiness (the degree to which the stimuli elicited the emotion in the viewer).

In summary, a large number of published studies conducted among normal subjects demonstrate small but consistent effects indicating a right hemisphere advantage for the processing of stimuli with a negative emotional valence and a left hemisphere advantage for the processing of stimuli with a positive emotional valence.

1.2.7 Prosody

The most well-established domain of lateralized cerebral functioning is language comprehension and expression (Beaton, 1985). Linguists and aphasiologists have made considerable advances in demarcating the neural underpinnings of segmental language features (i.e., phonology, syntax, and semantics) but have invested less efforts in examining suprasegmental properties (such as stress and intonation), which comprise prosody. For normal right-handed people, the left hemisphere subserves the majority of segmental language functions. The right hemisphere appears to have a limited verbal processing capacity, such as recognizing concrete nouns (Zaidel, 1978; Searleman, 1983).

The right hemisphere also appears capable of acquiring greater segmental language ability. For example, in a

series of studies employing a variety of linguistic tasks and measurement techniques (evoked potentials, cerebral blood flow, and dichotic listening), Papanicolaou et al (1988) provide evidence to substantiate the phenomena of right hemispheric reorganization in recovery from aphasia. Earlier, Kinsbourne (1971) noted that 2 of 3 post-stroke aphasics who underwent sodium amytal testing lost speech following the right injection, but not the left. Such redundancy and plasticity for segmental aspects of language makes sense from an evolutionary viewpoint.

The verbal content of any message bears only a small portion of the entire meaning, thus equal consideration should be given to the subtext and the text. For example, the statement 'I went up to the boss and he gave me the news' may mean very different things if it is said with happy or sad prosody. Evidence of greater right hemisphere involvement in suprasegmental aspects of communication has recently begun to accumulate. Over 90% of the emotional information contained in interpersonal interactions may be conveyed through nonverbal channels (Mehrabian; in Tucker, 1986). Gesture, facial expression, and intonation are the areas of nonverbal communication most extensively studied in humans and primates (Harnad et al, 1976).

1.2.7.1 Evolution of Emotion Communication

Researchers from the fields of anthropology and social

psychology have contributed an evolutionary perspective to the study of language. The human face may have evolved in part to better serve as a source of emotional information (Etcoff, 1985). For example, the complex human facial musculature may have evolved largely to serve the communication of emotion. Human eyebrows as a facial feature may have developed in order to display more clearly reactions such as surprise and interest, which would be much more difficult to detect if their only visible signs were, for example, the raising of skin above the eyes. Make-up artists, especially those associated with nonverbal theater such as Japanese Noh plays, know this and accentuate this area to communicate emotions.

It has been argued that language arose out of gestural communication. Hewes (1976) suggests the possibility that the specially depigmented areas of the hands and feet of humans and primates may have developed to facilitate gestural behavior in dimly illuminated areas. Gradually, the limitations of gestural communication became apparent to early man; it is useless in caves and in darkness, cannot be used when some other task requiring the hands is in progress, and has a limited repertoire of signals. Vocal communication superseded gestures in the course of evolution. The first communicative sounds may have been crude vocalizations that accompanied gesticulations, and may have served to elaborate emotion-laden messages (e.g.

surprise or fear).

Vocal expression is hierarchically organized in the brain, and the complexity of this organization increases as one ascends the phylogenetic scale. A major difference between man and primates is the higher levels of voice control. Humans can exert direct voluntary control over vocal folds, while apes and monkeys cannot. This is due to extensive connectivity in humans between the primary motor cortex and the laryngeal motoneurons. Ablation of cortical and subcortical regions in monkeys results in minimal disturbance of their vocal communication abilities. Similar brain damage in humans typically results in profound speech and/or language loss. Thus, man has greater voice control (i.e., allowing the ability to sing, articulate, use prosody, etc.) but at the price of creating a much more fragile system (Ploog; 1986, 1988).

Apart from providing information about internal feeling states, communication about emotions contributes clues to intentions and actions. Further, it is often meant to direct the course of action of others, as they respond to the emotions displayed.

As mentioned in the introduction, many have speculated that the neural and behavior systems subserving cognition are overlaid on older systems controlling emotion. Plutchik (1984) postulated that cognitive capacities evolved to augment emotions, providing a method of predicting the

future (by adding a temporal component and allowing mapping of the environment). He argued:

> "The more precisely the environment could be assessed...the greater the capacity to make predictions about the likely course of external events and thus to initiate novel patterns of adaptive behavior...From this point of view, the complex processes of sensory input, evaluation, symbolization, comparison with memory stores, and the like-those processes we call cognitive-are in the service of emotion and biological needs" (p.209).

The evolution of communication reflects the evolution of the brain. The phylogeny of neural development, as glimpsed through animal models and clinical studies in humans, appears to have occurred via the layering of successively higher levels of brain organization (MacLean; 1973, and Hughlings Jackson, in Tucker; 1986). Consecutive layers achieved control by modulating the operations of more primitive underlying systems. This 'vertical dimension' of the brain is often overlooked in the quest to explore functional differentiations along the lateral or anterior/posterior dimensions.

1.2.7.2 Prosodic Disturbance Following Lateralized Brain Injury

Left hemisphere stroke patients can convey emotion through voice intonation (Goodglass and Kaplan, 1972), but it has long been recognized clinically that patients with right hemisphere strokes display a variety of impairments related to the perception and production of emotional

prosody. Patients with right parietal or temporo-parietal lesions are impaired in recognizing emotion from tone of voice, but can recognize sentence content (Tucker et al, 1977). Alternatively, others have found no difference between patients with right- or left-sided lesions on an emotion comprehension task (Schlanger et al, 1976). However, their sample of 20 right-hemisphere damaged patients contained only three with damage to temporo-parietal areas.

In another study, patients were presented with questions, statements, and commands from happy, sad, angry or indifferent speakers (Heilman et al, 1984). Compared with normals, both right- and left-hemisphere damaged patients were impaired in recognizing sentence type. However, only the right-hemisphere damaged patients were impaired in recognizing emotion conveyed through the sentences. There is, however, some disagreement in the literature. For example, in a dichotic listening study in which normals had to detect sentence type (question, statement, or continuation) or emotion (happy, sad, or angry), Shipley-Brown et al (1988) found a left ear advantage for the identification of either affectively or linguistically intoned sentences. The left ear (right hemisphere) effect was much more pronounced for the affective task.

The right hemisphere may be organized for prosody in a manner analogous to the left hemisphere's organization for

linguistic material (Ross, 1984). Ross coined the term "aprosodias" for the various deficits in the processing of prosody. From a small number of case studies, he proposed that anterior (fronto-temporal) lesions impair the production of prosody, while posterior (temporo-parietal) lesions impair the perception of prosody. Of note, face recognition is also disrupted by right temporo-parietal lesions.

Data from a number of studies employing different methodologies indicate that emotional information is dissociable from the speech signal. For example, in a dichotic listening study of normal subjects, Bryden and Ley (1983) found a left hemispheric advantage for sentence content and a right hemisphere advantage for the perception of the emotional tone of voice. They repeated these results in children as young as 5 and 6 years, suggesting that this specialization appears at an early age. Listening to an affectively charged conversation in a foreign language (Greek), normal subjects showed left hemisphere attenuation of evoked potential amplitude when attending to phonetic aspects, and right hemisphere attenuation when attending to emotional aspects (Papanicolaou et al, 1983).

Perception and production of linguistic prosody, as well as affective prosody, can be disrupted by right-hemisphere lesions. Weintraub et al (1981) suggested that deficits in prosodic production among right-hemisphere damaged patients

might be related to the general paucity of emotional behavior they display. They further proposed that there may be one group of patients in whom disturbances of prosody are primary and another group in whom prosodic deficits reflect an underlying disturbance of affect. While provocative, this study had several methodological constraints. The right-hemisphere stroke sample consisted of only nine patients, and the location of their lesions was unspecified. There was no left-hemisphere stroke comparison group, and little information was given regarding ten control subjects. It is possible that the effect reported by Weintraub et al may be the result of generalized brain damage, and may also follow left hemisphere stroke. For this reason, a subset of the tasks used in their study was applied to the population used in this dissertation.

Many facial expressions of emotion have been found universal across populations (Ekman and Friesen, 1975), and numerous affective fluctuations in pitch are also believed to exist in all languages. Hemispheric specialization for language may depend more upon the particular task being performed (linguistic versus nonlinguistic) than on the presence of certain prosodic features themselves. Indeed, apparently contradictory findings such as those of Heilman (1984) and Shipley-Brown (1988) suggest some overlap between the right and left hemispheres with regard to prosodic processing. It appears that pitch contrasts are processed

by the right hemisphere either when alone or when used to signal affective prosody. However, when pitch is used to signal linguistic prosody, greater left hemisphere involvement results. The more segmental language features contained in the stimulus, the greater the likelihood of left hemisphere activation.

Chapter 2

Research Design and Methods

2.1 Specific Aims

The specific aims of this research are:

1. To determine whether the ability to perceive emotions in photographs of faces is distinct from other visuospatial abilities, including simple face recognition. Hypothesis:

   The right hemisphere has greater involvement in emotional processing, over and above its superiority in facial processing. Patients with right hemisphere lesions will have more difficulty with other visuospatial tasks than patients with left hemisphere tasks, but equating the two groups for this difference will show distinct patterns of emotion recognition for both groups. These patterns are described below.

2. To determine the effects of hemispheric stroke on the ability to perceive gradations in the intensity of emotions expressed on the human face. Hypothesis:

   The right hemisphere is superior in processing

emotional intensity and negative emotional valence, and

1) lesions involving the right hemisphere (left hemisphere intact) result in greater overall difficulty judging faces, given the involvement of the right hemisphere in most visuospatial tasks. However, the largest difference between this group and controls will be for the judgment of sad (versus happy) faces.
2) lesions involving the left hemisphere result in less overall visuospatial impairment, but greater difficulty judging happy (versus sad) faces.

3. To determine the effects of right versus left hemispheric stroke on the comprehension of emotional and nonemotional prosody. Hypothesis:

The right hemisphere is superior for prosodic processing, and

1) patients with left hemisphere lesions will have difficulty comprehending nonemotional communication, but will be able to recognize emotions expressed through prosodic shifts.
2) patients with right hemisphere lesions will have difficulty perceiving both emotional and nonemotional prosody.

4. To determine the effects of lateralized stroke on mood.

Hypotheses:

The right hemisphere is characterized by negative emotional valence whereas the left is characterized by positive valence, and

1) patients with left hemisphere lesions will exhibit more symptoms of depression and/or anxiety than those with right hemisphere lesions.
2) the degree of mood disturbance will not be related to the level of cognitive impairment.

2.2 Subject Selection and Screening

2.2.1 Patient Selection

Several methods were employed to recruit patients. Continuous review of hospitalization records at both the Hospital of the University of Pennsylvania (HUP) and its affiliate Graduate Hospital (GH) yielded an average of three to four patients per week admitted with the diagnosis of cerebrovascular accident. Contacts were developed with three local stroke support groups, and invited lectures describing this work and related research were given by this author. Introductory letters from Martin Reivich, M.D., Director of the Cerebrovascular Research Center at HUP, were sent via bulk mail to over 200 neurologists in the Philadelphia area. Howard Hurtig, M.D., Chairman of Neurology at GH, granted access to all departmental patient records and provided a letter of introduction which was sent to potential subjects.

Initial screening of identified inpatients was conducted via chart review. Patients were then informed of the study and briefly interviewed to determine their eligibility and ability to sustain a neuropsychological evaluation (i.e., exclude those with dementia or significant limitations in attention or concentration). Potential outpatient volunteers were screened via telephone. The standardized interview consisted of a series of questions designed to obtain information regarding age, handedness, medical, neurologic, and psychiatric history, and level of alcohol or drug use. The exclusionary criteria were:

History of:

- non-native English speaking.
- Significant (more than 2 drinks/day) alcohol or drug use.
- Head injury resulting in loss of consciousness.
- Seizures not related to stroke.
- Stroke caused by aneurysm, lupus, anoxia, or cancer.
- Parkinson's or Alzheimer's disease, encephalitis, toxic encephalopathy or other previous or concurrent 'dementia' or neurological disorder known to affect cognitive functioning.
- Poorly controlled diabetes.
- Psychiatric disturbance (as defined by DSM III-R) prior to stroke.
- Previous lesion in opposite hemisphere.

More than 300 stroke survivors were screened over a two-

year period. Of these, approximately five percent met criteria for this study. The vast majority were rejected on the basis of dementia, previous contralateral stroke(s), or alcohol abuse. Only three patients who met criteria refused to participate. One patient (#7112) who had completed the experimental emotions tasks suffered a second stroke and expired prior to completing cognitive testing. Table 2.1 describes some major demographic features of the twenty-one patients who completed the study.

TABLE 2.1

PATIENT CHARACTERISTICS

	ID#	Sex/ Age	Race	Dom. hand	Lesion Site	Education(yrs)	Occupation
1)	3406	70/M	C	Right	R(FR)	19	*Engineer
2)	3268	80/F	AA	Right	R(MCA)	16	*Reg. Nurse (RN)
3)	3240	75/M	AA	Right	L(PAR)	18	*Educator
4)	3245	55/M	C	Right	L(OCC/PAR)	12	Bank Guard
5)	7112	67/F	AA	Right	R(MCA)	9	*Factory Worker
6)	3433	60/M	C	Right	R(SUBCX)	16	Realtor
7)	3511	45/M	C	Right	L(MCA)	12	*Elec.Tech.
8)	3909	49/F	AA	Right	R(SUBCX)	12	Factory Worker
9)	4023	80/F	C	Right	R(PAR)	9	Homemaker
10)	3707	72/F	C	Right	L(MCA)	16	*Dean of Nursing
11)	3513	51/F	AA	Right	R(MCA)	12	*Data Entry
12)	3990	64/F	AA	Right	R(SUBCX)	6	*Laundress
13)	4231	61/F	AA	Right	R(MCA)	12	Supply Clerk
14)	4198	75/F	C	Right	R(TMP/PAR)	12	*Hospital Clerk
15)	4194	79/M	AA	Right	L(OCC/PAR)	6	*Construction
16)	4019	59/M	C	Right	R(MCA)	14	*Realtor
17)	4088	56/F	AA	Right	L(MCA)	15	*Reg. Nurse (RN)

Legend

R = right
L = left

F = female
M = male

AA = African-American
C = Caucasian

MCA = middle cerebral artery
OCC = occipital
PAR = parietal
SUBCX = subcortical
FR = frontal
TMP = temporal

* = unemployed (retired and/or disabled)

2.2.2 Selection of Control Subjects

Twenty control subjects were recruited through advertisements in hospital and community newspapers, and lectures at labor unions, retirement communities, and senior citizen centers. All potential control subjects underwent a lengthy telephone screening identical to that of the patients. Spouses and family members of patients enrolled in the study were excluded, despite their availability and desire to participate. This laboratory policy decision was based on concerns regarding increased situational depression and anxiety among this cohort (also see Schulz et al, 1988). All the aforementioned exclusionary criteria were applied to control subjects. Further, none were taking medications with known CNS effects.

Data from two control subjects were excluded from analysis, reducing the final number to eighteen. One male subject was excluded on suspicion of having a personality disorder, and one female subject was excluded when two meningiomas were detected on a CT scan of her brain.

Differences between mean demographic variables of age, education, sex, and race were assessed by t-tests. Table 2.2 contains the means, standard deviations, and significance levels for these variables. Significant differences between the stroke and control subjects were found for education ($t[36]=2.27$, $p=0.03$) and race ($t[36]=-4.13$, $p=0.0002$). On average, control subjects

attended two more years of college than stroke patients. All the control subjects were white, while nine of the stroke patients were African-American. There were no significant differences in these demographic variables between the left or right stroke groups.

TABLE 2.2

DEMOGRAPHIC VARIABLES FOR PATIENTS AND CONTROL SUBJECTS

Variable	CVA	RCVA	LCVA	NC	Significance
Age	63.8 (12.1)	65.1 (9.7)	61.3 (16.3)	69.9 (11.5)	n.s.
Sex	10 F /7 M	8 F /3 M	2 F /4 M	7 F 11 M	n.s.
Race	9 AA/8 C	6 AA/5 C	3 AA/3 C	0 AA/18 C	p<0.0002*
Education	13.2 (3.7)	12.8 (3.5)	13.9 (4.3)	15.4 (2.4)	p<0.03*

Legend
RCVA = right cerebrovascular accident
LCVA = left cerebrovascular accident
NC = Normal Control

F = female
M = male

AA = African-American
C = Caucasian

* = Stroke Patients (CVA) versus Normal Controls (NC) (there were no significant differences between the RCVA and LCVA groups on these variables)

2.3 Procedures

2.3.1 The Neuropsychological Battery

Each patient and control subject in this study received the same comprehensive neuropsychological examination. The test battery is the result of collaborative efforts among members of the Neuropsychology Service at HUP to efficiently measure a large number of cognitive functions in a reasonable amount of time. Tests were selected for their ability to yield reliable information regarding: 1) the presence of brain dysfunction, 2) lateralization of dysfunction, 3) localization of dysfunction, and 4) measurement of specific skills.

Areas of cognitive functioning assessed by the battery include expressive and receptive language, visuo-constructional skill, verbal learning and memory, visual memory, manual fine motor speed, tactile perception, attention and concentration, and nonverbal abstraction. The average administration time for this battery was approximately three hours. Breaks were taken whenever subjects appeared fatigued or requested them. Table 2.3 lists the tests which comprise the battery, grouped by the function they are designed to measure.

TABLE 2.3

NEUROPSYCHOLOGICAL TESTS BY FUNCTION

I. General Orientation
   a. Orientation to person, place, and time
   b. Information and Orientation subtests of the Wechsler Memory Test (WMS)

II. Abstraction and Conceptual Flexibility
   a. Modified Wisconsin Card Sorting Test

III. Verbal Comprehension
   a. Complex Ideational Material subtest of the Boston Diagnostic Aphasia Examination (BDAE)
   b. Information subtest of the Wechsler Adult Intelligence Scale-Revised (WAIS-R)

IV. Expressive Language
   a. Controlled Oral Word Association
   b. Animal Naming Test
   c. Sentence Repetition subtest of the Multi-lingual Aphasia Examination (MAE)
   d. Boston Naming Test
   e. Vocabulary subtest of the WAIS-R
   f. Reading subtest of the Wide Range Achievement Test-Revised (WRAT-R)

V. Verbal Memory and Learning
   a. Semantic Memory subtest of the WMS
   b. California Verbal Learning Test

VI. Visual Memory
   a. Visual Memory subtest of the WMS

VII. Visuo-perceptual and visuo-constructional
   a. Block Design subtest of the WAIS-R
   b. Drawings to Command and Copy
   c. Benton Face Recognition Test

VIII. Visual Attention and Scanning
   a. Trail-Making Test of the Halstead-Reitan Battery (HRB)
   b. Digit-Symbol subtest of the WAIS-R
   c. Letter Cancellation

IV. Auditory Attention
   a. Digit Span subtest of the WAIS-R
   b. Mental Control subtests of the WMS

X. Manual Fine Motor Speed
   a. Finger Oscillation subtest of the HRB

XI. Sensory-Perceptual Examination
   a. Fingertip Number Writing
   b. Double Simultaneous Stimulation in the Tactile, Auditory, and Visual modalities

XII. Perceptual-Motor
   a. Bucco-facial, transitive limb, intransitive limb, and whole body praxis

2.3.2 The Examination of Emotion Perception

Since emotions are communicated substantially through facial expression and voice, tests which accessed these faculties were employed. Table 2.4 presents the structure of the examination of emotion perception.

TABLE 2.4

EMOTION PERCEPTION ASSESSMENT BATTERY

I. Visual
- A. Receptive: (Non-affective)
  - 1. Benton's Face Recognition Test.
- B. Receptive: (Affective)
  - 1. Test of Emotion Expression Recognition.

II. Linguistic

Examination of affective and non-affective prosody.
- A. Receptive: (Non-affective)
  - 1. Discrimination of stress as a semantic cue.
  - 2. Discrimination of intonation in semantically neutral sentences.
- B. Receptive: (Affective)
  - 1. Identification of emotional tone of spoken sentences.

III. Intra-psychic (mood)

A. Depression:
- 1. Beck Depression Scale (BDI)

B. Anxiety:
- 1. State-Trait Anxiety Inventory (STAI)

2.3.2.1 Recognition of Facial Emotion Intensity

The inability to recognize unfamiliar faces is thought to result from damage to posterior regions of either the right or left hemisphere (Benton 1980). To assess basic face recognition skills, all subjects received Benton's well-normed Test of Facial Recognition (Benton et al, 1983). The faces in this test express neutral emotions, and patients must identify them under three conditions: 1) match to sample, 2) match the same face seen from different perspectives, and 3) match the same face seen under different lighting conditions.

Several sets of photographs of people expressing various emotions are currently available. Although the set produced by Ekman and Friesen (1975) is most commonly used, it has several problems. A limited number of models were used, and all were non-professional models posing various emotions. Clothing and hair cues distract from many faces.

For the current study, on facial emotion expression, a large set of high quality black-and-white photographs of actors and actresses portraying happy, sad and neutral emotions was developed in the Brain Behavior Laboratory at HUP from 1981-1983. One hundred and seventeen actors and actresses from Philadelphia and New York volunteered to be photographed during several casting sessions in both cities. All were right-handed caucasians with no history of psychiatric or neurologic disturbance. Those with

noticeably asymmetric faces were screened out. These models were asked to recall situations in which they were very happy and very sad. While they were thus engaged, photographs were taken every few seconds by a professional photographer using a motor-driven 35 mm. camera. Thus a multitude of highly detailed transitional facial expressions at varying levels of intensity were captured. The models were draped in black fabric and photographed against a black background to eliminate all clothing and background distractors. Hair cues were uniformly darkened out during the printing process.

Contact sheets of the photographs were reviewed by laboratory members to delete obviously unusable pictures. A preliminary set of 471 photographs were rated for emotion intensity by 160 male and female undergraduates enrolled in an Introductory Psychology course at the University of Pennsylvania during one group rating session using slides. Participants were asked to rate the faces for the degree to which they appeared happy, sad, angry, fearful, sleepy, surprised or neutral. Only photographs reaching 75% or greater agreement among raters as being happy, sad, or neutral were included in the final set.

For the purposes of this study, it was decided to create a set of faces portraying graded emotions to examine possible biases and fine discrimination abilities. Ten faces were selected from each of the following six groups: happy

males, happy females, sad males, sad females, neutral males, and neutral females. Only those actors and actresses who had successfully produced all three (happy, sad and neutral) expressions were used, and the same models appear in all three conditions. Male and female sets were created to avoid possible sexual attraction confounds; male subjects were shown only male faces, and female subjects were shown only female faces.

All stimuli were printed by a professional photography laboratory as high resolution 4 x 6 inch prints. These prints were then individually laminated onto a triple-weight black paper background. This produced a set of durable, easily cleaned cards which were transportable for bedside examinations. Stickers bearing coded identification information were affixed to the back of each card.

In order to further insure that the faces used in this study were portraying the intended emotion, all six sets of cards were sent to Dr. Richard J. Davidson's Laboratory for Cognitive Psychobiology at the University of Wisconsin at Madison. There they were submitted to FACS coding. The FACS (Facial Action Coding System; Ekman and Friesen, 1978) procedure catalogues all observable movements of the skin on the face, and the muscle movements required to make them. These movements are then translated into emotions. This method has the advantage of providing a means to describe any facial configuration which circumvents the possible

biases of subjective interpretation. Although most studies attempt to avoid this confound by employing multiple raters, this only increases the reliability of the judgments, but it is not possible to determine whether raters use the same criteria to arrive at their decisions (Rinn, 1984). Any faces in the current set that were not predominantly happy, sad, or neutral were removed from the final set.

Another reason for using multiple rating systems to validate these stimuli was to equate the happy and sad stimuli for level of intensity. Greater intensity of one or the other might obscure differences between either the patients and controls or between the right versus left hemisphere stroke groups. Following FACS coding, seven photographs remained in each of the six sets. Two photographs rejected from each set were used for task orientation and practice, and no data were collected with them. Photocopies of the final set of emotion recognition test stimuli are provided in Appendix I (reduced to 70 percent of their original size in order to fit on the page).

Stimuli were presented to subjects in pairs, within an emotion. Each of the seven faces comprising a group was paired with every other face, for a total of 21 presentations per emotion. Faces were presented one above the other in order to control for possible lateralized neglect or spatial inattention. Since random pairings of the faces risked random order effects (e.g., the same face

might wind up on top too many times), two counterbalanced presentation orders were established, and half of each group received each order. For the happy faces, subjects were asked "Which face is happier?", and for the sad faces, they were asked "Which face is sadder?". Half the subjects received the sad faces first, and half received the happy faces first. Neutral faces were always presented last, and they were presented twice so that they could be ranked for both happiness and sadness. The response mode was nonverbal; subjects pointed to their choice.

In addition to the sorting procedure described above, a second method was also used with each subject at the end of each set of the first procedure. All the cards within an emotion were shuffled and spread before the subjects. They were asked to arrange the cards from left to right, placing the least happy/sad face on the left and the happiest/saddest face on the right. All other faces in the set were to be placed in order of increasing intensity between these two. This was also executed following the neutral face pairings. Since each sorting method had advantages and disadvantages (i.e., the pairings are cumbersome for the examiner and more time-consuming, but may be more psychometrically stable) both were used in an effort to determine empirically the most effective method. Response times were recorded for each pairing, and for the group sorting.

2.3.2.2 Prosody Perception

To examine perception of emotional and nonemotional prosody, subtests of a battery developed by Weintraub and colleagues (1981) were used. All stimuli were delivered via audiotape created by Weintraub et al.

Subtest 1 - Discrimination of stress as a semantic cue in single words:

This subtest measures the ability to discriminate the meanings of 20 different words utilizing alterations in stress. For example, the noun bluejay is differentiated from the noun phrase blue J by differing stress patterns. The subjects select their answer by pointing to a page containing four color drawings (the bird, a letter J colored in blue, a letter B colored in blue which serves as a semantic distractor, and an unrelated drawing of a canary).

Subtest 2 - Discrimination of intonation in semantically neutral sentences:

Subjects hear 25 pairs of sentences in which the words are invariant but the intonation of the speaker may change. For example, 'Linda ate three peaches.''Linda ate three peaches'. In a subset (5) of these sentence pairs, the shift in intonation changes the sentence from declarative to interrogative or vice versa. For example,

'Steve drives a car.''Steve drives a car ?'. Subjects identify the pair of sentences as "same" or "different".

Subtest 3 - Discrimination of emotion presented via prosody: Ten semantically neutral sentences from subtest 2 are presented with happy, sad, angry, puzzled, or neutral intonation. Subjects listen to the sentence, then select one of these choices from a card listing all five in large type.

2.3.2.3 Quantification of Mood

A. Depression:

1. Beck Depression Scale (BDI)

B. Anxiety:

1. State-Trait Anxiety Inventory (STAI)

The total administration time for the facial and prosody stimuli and the self-rating scales was approximately ninety minutes. Total administration time for the complete neuropsychologic and emotional test battery was approximately four and one-half hours.

Chapter 3

Results

3.1 Analysis Strategy

Responses to all emotion perception tasks were recorded on specially prepared coding sheets (see Appendix II). Subjects were divided into four groups: stroke (CVA), right hemisphere stroke (RCVA), left hemisphere stroke (LCVA), and normal controls (NC). Since each sex viewed a same-sex set of faces for the two facial emotion tasks, these data were further divided by sex. Unfortunately, these subdivisions ultimately resulted in subject pools too small to make valid generalizations about sex differences in hemispheric specialization for emotion perception. While these data are included in order to complement the major analyses examining differences between brain-injured and normal elderly control subjects, they should be regarded as exploratory.

3.2 Facial emotion paired comparison task

Because the facial emotion paired comparison task is the primary focus of this research, it received the most

comprehensive investigation. Analysis of the paired photographic data was based on the Bradley-Terry model for paired comparisons (Bradley & Terry, 1952), which has been cited and reviewed extensively in the 40 years since its development. Following a 1976 survey article on the method (Bradley, 1976) is a bibliography of several hundred technical papers on paired comparisons (Davidson & Farquhar, 1976), many of which refer to extensions of the Bradley-Terry model or investigations of its statistical properties. In a more recent review of theory relevant to the Bradley-Terry model, Agresti (1990) discussed data analysis for several ordinal responses (e.g., "strong agreement, moderate agreement, neutral [tie], moderate disagreement, strong disagreement") and other related outcome measures. The Bradley-Terry model has been used extensively in experimental situations in which individuals' subjective judgments result in qualitative comparative responses. Several relevant examples of situations requiring this approach have been offered in various articles, including wine tasters comparing wines in pairwise taste tests (indicating the preferable brand in each comparison), and secretaries making pairwise comparisons of typewriter ribbons.

The application of this model to the paired photographs in the current study was a three step process:

Step 1. The paired comparison data collected in this experiment were summarized in a data matrix. There are seven photographs in each of the four emotional valences (happy, sad, happy/neutral, and sad/neutral). The number of times that object i is preferred to object j (when the two objects are compared n_{ij} times) is denoted by a_{ij}. These data are displayed in Table 3.1, using the following format, where the paired integers (a_{ij}'s) below refer to the pair of photos to be compared:

12	13	14	15	16	17
	23	24	25	26	27
		34	35	36	37
			45	46	47
				56	57
					67

The multi-page Table 3.1 shows triangular matrices for each combination of sex, group (L-CVA, R-CVA, NC), and valence (positive, negative, or neutral emotion). The two numbers in the upper left-corner of each triangular matrix represent the comparison of photos 1 and 2. The first entry is the number of times, a_{12}, photo 1 was preferred to photo 2 (2 times for male, R-CVA, happy) and the second element is a_{21} (0 times). As displayed in Table 3.1, there were two male R-CVA subjects and so each pair of entries in the first matrix sum to two. Similarly, there were eight female R-CVA subjects and the paired entries in the next matrix sum to eight.

Inspection of Table 3.1 revealed that the comparisons

were often very unidirectional in preference. Even for happy/neutral and sad/neutral photos, one photo in each pair was almost always selected as displaying more emotional intensity than the other. However, the position of a particular photo in a set of seven was not obvious.

Table 3.1

Preference matrices for all combination of sex, left or right stroke, and valence. Each pair of adjacent numbers gives the number of times that photo i was preferred to photo j, and the reverse. See the text for the key to finding a given combination.

Preference matrices for **HAPPY**

Male - Right Stroke

2, 0	2, 0	2, 0	2, 0	2, 0	2, 0
	0, 2	2, 0	0, 2	0, 2	0, 2
		2, 0	1, 1	2, 0	1, 1
			0, 2	0, 2	0, 2
				1, 1	1, 1
					1, 1

Female - Right Stroke

0, 8	0, 8	2, 6	2, 6	6, 2	4, 4
	4, 4	7, 1	7, 1	7, 1	7, 1
		8, 0	8, 0	7, 1	7, 1
			3, 5	6, 2	7, 1
				5, 3	6, 2
					2, 6

Male - Left Stroke

3, 1	2, 2	4, 0	1, 3	1, 3	3, 1
	1, 3	3, 1	2, 2	1, 3	1, 3
		4, 0	3, 1	2, 2	3, 1
			0, 4	0, 4	0, 4
				4, 0	3, 1
					0, 4

Female - Left Stroke

0, 2	0, 2	0, 2	0, 2	2, 0	0, 2
	1, 1	2, 0	2, 0	2, 0	1, 1
		2, 0	2, 0	2, 0	2, 0
			1, 1	1, 1	2, 0
				2, 0	1, 1
					1, 1

Male - Control

11, 0	6, 5	11, 0	7, 4	6, 5	3, 8
	1,10	11, 0	5, 6	4, 7	2, 9
		11, 0	5, 6	7, 4	3, 8
			0,11	0,11	0,11
				7, 4	3, 8
					2, 9

Female - Control

0, 7	0, 7	1, 6	2, 5	6, 1	3, 4
	6, 1	7, 0	6, 1	6, 1	6, 1
		7, 0	7, 0	7, 0	7, 0
			2, 5	6, 1	6, 1
				6, 1	5, 2
					0, 7

Table 3.1, continued

Preference matrices for **SAD**

Male - Right Stroke

0, 2	0, 2	1, 1	1, 1	1, 1	1, 1
	2, 0	2, 0	2, 0	2, 0	2, 0
		2, 0	2, 0	2, 0	2, 0
			1, 1	1, 1	1, 1
				0, 2	0, 2
					0, 2

Female - Right Stroke

5, 3	5, 3	3, 5	4, 4	2, 6	3, 5
	3, 5	2, 6	2, 6	2, 6	3, 5
		3, 5	5, 3	4, 4	5, 3
			5, 3	2, 6	6, 2
				1, 7	5, 3
					6, 2

Male - Left Stroke

1, 3	0, 4	2, 2	4, 0	1, 3	1, 3
	3, 1	3, 1	4, 0	3, 1	3, 1
		4, 0	4, 0	3, 1	4, 0
			4, 0	2, 2	2, 2
				0, 4	0, 4
					1, 3

Female - Left Stroke

1, 1	2, 0	0, 2	1, 1	0, 2	1, 1
	2, 0	0, 2	1, 1	0, 2	1, 1
		1, 1	1, 1	1, 1	1, 1
			1, 1	1, 1	1, 1
				1, 1	2, 0
					1, 1

Male - Control

0,11	2, 9	4, 7	9, 2	4, 7	7, 4
	9, 2	11, 0	11, 0	11, 0	11, 0
		9, 2	11, 0	11, 0	11, 0
			10, 1	6, 5	6, 5
				2, 9	4, 7
					8, 3

Female - Control

3, 4	3, 4	1, 6	4, 3	1, 6	4, 3
	4, 3	4, 3	5, 2	1, 6	3, 4
		4, 3	6, 1	0, 7	7, 0
			6, 1	3, 4	6, 1
				2, 5	2, 5
					7, 0

Table 3.1, continued

Preference matrices for **HAPPY/NEUTRAL**

Male - Right Stroke

1, 1	2, 0	2, 0	1, 1	1, 1	0, 2
	1, 1	2, 0	1, 1	2, 0	0, 2
		2, 0	1, 1	1, 1	0, 2
			0, 2	0, 2	0, 2
				2, 0	0, 2
					0, 2

Female - Right Stroke

4, 3	0, 7	1, 6	2, 5	2, 5	2, 5
	2, 5	1, 6	6, 1	4, 3	4, 3
		4, 3	7, 0	6, 1	5, 2
			7, 0	4, 3	6, 1
				1, 6	1, 6
					3, 4

Male - Left Stroke

1, 3	0, 4	4, 0	3, 1	3, 1	0, 4
	3, 1	4, 0	3, 1	4, 0	1, 3
		4, 0	3, 1	3, 1	0, 4
			1, 3	1, 3	0, 4
				3, 1	1, 3
					0, 4

Female - Left Stroke

0, 2	0, 2	1, 1	1, 1	2, 0	2, 0
	0, 2	0, 2	1, 1	2, 0	1, 1
		1, 1	1, 1	2, 0	2, 0
			2, 0	2, 0	2, 0
				2, 0	2, 0
					0, 2

Male - Control

5, 6	8, 3	10, 1	10, 1	7, 4	10, 1
	8, 3	11, 0	11, 0	6, 5	5, 6
		10, 1	9, 2	5, 6	5, 6
			4, 7	2, 9	1,10
				3, 8	2, 9
					5, 6

Female - Control

2, 5	2, 5	2, 5	3, 4	5, 2	4, 3
	3, 4	1, 6	5, 2	6, 1	4, 3
		2, 5	7, 0	6, 1	6, 1
			6, 1	7, 0	7, 0
				5, 2	5, 2
					2, 5

Table 3.1, continued

Preference matrices for **SAD/NEUTRAL**

Male - Right Stroke

0, 2	1, 1	0, 2	2, 0	0, 2	2, 0
	0, 2	0, 2	1, 1	0, 2	2, 0
		1, 1	2, 0	0, 2	2, 0
			2, 0	2, 0	2, 0
				0, 2	2, 0
					2, 0

Female - Right Stroke

1, 6	4, 3	5, 2	1, 6	3, 4	2, 5
	5, 2	4, 3	1, 6	2, 5	2, 5
		4, 3	0, 7	2, 5	1, 6
			1, 6	2, 5	0, 7
				4, 3	4, 3
					3, 4

Male - Left Stroke

3, 1	2, 2	0, 4	2, 2	1, 3	1, 3
	0, 4	0, 4	2, 2	0, 4	3, 1
		0, 4	2, 2	1, 3	4, 0
			4, 0	3, 1	4, 0
				1, 3	2, 2
					3, 1

Female - Left Stroke

0, 2	2, 0	2, 0	1, 1	0, 2	0, 2
	1, 1	2, 0	1, 1	0, 2	0, 2
		1, 1	0, 2	0, 2	0, 2
			1, 1	1, 1	1, 1
				2, 0	0, 2
					0, 2

Male - Control

6, 5	2, 9	1,10	2, 9	5, 6	3, 8
	0,11	0,11	4, 7	6, 5	6, 5
		4, 7	6, 5	9, 2	10, 1
			9, 2	9, 2	8, 3
				5, 6	8, 3
					7, 4

Female - Control

5, 2	5, 2	6, 1	2, 5	1, 6	2, 5
	5, 2	5, 2	2, 5	1, 6	1, 6
		4, 3	0, 7	1, 6	0, 7
			2, 5	2, 5	1, 6
				5, 2	4, 3
					3, 4

Step 2. The Bradley-Terry models posits the existence of non-negative constants $\pi_1, \ldots, \pi_k$ such that the "true" probability of preferring object i to object j is

$$\pi_{ij} = \pi_i/(\pi_i+\pi_j).$$

The π_i's satisfy $\Sigma\pi_i = 1$ and so may be thought of as "relative selection probabilities" (or "preference probabilities") whose order implies an order for the objects (Bradley, 1976). For the purpose of this analysis, the π_i's are simply a mechanism that permits the paired comparison data to yield an ordering, or ranking, for the photographs.

There were two within-group hypotheses upon which all subsequent analyses were predicated: a) that the Bradley-Terry model fits these data, and b) the null hypothesis, that all selections were equally likely (random). To test these two hypotheses; 1) the maximum likelihood estimates and likelihood functions were obtained (this process is described in detail in Appendix III), 2) the hypothesis that the Bradley-Terry model fits these data was tested[1] via chi-square (always strongly accepted), and 3) the null hypothesis, that all selections are random, was tested[2] via chi-square (always rejected).

---

[1] Goodness-of-fit: The test statistic is $-2\{\Sigma a_{ij} \ln(n_{ij}p_i/a_{ij}(p_i+p_j))$ summed over $i \neq j$. Under the null hypothesis of good fit, and for large n_{ij}, this has a chi-square distribution with $\frac{1}{2}K(K-1)-K+1$ degrees-of-freedom.

[2] Equal selection probabilities: The test statistic is $2(N \ln(2) - B)$ where $N = \Sigma n_{ij}$ summed over $i<j$ and $B = \Sigma\Sigma n_{ij} \ln(p_i+p_j) - \Sigma a_i \ln(p_i)$ which has, under the null hypothesis of equal selection probabilities, a chi-

These analyses were calculated on an individual sex x diagnosis basis, since the male and female data could not be merged. The rankings for each set of photographs were thus derived for each subject population. In each case, the Bradley-Terry model was validated as an appropriate approach to the data analysis, and all subjects in the study expressed preferences for the ordering of the photos. These twenty-four individual analyses are presented in Appendix IV. The estimated preference probabilities resulting from these analyses are displayed in Table 3.2. Below is an annotated [in square brackets] example from the program output for this analysis. The first analysis displayed in Table 3.2 is used as the exemplar:

happy; sex 1 diagnosis 1 [males, right stroke]
p(i): 0.9560 0.0000 0.0173 0.0000 0.0103 0.0061 0.0103 [Σ=1]
log likelihood -7.920
X^2 test of = selection: 42.384(6) [equal selection rejected]
X^2 test of fit : 1.978(15) [excellent fit]

---

square distribution with K-1 degrees-of-freedom.

Table 3.2

Estimated preference probabilities (summing to 1) for each combination of valence, sex, and diagnosis. The higher the number, the greater the likelihood that a particular face was selected as displaying a specific emotion more intensely.
Key: diagnosis (dx) R=right stroke, diagnosis L=left stroke, and diagnosis C=control. Sex M=male and sex F=female.

valence
sex dx

happy

		photograph #						
		1	**2**	**3**	**4**	**5**	**6**	**7**
M	R	0.9560	0.0000	0.0173	0.0000	0.0103	0.0061	0.0103
F	R	0.0223	0.3544	0.4771	0.0526	0.0526	0.0164	0.0246
M	L	0.1527	0.0624	0.2592	0.0057	0.2592	0.1080	0.1527
F	L	0.0058	0.2950	0.5974	0.0363	0.0363	0.0058	0.0234
M	C	0.1969	0.0444	0.1607	0.0000	0.1230	0.0938	0.3812
F	C	0.0110	0.5411	0.3592	0.0303	0.0391	0.0032	0.0162

sad

		1	**2**	**3**	**4**	**5**	**6**	**7**
M	R	0.0007	0.9374	0.0586	0.0007	0.0003	0.0007	0.0017
F	R	0.1090	0.0630	0.1366	0.1854	0.1090	0.3034	0.0936
M	L	0.0405	0.3203	0.4090	0.0620	0.0000	0.0758	0.0923
F	L	0.0944	0.0944	0.0689	0.2373	0.1732	0.2373	0.0944
M	C	0.0097	0.8275	0.1285	0.0142	0.0024	0.0121	0.0057
F	C	0.0626	0.1002	0.1330	0.1780	0.0377	0.4420	0.0465

happy/neutral

		1	**2**	**3**	**4**	**5**	**6**	**7**
M	R	0.0112	0.0112	0.0047	0.0000	0.0112	0.0029	0.9590
F	R	0.0326	0.0836	0.3803	0.2960	0.0226	0.0924	0.0924
M	L	0.0401	0.1909	0.0947	0.0040	0.0323	0.0130	0.6251
F	L	0.0612	0.0612	0.3852	0.3852	0.0951	0.0000	0.0120
M	C	0.3135	0.2535	0.1159	0.0165	0.0286	0.1317	0.1404
F	C	0.0638	0.1159	0.2198	0.4791	0.0577	0.0214	0.0425

sad/neutral

		1	**2**	**3**	**4**	**5**	**6**	**7**
M	R	0.0143	0.0143	0.0823	0.5953	0.0040	0.2899	0.0000
F	R	0.0645	0.0945	0.0430	0.0386	0.3547	0.1521	0.2525
M	L	0.0209	0.0117	0.0438	0.7861	0.0209	0.1023	0.0143
F	L	0.0481	0.0682	0.0147	0.0336	0.0972	0.0972	0.6410
M	C	0.0402	0.0458	0.2712	0.4011	0.1153	0.0709	0.0554
F	C	0.1021	0.0622	0.0288	0.0365	0.2828	0.2049	0.2828

Step 3. Between-group hypotheses, for example that cases and controls do not differ, were tested by comparing the log likelihoods assuming that 1) there is a distinction between cases and controls and 2) there is no distinction. Assuming that there is no distinction is equivalent to adding the a_{ij}'s for the two groups. Hence, to compare any two groups, the procedure is as follows:

1: To compare subject groups A and B, sum their preference matrices.

2: Obtain the maximum likelihood estimates and likelihood function for group A, for group B, and for the pooled data of groups A and B (this uses the summed preference matrix).

3: Let L(A) be the log-likelihood for group A, L(B) be the log-likelihood for group B, and L(A+B) be the log-likelihood for the pooled group (A+B). Compute $D = 2(L(A+B)-L(A)-L(B))$.

4: Compare D to a chi-square with K degrees-of-freedom. If the result is significant, then the null hypothesis of equality of the groups A and B is rejected.

The estimated preference probabilities for the pooled combinations of diagnoses are displayed in Table 3.3. Below is an annotated [in square brackets] example from the program output for this analysis. The first analysis displayed in Table 3.3 is used as the exemplar:

Example:

We test the null hypothesis that, among males viewing the happy photos, L-CVA patients and R-CVA patients give the same ordering to the photos.

(A) happy; sex 1 diagnosis 1 [males, right stroke]
p(i): 0.9560 0.0000 0.0173 0.0000 0.0103 0.0061 0.0103
[Σ=1]
log likelihood -7.920 [this is L(A)]
X^2 test of = selection: 42.384(6) [equal selection rejected]
X^2 test of fit : 1.978(15) [excellent fit]

(B) happy; sex 1 diagnosis 2 [males, left stroke]
p(i): 0.1527 0.0624 0.2592 0.0057 0.2592 0.1080 0.1527
[Σ=1]
log likelihood -41.774 [this is L(B)]
X^2 test of = selection: 32.900(6) [equal selection rejected]
X^2 test of fit : 17.427(15) [good fit]

(A+B) happy; sex 1 diagnosis 1 **or** sex 1 diagnosis 2
p(i): 0.2680 0.0386 0.2361 0.0031 0.2086 0.1007 0.1450
log likelihood -57.587 [this is L(A+B)]
X^2 test of = selection: 59.499(6) [equal selection rejected]
X^2 test of fit : 9.455(15) [very good fit]

Computing D = 2(L(A+B)-L(A)-L(B)), we find
D = 2(57.587-7.920-41.774)=15.786.

Compared to a chi-square with 6 degrees-of-freedom, this has p-value 0.0149, so we reject the null hypothesis that, for males, side of stroke has no impact on the ordering of the pictures for the happy valence. Visual inspection of the raw data, converted to matrix form in Table 3.1, appears to support this result. Examination of the p_i's in the current example for males with a right stroke (diagnosis 1) and males with a left stroke (diagnosis 2), indicates large

differences between these groups. For right stroke, picture 1 has, by far, the largest selection probability (0.9560) and no other photo has a large selection probability. Reviewing the first matrix of Table 3.1 (male, R-CVA, happy valence), picture 1 is preferred to every other picture by 2 to 0. In contrast, for males, L-CVA, happy valence (matrix, Table 3.1) picture 1 is sometimes strongly preferred and sometimes not preferred.

Table 3.3

Estimated preference probabilities for pooled combinations of diagnoses. Key: diagnosis (dx) R=right stroke, diagnosis L=left stroke and diagnosis C=control. Sex M=male and Sex F=female.

valence	sex	dx	photograph #						
happy			**1**	**2**	**3**	**4**	**5**	**6**	**7**
M	R	L	0.2680	0.0386	0.2361	0.0031	0.2086	0.1007	0.1450
F	R	L	0.0181	0.3449	0.4980	0.0500	0.0500	0.0140	0.0249
M	R	L C	0.2293	0.0450	0.1929	0.0012	0.1560	0.1018	0.2739
F	R	L C	0.0159	0.4146	0.4470	0.0435	0.0479	0.0088	0.0224
M	R	C	0.2523	0.0371	0.1673	0.0000	0.1256	0.0939	0.3238
M	L	C	0.1920	0.0522	0.1920	0.0014	0.1587	0.1033	0.3003
F	R	C	0.0176	0.4293	0.4293	0.0439	0.0489	0.0091	0.0219
F	L	C	0.0102	0.4813	0.4120	0.0333	0.0406	0.0040	0.0186
sad									
M	R	L	0.0303	0.4441	0.3671	0.0401	0.0037	0.0459	0.0688
F	R	L	0.1072	0.0695	0.1209	0.1963	0.1209	0.2902	0.0950
M	R	L C	0.0206	0.6599	0.2392	0.0288	0.0043	0.0275	0.0197
F	R	L C	0.0907	0.0844	0.1299	0.1944	0.0813	0.3438	0.0755
M	R	C	0.0075	0.8481	0.1174	0.0104	0.0020	0.0091	0.0055
M	L	C	0.0243	0.6278	0.2534	0.0355	0.0046	0.0336	0.0207
F	R	C	0.0886	0.0815	0.1392	0.1868	0.0718	0.3603	0.0718
F	L	C	0.0737	0.1048	0.1204	0.1988	0.0593	0.3838	0.0593
happy/neutral									
M	R	L	0.0431	0.1160	0.0566	0.0025	0.0377	0.0136	0.7306
F	R	L	0.0432	0.0856	0.3858	0.3160	0.0367	0.0589	0.0738
M	R	L C	0.2139	0.2535	0.1259	0.0145	0.0476	0.0910	0.2535
F	R	L C	0.0544	0.1021	0.3079	0.3842	0.0478	0.0418	0.0618
M	R	C	0.2832	0.2385	0.1125	0.0153	0.0406	0.1186	0.1913
M	L	C	0.2245	0.2731	0.1346	0.0162	0.0400	0.0976	0.2140
F	R	C	0.0515	0.1056	0.2983	0.3822	0.0421	0.0515	0.0689
F	L	C	0.0656	0.1058	0.2482	0.4625	0.0656	0.0153	0.0369
sad/neutral									
M	R	L	0.0232	0.0157	0.0589	0.7250	0.0179	0.1504	0.0089
F	R	L	0.0674	0.0977	0.0386	0.0420	0.2879	0.1522	0.3142
M	R	L C	0.0434	0.0416	0.1951	0.4968	0.0791	0.1043	0.0398
F	R	L C	0.0816	0.0816	0.0347	0.0402	0.2869	0.1739	0.3012
M	R	C	0.0429	0.0479	0.2520	0.4309	0.0941	0.0894	0.0429
M	L	C	0.0427	0.0407	0.2022	0.4816	0.0919	0.0919	0.0491
F	R	C	0.0822	0.0784	0.0363	0.0384	0.3181	0.1776	0.2690
F	L	C	0.0945	0.0697	0.0275	0.0396	0.2400	0.1881	0.3407

In the previous example, the male left and right stroke patients judged the happy faces differently. In the example below, we determine whether either of these patient groups agrees with the control group. Control group results appear below as do the three sets of p_i's, repeated for easier scanning.

happy; sex 1 diagnosis 3 [males, controls]
p_new: 0.1969 0.0444 0.1607 0.0000 0.1230 0.0938 0.3812
log likelihood -97.355
X^2 test of = selection: 125.525(6) [equal selection rejected]
X^2 test of fit : 10.157(15) [very good fit]

	photograph #						
males	1	2	3	4	5	6	7
Right CVA :	0.9560	0.0000	0.0173	0.0000	0.0103	0.0061	0.0103
Left CVA :	0.1527	0.0624	0.2592	0.0057	0.2592	0.1080	0.1527
Control :	0.1969	0.0444	0.1607	0.0000	0.1230	0.0938	0.3812

Using the same methods described above, we find a p-value of 0.0188 for the null hypothesis that right and control agree (i.e., the hypothesis rejected) and a p-value of 0.1422 for the null hypothesis that left and control agree (i.e., the hypothesis is not rejected). These results are consistent with an informal examination of the three sets of estimated π_i's. That is, the preference probabilities for each individual photograph in the L-CVA group appear quite similar to those of the NC group, while those of the R-CVA group appear quite different.

The same computations were performed for each sex, diagnosis, valence combination and the results are shown in

Table 3.3. Besides division along lines of valence, the table is also divided into those results concerning a single group (e.g., male, L-CVA, happy) and those concerning pooled groups (e.g., male, L- or R- CVA, happy). The latter set of results was included so that their estimated selection probabilities could be compared to those of individual combinations. Additionally, estimated selection probabilities of the case group (either left or right stroke) appear only in this table.

For each valence and sex, likelihood ratio tests[3] were used to compare left stroke with right stroke, all cases (left or right stroke) with controls, left stroke with controls, and right stroke with controls (Table 3.4).

These data are also presented in graphs in Figure 1 (males) and Figure 2 (females). As mentioned earlier, the order of the preference probabilities implies an order for the photographs. For display purposes, these implied

---

[3] Hypotheses about the π_i's are tested by using the likelihood ratio test. Suppose that $p_1, \ldots, p_K$ are maximum likelihood estimates for parameters $\pi_1, \ldots, \pi_K$ (not necessarily referring to the Bradley-Terry model). Consider the hypothesis H_0: $\pi_1 = \pi_2 = \ldots \pi_k = 0$ for $k < K$. That is, we hypothesize that $k < K$ of the parameters are zero. Furthermore, let L_0 denote the likelihood function, evaluated at its maximum, when the first k parameters are set to zero, and let L_1 denote the unrestricted maximum of the likelihood function. The likelihood ratio test is based on the observation that, when H_0 is true and the sample size is sufficient, $X^2 = 2 \ln(L_1-L_0)$ has an approximate chi-square distribution with K-k degrees-of-freedom. Non-significant values of X^2 imply that the data are consistent with H_0 while large values of X^2 imply that some of the π_i's, i = 1, ..., k are non-zero so that H_0 is not supported.

sequences were converted to explicit rankings. The rankings for the control subjects were then set as the standard against which the patient groups (left and right combined) were compared.

Table 3.4

Likelihood ratio p-values for comparison of subgroups of subjects. Significant group differences are denoted by *.

HAPPY VALENCE

comparison	males	females
left vs. right	.0149 *	.92
all vs. controls	.147	.59
left vs. controls	.1422	.91
right vs. controls	.0188 *	.54

SAD VALENCE

comparison	males	females
left vs. right	.058	.86
all vs. controls	.0388 *	.068
left vs. controls	.0039 *	.23
right vs. controls	.4922	.13

HAPPY/NEUTRAL VALENCE

comparison	males	females
left vs. right	.24	.0002 *
all vs. controls	<.0001 *	.084
left vs. controls	<.0001 *	.25
right vs. controls	.0003 *	.0020 *

SAD/NEUTRAL VALENCE

comparison	males	females
left vs. right	.086	.56
all vs. controls	.0002 *	.80
left vs. controls	.0143 *	.65
right vs. controls	.0003 *	.77

FIGURE 1

PAIRED COMPARISON TASK

STROKE VS CONTROL

MALE SUBJECTS

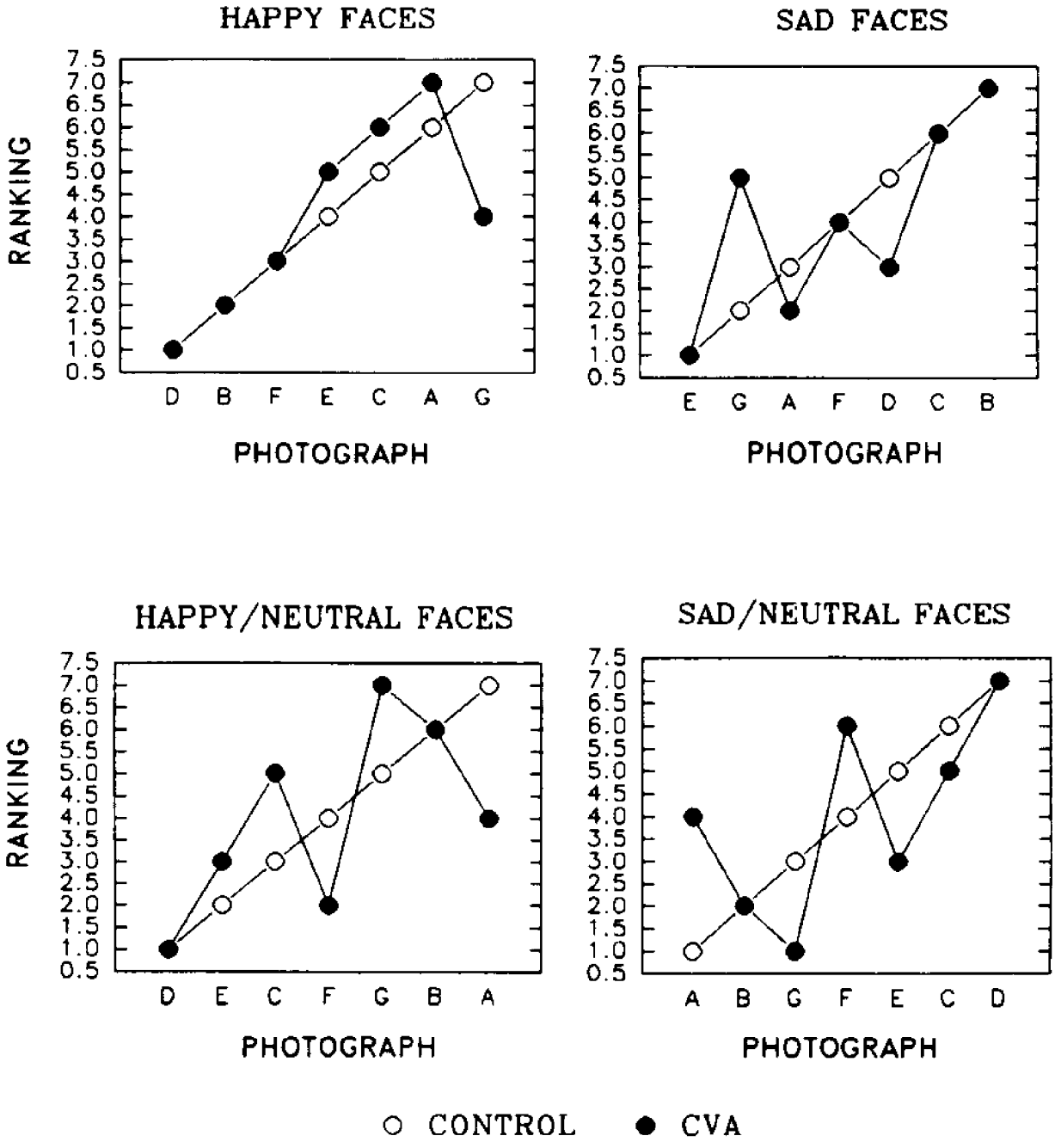
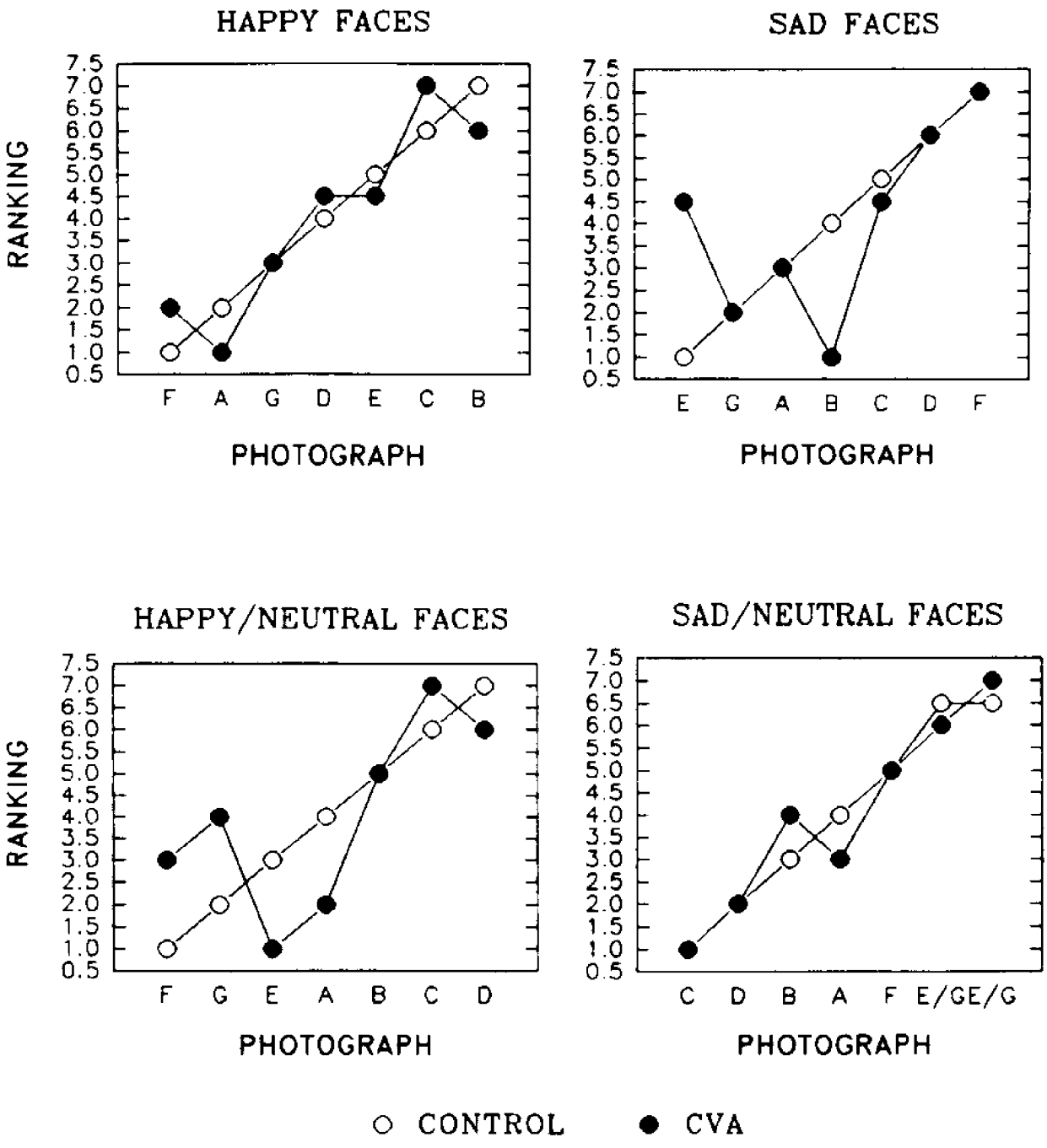


FIGURE 2

PAIRED COMPARISON TASK

STROKE VS CONTROL

FEMALE SUBJECTS



Summary

For the facial emotion paired comparison task, the outcome, as displayed in Table 3.4, indicates numerous statistically significant findings. These findings are described here for each emotion condition. Overall, the male groups achieved a greater amount of statistically significant differences than did the female groups.

Happy condition

For the Happy condition, the ordering of the photographs did not differ significantly between the stroke patients combined and the normal control subjects for either sex. The male R-CVA and L-CVA groups and the R-CVA and NC groups showed significant differences, while the L-CVA and NC groups did not differ from each other. Comparisons in ordering within female groups were nonsignificant. Examination of Figures 1 and 2 also suggests that, comparing the Happy condition with the other emotion conditions, there were smaller deviations between the intensity rankings presented by the CVA and NC groups.

Sad condition

For the Sad condition, the ordering of the photographs was significantly different between the male stroke and normal control subjects, while female subjects showed a trend in this direction. Among the males, significant

differences between the orderings offered by the L-CVA and NC groups were found, while the R-CVA and NC groups did not differ. In addition, differences between the stroke groups nearly reached significance (p=.058).

Happy/Neutral condition

In this condition, a highly significant difference between the male stroke patients and NCs emerged, as well as a trend toward differences between the female stroke patients and NCs (p=.084). For the males, the ordering of the pictures did not differ between the two CVA groups, but both CVA groups showed highly significant differences from the NCs. For the females, the R-CVA group differed significantly from both the L-CVA and NC groups, which did not differ from each other.

Sad/Neutral condition

The data from this condition was very similar to that of the Happy/Neutral condition for the male subjects only, while the female groups showed no significant differences. Again, a highly significant difference surfaced between the combined male CVA patients and NCs. As in the previous Neutral task condition, the ordering of the pictures did not differ between the two male CVA groups, but both CVA groups showed highly significant differences from the NCs.

3.3 Facial emotion sorting task

After completing the paired comparison task for each of the four emotion valences, all subjects arranged all seven photographs in order of increasing intensity in a left-to-right spatial layout. The order of the photographs was recorded by the examiner. Each arrangement was converted to an ordinal series, and individual photographs were ranked with every sorting. The average position of each photo in a series was calculated, and these means were ranked. When two positions were tied, each was assigned the mean of the ranks they would otherwise occupy (Hays, 1963). These data are presented in Table 3.5, and are displayed in graphs in Figure 3 (male) and Figure 4 (female). The rankings for the control subjects are again set as the standard against which the combined CVA groups are compared.

Both males and females displayed a large degree of variability in the placement of the pictures for nearly all the emotion conditions. The averages for most of the placements show a restricted range from 3 to 4, thus clustering toward the middle values. Extensive heterogeneity in the intensity judgments is indicated by this restricted range, as greater agreement would have produced a greater number of intensity levels. Spearman rank order correlations of these data are presented in Table 3.6. There were no significant correlations between the CVA and NC groups for any of the emotion task conditions for

either the male or female subjects. This suggests that the intensity rankings differed between the two groups. It is noteworthy that, while the HAPPY and SAD conditions show correlations ranging from .35 to .69, the two NEUTRAL conditions have much lower (or negative) correlations. The NEUTRAL task conditions presented a rather arbitrary task to all the subjects, which may have resulted in the extremely small correlations between the groups.

Table 3.5

Average photograph positions for the pooled patient group (right and left CVA combined) and NC subjects for the facial emotion sorting task. Tied ranks are presented as the mean of the two possible positions.

HAPPY (MALE)

	CVA	RANK	CTL	RANK
1)	3.33	2	4.0	4.5
2)	3.17	1	3.09	2
3)	3.5	3	2.82	1
4)	4.67	6.5	4.82	6
5)	4.5	5	3.55	3
6)	4.67	6.5	4.0	4.5
7)	4.17	4	5.73	7

HAPPY (FEMALE)

	CVA	RANK	CTL	RANK
1)	4.4	6	5.14	6.5
2)	4.7	7	4.29	4
3)	4.2	5	4.43	5
4)	4.00	3	4.00	3
5)	4.1	4	5.14	6.5
6)	3.2	1	2.86	2
7)	3.4	2	2.14	1

SAD (MALE)

	CVA	RANK	CTL	RANK
1)	3.83	3.5	5.09	7
2)	3.50	2	4.00	3
3)	4.83	7	5.00	6
4)	4.67	6	4.45	4.5
5)	4.5	5	4.45	4.5
6)	3.83	3.5	2.82	2
7)	2.83	1	2.18	1

SAD (FEMALE)

	CVA	RANK	CTL	RANK
1)	4.0	3	3.57	3
2)	4.6	6.5	5.29	7
3)	3.0	1	3.14	2
4)	4.5	5	2.86	1
5)	3.1	2	4.43	5
6)	4.6	6.5	4.0	4
7)	4.2	4	4.71	6

HAPPY/NEUTRAL (MALE)

	CVA	RANK	CTL	RANK
1)	4.17	5	4.0	4
2)	4.00	4	4.27	6
3)	3.17	2.5	3.91	3
4)	5.00	6	4.09	5
5)	3.00	1	3.73	2
6)	3.17	2.5	4.36	7
7)	5.50	7	3.64	1

HAPPY/NEUTRAL (FEMALE)

	CVA	RANK	CTL	RANK
1)	4.1	6	4.43	6
2)	3.1	1.5	4.14	4
3)	3.3	3	4.29	5
4)	3.8	5	5.29	7
5)	4.2	7	3.14	1.5
6)	3.6	4	3.14	1.5
7)	3.1	1.5	3.57	3

SAD/NEUTRAL (MALE)

	CVA	RANK	CTL	RANK
1)	5.83	7	3.55	1.5
2)	3.17	2.5	3.73	3
3)	3.17	2.5	4.18	6
4)	4.83	6	3.55	1.5
5)	3.00	1	4.09	4.5
6)	3.83	4	4.82	7
7)	4.17	5	4.09	4.5

SAD/NEUTRAL (FEMALE)

	CVA	RANK	CTL	RANK
1)	4.00	5	3.29	2
2)	3.10	3	3.86	3
3)	3.00	2	2.29	1
4)	4.20	6	5.14	6
5)	3.90	4	5.29	7
6)	2.50	1	4.14	5
7)	4.50	7	4.00	4

FIGURE 3

SORTING TASK

STROKE VS CONTROL

MALE SUBJECTS

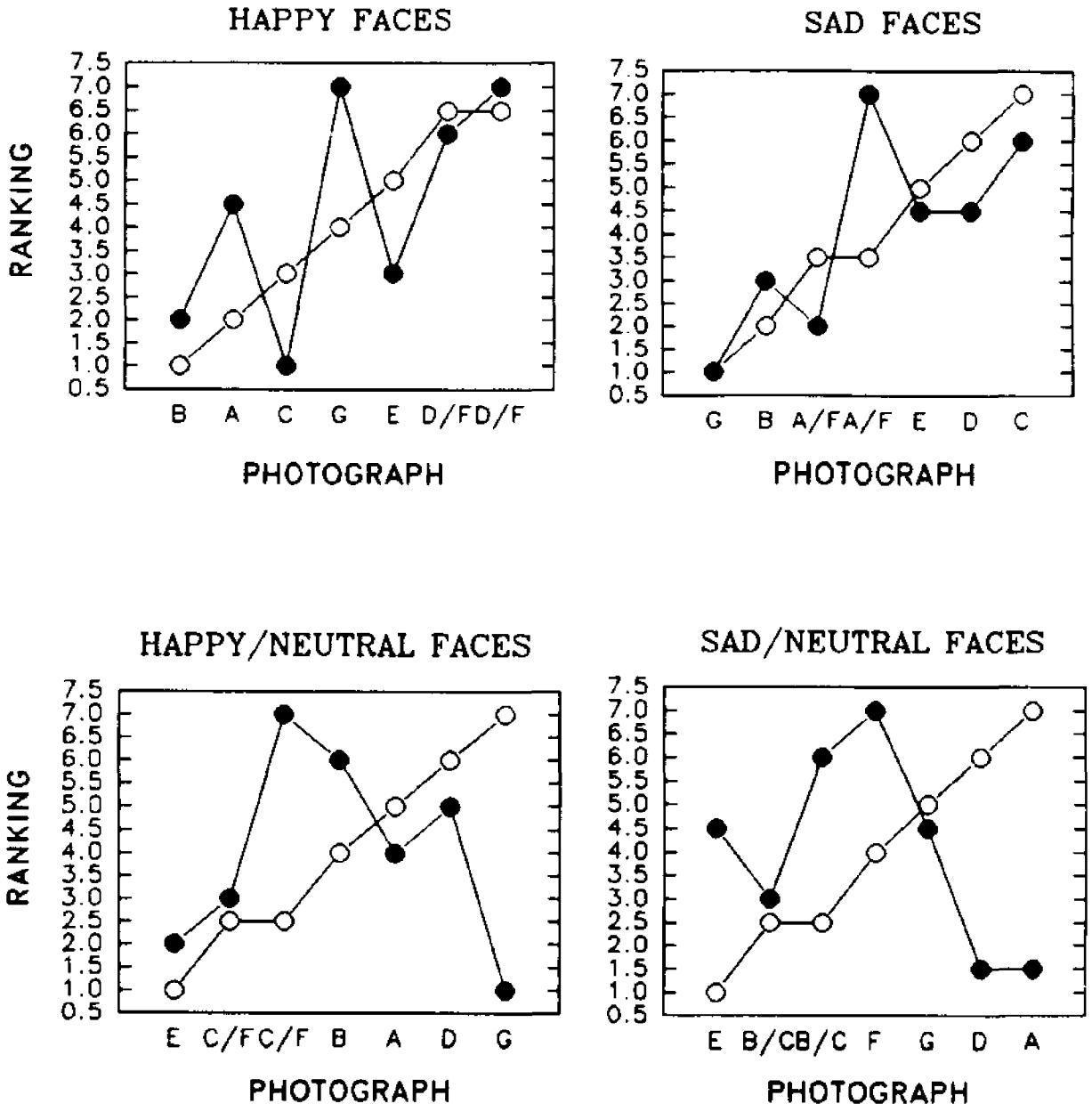


FIGURE 4

SORTING TASK

STROKE VS CONTROL

FEMALE SUBJECTS

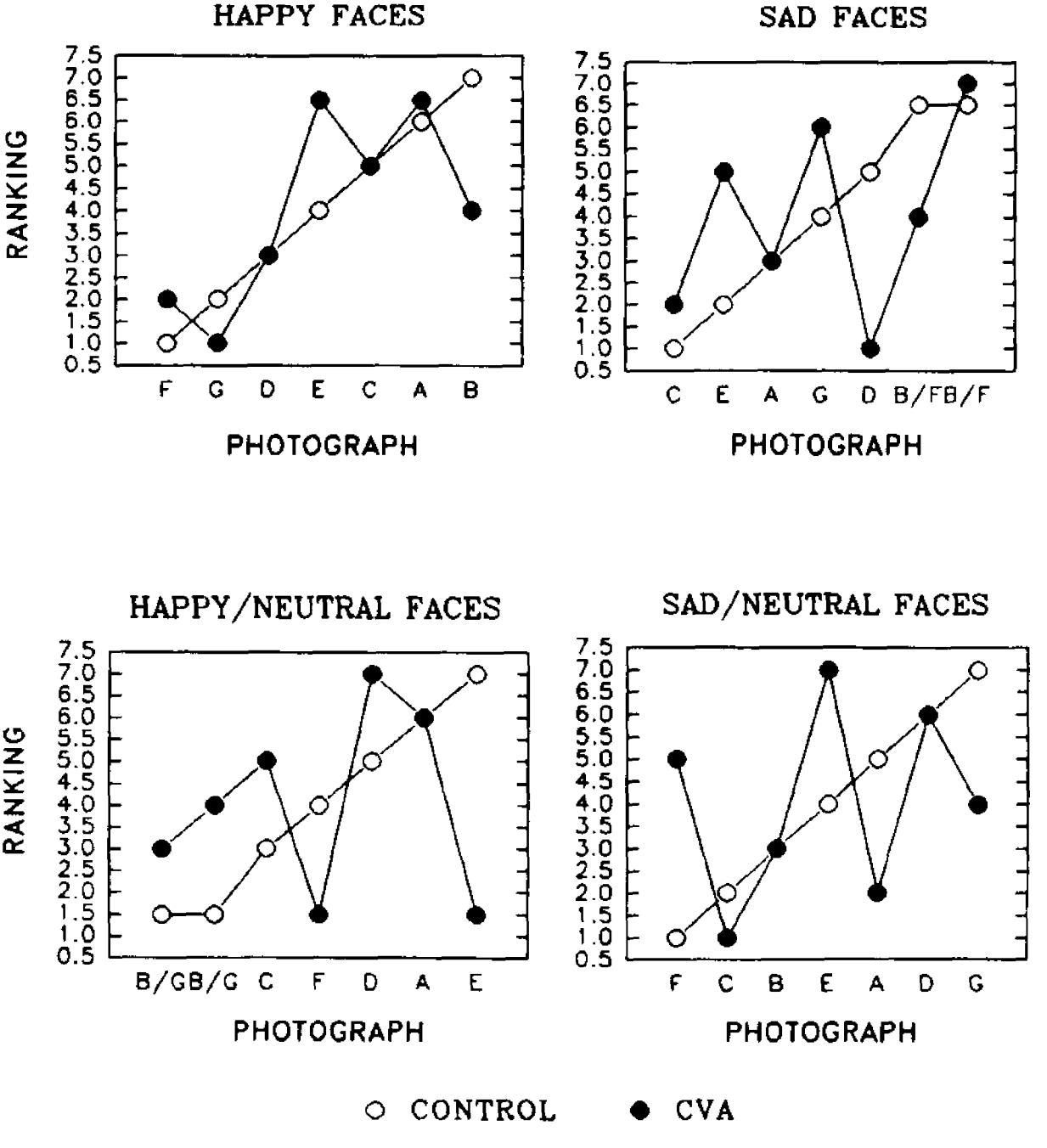


Table 3.6

Spearman rank order correlations between pooled patient group (right and left CVA combined) and NC subjects for the facial emotion sorting task.

	MALE	FEMALE
HAPPY	.49	.69
SAD	.66	.35
HAPPY/NEUTRAL	-.13	.05
SAD/NEUTRAL	-.51	.21

3.4 Relationship between the facial emotion paired comparison and sorting tasks

Since two related tasks were developed to examine the perception of emotion on faces, analyses were conducted to explore the relationship between the two tasks. The raw rankings of the faces for the paired comparison and sorting tasks, separated into brain-injured and control groups by sex, are presented in Table 3.7. Examination of this table suggests different rankings for identical faces, depending upon the task. For example, the first set of rankings (for the male control subjects, ranking the Happy male faces) shows that only two of the seven faces shared the same intensity ranking between the two tasks. Three of the remaining faces were closely ranked, discrepant only by about one intensity level, but the two remaining faces were separated by four to five intensity levels.

These data were subjected to Spearman rank order correlations, and the results are displayed in Table 3.8. The female control subjects were the only group to demonstrate statistical significance ($p<.05$), and only for the female version of the Happy/Neutral face set. Thus the female controls arranged the Happy/Neutral faces in the same order of intensity for both tasks. Referring again to Table 3.7, under the happy/neutral female control condition, the intensity rankings for the two tasks are quite similar, deviating by only one to two levels of intensity.

Table 3.7

Estimated preference probabilities for pooled combinations of diagnoses in the paired comparison task (taken from Table 3.7) are explicitly ranked (under PAIR column). The average placements of the photographs during the sorting task are also ranked (under SORT column).

CONTROLS SUBJECTS

HAPPY (MALE)

PAIR	RANK	SORT	RANK
.1969	6	4.0	4.5
.0444	2	3.09	2
.1607	5	2.82	1
.0000	1	4.82	6
.1230	4	3.55	3
.0938	3	4.0	4.5
.3812	7	5.73	7

HAPPY (FEMALE)

PAIR	RANK	SORT	RANK
.0110	2	5.14	6.5
.5411	7	4.29	4
.3592	6	4.43	5
.0303	4	4.00	3
.0391	5	5.14	6.5
.0032	1	2.86	2
.0162	3	2.14	1

SAD (MALE)

PAIR	RANK	SORT	RANK
.0097	3	5.09	7
.8275	7	4.00	3
.1285	6	5.00	6
.0142	5	4.45	4.5
.0024	1	4.45	4.5
.0121	4	2.82	2
.0057	2	2.18	1

SAD (FEMALE)

PAIR	RANK	SORT	RANK
.0626	3	3.57	3
.1002	4	5.29	7
.1330	5	3.14	2
.1780	6	2.86	1
.0377	1	4.43	5
.4420	7	4.0	4
.0465	2	4.71	6

RIGHT AND LEFT STROKE PATIENTS

HAPPY (MALE)

PAIR	RANK	SORT	RANK
.2680	7	3.33	2
.0386	2	3.17	1
.2361	6	3.5	3
.0031	1	4.67	6.5
.2086	5	4.5	5
.1007	3	4.67	6.5
.1450	4	4.17	4

HAPPY (FEMALE)

PAIR	RANK	SORT	RANK
.0181	2	4.4	6
.3449	6	4.7	7
.4980	7	4.2	5
.0500	4.5	4.0	3
.0500	4.5	4.1	4
.0140	1	3.2	1
.0249	3	3.4	2

SAD (MALE)

PAIR	RANK	SORT	RANK
.0303	2	3.83	3.5
.4441	6	3.5	2
.3671	5	4.83	7
.0401	3	4.67	6
.0037	1	4.5	5
.0459	4	3.83	3.5
.0688	7	2.83	1

SAD (FEMALE)

PAIR	RANK	SORT	RANK
.1072	3	4.0	3
.0695	1	4.6	6.5
.1209	4.5	3.0	1
.1963	6	4.5	5
.1209	4.5	3.1	2
.2902	7	4.6	6.5
.0950	2	4.2	4

Table 3.7, continued

CONTROLS SUBJECTS

HAPPY/NEUTRAL (MALE)

PAIR	RANK	SORT	RANK
.3135	7	4.0	4
.2535	6	4.27	6
.1159	5	3.91	3
.0165	1	4.09	5
.0286	2	3.73	2
.1317	3	4.36	7
.1404	4	3.64	1

HAPPY/NEUTRAL (FEMALE)

PAIR	RANK	SORT	RANK
.0638	4	4.43	6
.1159	5	4.14	4
.2198	6	4.29	5
.4791	7	5.29	7
.0577	3	3.14	1.5
.0214	1	3.14	1.5
.0425	2	3.57	3

SAD/NEUTRAL (MALE)

PAIR	RANK	SORT	RANK
.0402	1	3.55	1.5
.0458	2	3.73	3
.2712	6	4.18	6
.4011	7	3.55	1.5
.1153	5	4.09	4.5
.0709	4	4.82	7
.0554	3	4.09	4.5

SAD/NEUTRAL (FEMALE)

PAIR	RANK	SORT	RANK
.1021	4	3.29	2
.0622	3	3.86	3
.0288	1	2.29	1
.0365	2	5.14	6
.2828	6	5.29	7
.2049	5	4.14	5
.2828	7	4.00	4

RIGHT AND LEFT STROKE PATIENTS

HAPPY/NEUTRAL (MALE)

PAIR	RANK	SORT	RANK
.0431	4	4.17	5
.1160	6	4.0	4
.0566	5	3.17	2.5
.0025	1	5.0	6
.0377	3	3.0	1
.0136	2	3.17	2.5
.7306	7	5.5	7

HAPPY/NEUTRAL (FEMALE)

PAIR	RANK	SORT	RANK
.0432	2	4.1	6
.0856	5	3.1	1.5
.3858	7	3.3	3
.3160	6	3.8	5
.0367	1	4.2	7
.0589	3	3.6	4
.0738	4	3.1	1.5

SAD/NEUTRAL (MALE)

PAIR	RANK	SORT	RANK
.0232	4	5.83	7
.0157	2	3.17	2.5
.0589	5	3.17	2.5
.7250	7	4.83	6
.0179	3	3.0	1
.1504	6	3.83	4
.0089	1	4.17	5

SAD/NEUTRAL (FEMALE)

PAIR	RANK	SORT	RANK
.0674	3	4.0	5
.0977	4	3.1	3
.0386	1	3.0	2
.0420	2	4.2	6
.2879	6	3.9	4
.1522	5	2.5	1
.3142	7	4.5	7

Table 3.8

Spearman rank order correlations for pooled combinations of diagnoses, comparing performance on the facial emotion paired comparison task with performance on the sorting task. * = significant at p<.05

	MALE CONTROLS	MALE CVA	FEMALE CONTROLS	FEMALE CVA
HAPPY	.17	-.38	.31	.56
SAD	.12	-.49	-.50	.07
HAPPY/NEUTRAL	.04	.28	.83 *	-.58
SAD/NEUTRAL	-.23	.28	.46	.25

3.5 Analysis strategy for the prosody, mood, and cognitive tests.

While it was necessary to analyze the male and female groups separately for the two emotion face perception tasks, their data were merged for the remaining analyses (except reaction time measures of the face perception tasks) because all subjects received the same tests. The large number of measures used for assessment of prosody, mood, and cognitive functioning presented a wide variety of performance criteria including reaction time, number of errors, fine motor speed, scaled scores, etc. To standardize the analysis of this large number of variables, raw scores were converted to standard (z) scores (method described by Wallace, 1984). Then, utilizing the control data, a baseline (zero) was established for comparison of patient data.

Z-scores for each test were subjected to one-way analysis of variance (ANOVA) using diagnosis subtype (CVA, RCVA, LCVA, NC) as the grouping factor. Significant main effects were explored with post-hoc t-tests to determine which groups differed. The t-test significance values were adjusted for multiple and nonorthogonal comparisons using Bonferroni's inequality. This method provides simple conservative adjustments to the p-values to correct for multiple tests regardless of dependence or independence. The observed p-values are multiplied by the number of contrasts or, alternatively, divides the cutoff for

significance by that same integer. For example, in the case of three contrasts (RCVA, LCVA, NC), each must be significant at the .05/3=.017 level to be declared individually significant at p=.05.

3.6 Perception of Non-emotional Faces

In order to assess non-affective face recognition skills, all subjects received the Facial Recognition Test (Benton et al, 1983). Mean scores for the patients and controls are shown in Table 3.9. Analysis of variance revealed significant group differences ($F[1, 30] = 10.57$, $p<0.003$). Further analyses demonstrated impaired performance by the LCVA's relative to the NC's ($t[29] > 2.54$, $p<0.05$) for the perception of these non-emotional faces. No significant differences occurred between the LCVA's and RCVA's ($t[29] < 2.54$, n.s.) or RCVA's and NC's ($t[29] < 2.54$, n.s.).

Table 3.9

Mean (and s.d.) number correct on Facial Recognition Test for all groups

Variable	RCVA	LCVA	NC	Significance
Benton Faces	42.2 (4.2)	39.6 (6.7)	46.8 (3.3)	p<.003 (*) p<.05 (**)

Key: * = Stroke Patients (CVA) versus Normal Controls (NC)
** = Left Stroke (LCVA) versus Normal Controls

3.7 Reaction Time

Response times were recorded for each PC pairing, and for each ST condition. Mean reaction time data for all components of the PC and ST tasks is shown in Tables 3.10 and 3.11. Male and female reaction time data were analyzed separately, since different sets of photographs were viewed by these groups. T-test analysis of this data yielded no significant findings. The response times were then log-transformed and re-analyzed, and again no significant difference emerged for either sex in any of the four emotion conditions. T-test values for the log-transformed data are listed in Tables 3.10 and 3.11.

Table 3.10

Mean (and s.d.) reaction time (in seconds) for Paired Comparison (PC) task

MALES

Variable	CVA	NC	Significance
Happy	3.32 (2.28)	2.99 (1.20)	t[16]=0.001, n.s.
Sad	3.05 (1.48)	3.12 (1.11)	t[16]=0.12, n.s.
Neutral/Happy	3.11 (1.05)	3.68 (2.05)	t[15]=0.36, n.s.
Neutral/Sad	4.07 (1.60)	3.74 (1.83)	t[15]=0.42, n.s.

FEMALES

Variable	CVA	NC	Significance
Happy	3.82 (2.53)	4.62 (2.36)	t[16]=0.80, n.s.
Sad	4.86 (2.93)	6.86 (3.68)	t[16]=1.18, n.s.
Neutral/Happy	13.62 (28.57)	5.72 (2.79)	t[15]=-0.19, n.s.
Neutral/Sad	13.19 (28.54)	6.10 (3.77)	t[15]=-0.06, n.s.

Table 3.11

Mean (and s.d.) reaction time (in seconds) for Sorting (ST) task

MALES

Variable	CVA	NC	Significance
Happy	42.49 (17.73)	116.02 (278.20)	t[16]=0.36, n.s.
Sad	178.76 (361.80)	118.20 (277.85)	t[16]=-0.58, n.s.
Neu/Hap	30.59 (10.32)	113.51 (279.10)	t[15]=0.88, n.s.
Neu/Sad	40.43 (16.25)	123.18 (276.60)	t[15]=0.73, n.s.

FEMALES

Variable	CVA	NC	Significance
Happy	55.35 (36.93)	37.80 (21.92)	t[16]=1.54, n.s.
Sad	60.63 (33.06)	46.38 (27.99)	t[16]=-1.14, n.s.
Neu/Hap	136.31 (286.83)	42.62 (24.8)	t[15]=-1.08, n.s.
Neu/Sad	224.97 (383.51)	44.30 (21.34)	t[15]=-1.22, n.s.

3.8 Prosody Perception

Mean scores on the three prosody perception tasks for all groups are shown in Table 3.12. ANOVA revealed no significant differences between CVA's and NC's for prosodic stress ($F[1, 30] = 0.04$, n.s.), intonation ($F[1, 29] = 0.06$, n.s.), or emotion ($F[1, 27] = 1.63$, n.s.).

Table 3.12

Mean (and s.d.) scores for prosody perception tasks

Variable	RCVA	LCVA	NC	Significance
Stress	50.2 (4.1)	49.4 (3.7)	49.6 (2.9)	n.s.
Intonation	11.9 (9.6)	14.9 (9.0)	17.8 (9.4)	n.s.
Emotion	31.4 (3.3)	34.8 (5.0)	33.2 (3.2)	n.s.

3.9 Mood Self-Rating

All subjects completed a Beck Depression Scale (BDI; Beck et al, 1961) and State-Trait Anxiety Inventory (STAI; Spielberger et al, 1970) at the end of their examination to assess self-reported mood at the time of testing.

Because eight CVA patients (5 RCVA, 3 LCVA) with somewhat greater cognitive impairment were unable to complete the BDI, they completed the simpler Zung Depression Scale (Zung, 1965). Thirteen normal control subjects received both the BDI and Zung scales, and their data was used in a regression analysis to equate the scores for the two scales. In this manner, a predicted BDI score was derived from the Zung scores of these eight patients.

3.9.1 Patients versus Controls

Significant differences emerged between the CVA and NC groups for scores on the BDI and both the state and trait scales of the STAI, indicating that all patients acknowledged more symptoms associated with depression and anxiety than controls (BDI: $F[1, 34] = 12.63$, $p<0.001$, State Anxiety: $F[1, 27] = 6.89$, $p<0.01$, Trait Anxiety: $F[1, 27] = 6.66$, $p<0.02$). Mean BDI and STAI scores for all subject groups are displayed in Table 3.13.

3.9.2 Lesion Laterality and Mood

To determine whether mood differences were dependent upon side of lesion, BDI and STAI scores of RCVA's and LCVA's were compared to NC's and to one another via t-tests. Analysis of the BDI data demonstrated increased acknowledgement of depressive symptoms by RCVA's relative to NC's ($t[33] > 2.52$, $p<0.05$), and LCVA's relative to NC's ($t[33] > 2.52$, $p<0.05$). While the two stroke groups did not differ from each other ($t[33] < 2.52$, n.s.). Analysis of the STAI data demonstrated increased trait anxiety among the RCVA's, relative to NC's ($t[26] > 2.56$, $p<.05$). There were no significant differences between LCVA's and RCVA's for state or trait anxiety scores (State Anxiety: $t[26] < 2.56$, n.s., Trait Anxiety: $t[26] < 2.56$, n.s.).

Table 3.13

Mean (and s.d.) scores for mood self-rating scales

Variable	RCVA	LCVA	NC	Significance
Beck Depression Scale (BDI):				
Total	14.1 (6.47)	14.9 (12.1)	6.2 (4.5)	p<.001 (*) p<.05 (**) p<.05 (***)
Spielberger State-Trait Anxiety Inventory (STAI):				
State	38.1 (8.3)	36.8 (5.7)	30.9 (6.4)	p<.01 (*)
Trait	45.4 (14.4)	41.4 (11.2)	33.4 (8.4)	p<.05 (*) p<.05 (**)

Key: * = Stroke Patients (CVA) versus Normal Controls (NC)
** = Right Stroke (RCVA) versus Normal Controls
*** = Left Stroke (LCVA) versus Normal Controls

3.10 Neuropsychological Tests

The neuropsychological test results are presented in Table 3.14. As described earlier, the raw test scores listed in Table 3.14 were converted to z-scores. The z-scores for the control and patient groups were examined with an ANOVA followed by post-hoc t-tests to determine which groups differed. The t-test significance values were adjusted for multiple and nonorthogonal comparisons using Bonferroni's inequality.

1. Verbal intellectual skills. When compared to the NCs, both the RCVA and LCVA patient groups displayed significant differences on WAIS-R subtests measuring expressive vocabulary and fund of general information. Both patient groups performed in the Average range, while the NCs performed in the Superior range. Overall, the difference

between the CVA and the NC groups may represent a combination of higher education of the NCs and post-stroke decline among the CVAs.

2. Visuospatial intellectual skills. Both patient groups performed significantly worse than the controls on the Block Design subtest of the WAIS-R. While the patients scored in the Average range, the controls scored in the Above Average range. Predictably, RCVAs performed worse than LCVAs, but this difference was not statistically significant.

3. Attention. Relative to the NCs, both patient groups were impaired on overall digit span (there was no significant difference between forward and backward digit span). Closer inspection revealed that this difference was accounted for by the LCVA group. Both patient groups were significantly less accurate than controls on the mental control subtest of the Wechsler Memory Scale.

4. Abstraction and mental flexibility. On the modified version of the Wisconsin Card Sorting Task (Nelson,1976), both patient groups were mildly impaired relative to NCs on the number of categories obtained. Though the RCVAs acquired the highest number of overall and perseverative errors, no significant differences were obtained between any of the groups on these comparisons.

5. Verbal Memory. There were no significant differences between any groups regarding orientation to person, place, and time. Surprisingly, there were no significant differences between any groups on the Wechsler Memory Scale subtest measuring immediate recall of prose passages. Following a 30-minute delay, both patient groups experienced a significant decline in recall while the NCs retained most of the information.

6. Verbal Learning. On the 16-item California Verbal Learning Test (CVLT) all groups started at the same level on the first presentation of the items. NCs showed a greater ability to benefit from repetition, and learned significantly more items by trial 5 than either the RCVAs or the LCVAs. No other comparisons reached statistical significance for this task. Comparing this to prose passages of the Wechsler Memory Scale, it appears that repetition helped both patient groups retain material over time.

7. Figural memory. Comparisons of all groups on the figural memory subtest of the Wechsler Memory Scale indicates that both patient groups performed worse than NCs. Closer inspection reveals that the bulk of this difference is accounted for by the RCVAs. Over a 30-minute delay, all groups experienced some decline in performance, but this

difference was only significant when comparing both stroke groups to the NCs.

8. Verbal expressive skills. Overall, patients were impaired relative to controls on tests measuring semantic and phonemic fluency, and confrontation naming. Further analyses indicated that, for the phonemic fluency and naming tests, while the RCVA and LCVA groups differed from the NCs, they did not differ from each other.

9. Verbal receptive skills. Both patient groups performed worse than controls on verbal comprehension. Unexpectedly, this difference appeared to be largely a result of performance differences between the RCVAs and NCs, rather than the LCVAs. There were no differences between groups on Benton's Sentence Repetition Test. Each stroke group performed worse than the NCs on a test of single word reading. As on the WAIS-R verbal subtests, the difference between the CVAs and NCs may reflect a combination of higher education of the NCs and post-stroke decline among the CVAs.

10. Perceptual speed and scanning. There was significant slowing among both patient groups on the WAIS-R Digit Symbol subtest. Patients scored in the Average range while controls scored in the Above Average range. All patients were slower than controls on Trails A, especially the RCVAs.

The RCVA and LCVA groups were both slower on Trails B, but the RCVAs also made more errors. The LCVAs were slower than either the RCVAs or NCs on a Letter Cancellation test. While the RCVAs made more errors on this task, the difference did not reach statistical significance.

11. Sensorimotor Functions. On a test of fingertip number writing (graphesthesia), each stroke group performed worse than the controls when using the hand contralateral to the side of the lesion. On a test of manual fine motor speed (finger tapping), only the RCVAs were significantly slower than the NCs when using the contralateral hand.

TABLE 3.14

Neuropsychological test results by diagnosis

1. **Verbal Intellectual Skills**

Variable	RCVA	LCVA	NC	Significance
WAIS-R (Age Corrected Scaled Scores):				
Vocabulary	10.0 (2.8)	10.3 (3.2)	14.1 (2.3)	p<.0001 (A) p<.05 (B) p<.05 (C)
Information	10.2 (2.9)	9.7 (3.1)	14.0 (2.2)	p<.0001 (A) p<.05 (B) p<.05 (C)

2. **Abstraction and Mental Flexibility**

Variable	RCVA	LCVA	NC	Significance
Modified Card Sorting Test (MCST):				
Categories	4.5 (1.9)	4.5 (1.6)	5.6 (1.0)	p<.03 (A)
Errors	13.4 (9.9)	10.7 (9.5)	7.1 (6.9)	n.s.
Persev.	5.5 (7.1)	3.8 (4.8)	2.0 (2.9)	n.s.

3. **Attention**

Variable	RCVA	LCVA	NC	Significance
WAIS-R (Age Corrected Scaled Scores):				
Digit Span	9.8 (3.1)	7.7 (1.6)	11.4 (2.7)	p<.02 (A) p<.05 (C)
Mental Control (WMS)	6.3 (2.2)	4.9 (2.4)	8.2 (1.0)	p<.0003 (A) p<.05 (B) p<.05 (C)

4. **Verbal Memory**

Variable	RCVA	LCVA	NC	Significance
Benton Orient.	1.2 (3.1)	0.9 (1.1)	0.3 (0.5)	n.s.
Wechsler Memory Scale (WMS) Stories:				
Immed. Recall	20.9 (6.4)	18.5 (5.6)	23.7 (5.2)	n.s.
Delay Recall	14.7 (8.4)	13.2 (8.5)	20.0 (5.7)	p<.02 (A)

5. **Verbal Learning**

Variable	RCVA	LCVA	NC	Significance
California Verbal Learning Test (CVLT):				
Trial 1	6.4 (2.1)	6.3 (2.6)	6.4 (1.9)	n.s.
Trial 5	10.4 (2.8)	10.2 (3.7)	12.3 (2.1)	p<.03 (A)
List B	6.4 (2.2)	5.9 (2.9)	6.3 (1.8)	n.s.
Short Delay	8.6 (3.3)	6.7 (3.4)	8.6 (3.3)	n.s.
S.D. cued	9.3 (4.1)	8.7 (4.3)	10.6 (2.5)	n.s.
Long Delay	9.2 (4.4)	8.1 (4.6)	9.8 (2.8)	n.s.
L.D. cued	9.8 (4.1)	8.9 (4.5)	9.9 (2.7)	n.s.
Recognition	13.0 (2.2)	12.4 (4.3)	14.1 (1.6)	n.s.
False Pos.	2.5 (2.6)	3.7 (3.2)	1.9 (2.6)	n.s.

6. **Figural Memory**

Variable	RCVA	LCVA	NC	Significance
WMS Figures:				
Immed Recall	5.3 (4.1)	6.3 (3.7)	9.2 (3.0)	p<.003 (A) p<.05 (B)
Delay Recall	5.2 (3.7)	5.0 (4.1)	7.7 (3.1)	p<.03 (A)

7. **Verbal Expressive Skills**

Variable	RCVA	LCVA	NC	Significance
CFL (age-corrected)	37.8 (13.4)	30.7 (16.7)	50.9 (13.3)	p<.002 (A) p<.05 (B) p<.05 (C)
Animal Naming	17.3 (6.1)	16.3 (8.0)	21.9 (6.4)	p<.03 (A)
Boston Naming	47.9 (10.1)	46.9 (9.1)	56.5 (3.2)	p<.0006 (A) p<.05 (B) p<.05 (C)

8. **Verbal Receptive Skills**

Variable	RCVA	LCVA	NC	Significance
BDAE Comp.	10.2 (1.2)	10.7 (0.8)	11.4 (0.6)	p<.002 (A) p<.05 (B)
Sentence Rep.	12.8 (2.8)	10.3 (3.1)	12.7 (2.0)	n.s.
WRAT-R:				
Reading (SS)	95.2 (16.3)	92.2 (21.8)	113.7 (5.2)	p<.0004 (A) p<.05 (B) p<.05 (C)

9. **Visuospatial Skills**

Variable	RCVA	LCVA	NC	Significance
WAIS-R (Age Corrected Scaled Scores):				
Block Design	7.8 (2.8)	9.6 (2.0)	13.3 (2.4)	p<.0001 (A) p<.05 (B) p<.05 (C)

10. **Perceptual Speed and Visual Scanning**

Variable	RCVA	LCVA	NC	Significance
Trails A	84.9 (66.8)	59.9 (24.5)	31.2 (10.5)	p<.002 (A)
(seconds)				p<.05 (B)
(errors)	0	0	0.06 (0.2)	n.s.
Trails B	180.3(114.6)	191.8(94.9)	84.3(39.4)	p<.002 (A)
(seconds)				p<.05 (B) p<.05 (C)
(errors)	1.8 (1.7)	1.5 (1.1)	0.4 (0.5)	p<.007 (A) p<.05 (B)
WAIS-R (Age Corrected Scaled Scores):				
Digit Symbol	8.3 (2.3)	7.8 (2.5)	12.7 (1.9)	p<.0001 (A) p<.05 (B) p<.05 (C)

Letter Cancellation:				
Time (minutes)	2.5 (0.8)	3.6 (1.3)	2.3 (0.4)	p<.04 (A) p<.05 (C) p<.05 (D)
Errors (Right)	2.7 (3.2)	2.6 (4.3)	2.6 (3.0)	n.s.
Errors (Left)	6.4 (8.8)	4.3 (4.9)	2.9 (3.7)	n.s.

11. **Sensorimotor Functions**

Variable	RCVA	LCVA	NC	Significance
Graphesthesia (errors):				
Right Hand	5.0 (2.1)	5.3 (3.0)	2.9 (2.8)	p<.02 (A) p<.05 (C)
Left Hand	7.0 (4.9)	5.8 (3.0)	2.8 (3.7)	p<.01 (A) p<.05 (B)
Finger Tapping:				
Right Hand	41.5 (9.1)	42.4 (4.2)	47.1 (10.5)	n.s.
Left Hand	29.5 (11.1)	36.8 (10.8)	40.6 (6.9)	p<.02 (A) p<.05 (B)

Comparisons represent two-tailed t-tests.

Key: A = Stroke Patients (CVA) versus Normal Controls (NC)
B = Right Stroke (RCVA) versus Normal Controls
C = Left Stroke (LCVA) versus Normal Controls
D = Left Stroke versus Right Stroke

Chapter 4

Discussion

The primary goal of this study was to examine the effects of acquired brain injury on the perception of emotion. Three domains of emotion (face perception, prosody perception, and mood) were examined concurrently among persons with unilateral right or left hemisphere damage and normal elderly controls. All subjects also received a battery of standardized tests of cognitive abilities. Two versions of a novel face perception test were developed to determine whether unilateral brain damage resulted in differential perceptions of gradations of intensity in expressions of happiness and sadness.

4.1 Effects of brain injury on the perception of emotion in faces

Brain-damaged patients as a group differed from age-matched controls in their overall ability to sequence the gradients of intensity within happy and sad emotions. Though the paired comparison and sorting variants of the

face perception task did not correlate with one another, each uncovered differences between the brain-damaged and control populations. The facial emotion sorting task showed differences for all emotion conditions, while the paired comparison task showed differences only between male subjects. Thus, the principal hypothesis of this study was confirmed; brain damage alters the ability to rank order subtle changes in facial expression within an emotion. This has not previously been reported in studies of face perception.

4.1.1 Facial Emotion Sorting Task

The rudimentary facial emotion sorting task required subjects to arrange each set of seven photographs in order from least to greatest degree of happiness/sadness. This task demonstrated discrepancies between the two subject groups across all emotion conditions (happy, sad, and neutral) for both sexes. The greatest differences between patients and controls appeared for the intensity rankings of the ambiguous neutral faces. Unfortunately, it appeared that there was little agreement among subjects, even within a group, for the intensity rankings of the neutral subjects. This excessive heterogeneity in the intensity judgments resulted in a restricted range of average values for all subject groups. That is, when these disparate rankings of each individual subject were averaged for each photograph,

the scores were very similar for each photograph. This effect may have been due to the unstructured format of the task. This design required subjects to examine seven faces arrayed from left to right and appraise inter-dependent relationships among several faces simultaneously. The fact that control subjects also showed heterogeneous rankings suggests that it was not the result of defective visual scanning among the brain damaged subjects. This concern had arisen during the initial design phase of the study, and was addressed via construction of the paired comparison task.

4.1.2 Facial Emotion Paired Comparison Task

The paired comparison task is psychometrically more stable than the sorting task and more sensitive to subtle gradations between rankings of emotions. It also constrains the subjects' choices and reduces the visual discriminations necessary to perform the task. The Bradley-Terry model was selected and validated as an appropriate approach to the analysis of the paired comparison data. Analyses were predicated upon the premise that subjects in the study would express non-random preferences for the ordering of the photos, and this was demonstrated by all participants. For the female subjects, this paired comparison format did not indicate any significant divergence between the brain injured and control groups for any of the three emotion

valences, though some trends were displayed for the sad and neutral/happy conditions. Male brain injured subjects did not deviate from the controls when ranking the happy faces, but diverged significantly when ranking the sad and neutral faces. As shown for the sorting task, this finding was stronger for the two neutral task conditions.

This face perception test was designed to segregate the sexes and to avoid possible rating biases by devising separate sets of male and female stimuli. Many more statistically significant differences occurred among the comparisons for the male subjects than for the female subjects. This divergence can be attributed to factors intrinsic to the subjects rather than the stimuli because the stimuli had been carefully balanced for the quality and intensity of the emotions displayed. Two different procedures (group ratings and a facial muscle coding system) were employed to select the faces used to construct the test.

Sex differences have emerged in several earlier studies of cerebral specialization for face perception and for perception of emotion (reviewed in Malatesta and Izard, 1984). For example, females have been shown to have greater lateralized facial asymmetries for the display of emotion than males, suggesting possible sex differences in brain structures for this ability (Borod et al, 1983). There is evidence that neuroanatomical sex differences for

emotionally-toned stimuli are 'hard-wired', and not simply a function of social learning. Malatesta and Izard (1984) describe findings of differentially lateralized EEG changes among male and female infants in response to emotionally evocative probes.

A number of studies of lateralization for cognitive abilities have demonstrated that females are less completely lateralized than males (reviewed in Waber, 1977). The current data suggests that females may be less vulnerable than males to the effects of brain damage on emotion perception. Females may be protected by either redundant neuroanatomical structures specialized for processing facial emotions, or may have a more distributed network of these neuroanatomical structures. Either scenario would offer greater defense against a single injury to the brain.

4.2 Cerebral lateralization for positive and negative emotions

While the small sample sizes preclude definitive statements, exploratory subgroup analyses of the performance of the male RCVA, LCVA, and control groups on the paired comparison task yielded clues to lateral asymmetries for the perception of emotion. These analyses were suggestive of the following relationships:

1) Persons with right hemisphere strokes sorted happy faces in a consistently different manner than

subjects with left hemisphere strokes or neurologically intact subjects.

2) Subjects with left hemisphere strokes sorted sad faces in a consistently different manner than control subjects. There was also a trend for the LCVA subjects to sort these sad faces differently than the RCVA subjects.
3) When ranking ambiguous neutral faces, each brain-injured subject group sorted in a different arrangement than the control subjects. There was no difference between the LCVA and RCVA groups.

These indications of right hemisphere brain damage altering the perception of positive emotion and left hemisphere brain damage altering the perception of negative emotion are the reverse of those hypothesized for this study. The most parsimonious explanation for this occurrence is the size of the samples, as this finding describes only four men with left-sided strokes and three men with right-sided strokes contrasted with eleven normal males. However, it is noteworthy that only the emotionally charged stimuli seemed to evoke hemisphere-specific and differentially lateralized rankings. Furthermore, the right and left brain damaged subjects did not diverge from one another in their rankings of the neutral faces, though they each differed from the control subjects. This pattern gives

credence to the notion that the ability to accurately perceive positive or negative emotions is affected by lateralized brain damage.

4.3 Perception of non-emotional faces

The two neutral task conditions showed the most robust differences between the patients and control subjects. There are two possible explanations for this effect. The random nature of the task may have resulted in greater task difficulty, which differentially affected the brain-injured group. However, the fact that reaction time measures for the neutral tasks failed to discriminate between patients and controls suggests that the level of difficulty was equivalent for all subject groups. Alternatively, the control subjects could grade the small yet discernible degrees of happiness or sadness displayed in the neutral faces, but the patients could not.

There was one other unexpected finding with regard to face perception. Only subjects with left hemisphere brain damage (males and females combined) performed significantly worse than control subjects on a test of non-affective face recognition skills (Benton et al, 1983).

Numerous studies of face perception among brain injured or normal populations (reviewed by Bruyer, 1986) indicate that right hemisphere mechanisms predominate for this skill.

It remains unclear whether face perception is just a sub-specialized form of complex pattern recognition, or whether the right hemisphere alone truly processes faces as a distinct entity.

Experimental investigations of prosopagnosia (the inability to recognize faces, especially those of familiar or famous people) have served as a prototype for face perception research. While early reports posited right hemisphere mechanisms for this disorder, there is now overwhelming evidence that prosopagnosia is caused by bilateral lesions involving occipito-temporal brain regions (Damasio et al, 1982). There are no reports of unilateral left hemisphere lesions causing chronic and stable prosopagnosia.

The fact that only patients with left hemisphere brain damage performed worse on Benton's Facial Recognition Test is intriguing, but may not be relevant to the findings observed for the emotion perception test. The task demands were not equivalent, since the subjects were required to simply match stimuli on Benton's test but performed a more intricate emotion ranking for the new test. Further, the stimuli for the emotion perception test were much larger and superior in quality to the pictures used in Benton's test, which probably affected the task demands. Finally, statistical comparisons of Benton's test included both sexes, while those of the experimental test were divided by

sex.

Results of the neuropsychological battery were examined for other evidence of right hemisphere dysfunction. One test often associated with right hemisphere processing showed the predicted deficit (Figural Memory) while another did not (Block Design). Subjects with right hemisphere strokes performed worse than control subjects on the Figural Memory subtest of the Wechsler Memory Scale. Though subjects with right hemisphere strokes performed worse than those with left hemisphere strokes on the Block Design subtest of the WAIS-R, this difference did not reach statistical significance.

4.4 Reaction time

Reviewing the literature on reaction time and brain disease, Benton (1986) cited a substantial number of studies demonstrating that unilateral damage to the right cerebral hemisphere correlates positively with increases in simple reaction time. Simple reaction time has been measured using various methods, but typically requires a subject to push a button as soon as a visual or auditory stimulus appears. Benton pointed out that no studies have reported increases in simple reaction time following left hemisphere lesions. Studies of complex reaction time, involving higher level decision-making, have yielded mixed results. Coslett et al (1987) found longer reaction times among patients with right

hemisphere damage, compared to those with left hemisphere damage or control subjects, for tasks assessing either simple or complex reaction time. They attributed the findings to a generalized reduction in activation levels among patients with right hemisphere lesions.

While most studies of the effects of brain damage on reaction time have selected patients with diffuse bilateral or focal lateralized brain injuries, several have probed the effects of injuries along the rostral-caudal plane. Tartaglione et al (1987) argued that anterior right hemisphere lesions result in slowed reaction time due to impaired programming of motor responses, while Newcombe et al (1989) posited that posterior right hemisphere injuries result in slowed reaction time specific to tasks requiring visuo-perceptual decisions, such as face perception.

For these reasons, one might expect reaction time differences for the complex facial affect judgment tasks between patients and controls or right- and left-hemisphere stroke patients. No such differences were detected for any of the task conditions.

Simple reaction time improves following the acute phase of stroke, especially with rehabilitation (Korner-Bitensky et al, 1990). Possible improvements in complex reaction time have not been reported. The sample of patients used in the current study may have recovered sufficiently so that their face perception reaction time was indistinguishable

from normal elderly controls. Also, the exploratory reaction time measure used for this study may have been in sufficiently sensitive to subtle between-group differences.

Serious potential confounds to this study were posed by possible differences in general arousal among either of the patient groups, and potential differences in task difficulty for the rankings of the happy, sad, or neutral faces. Since no disparities in reaction time emerged for the face perception tasks, it may be the case that the effects of brain injury on emotion perception and the suggestions of hemispheric specialization for emotion are independent of lateralized differences in overall arousal. As mentioned above, the lack of reaction time differences further indicates that deviations between the brain-injured and control groups were not simply a function of differential task difficulty.

4.5 Perception of emotion in voice (prosody)

No differences were found between any groups in their ability to discriminate stress, intonation, or emotion via prosodic shifts. The tasks used for this portion of the study were a subset of those developed by Weintraub et al (1981), who found that patients with right-sided brain damage performed worse than control subjects on all three tasks. However, no left brain-damaged comparison group was

included in their study, and their sample size was small.

Several task design problems were apparent during this administration. For example, it was difficult for elderly patients and controls to make the (often subtle) discriminations required by these tasks due to simple age-related hearing loss. Further, the small number of items for the stress and emotion subtests (ten questions each) reduced potential variability between subject groups.

4.6 Mood

Both CVA groups acknowledged more symptoms associated with depression and anxiety (both state and trait) than controls. Patients with either left- or right-sided stroke did not differ in their overall levels of self-reported anxiety or depression. Differences in trait anxiety occurred between right brain damaged and control subjects, indicating a greater willingness of the right brain damaged subjects to admit symptoms of general anxiety.

This latter finding is contrary to the hypothesized effect of stroke on mood, as others have reported an increase in self-reported depression and anxiety following left hemisphere stroke (eg, Robinson et al, 1984). Varying characteristics of the patient samples may account for the differing results. Both Robinson (1984) and Sinyor (1986) reported that a small, but significant, number of the right hemisphere stroke patients they studied developed

depression. These authors have disagreed as to whether the presence of anterior or posterior right hemisphere lesions places the patient at greater risk for depression. The sample used for this study was relatively small, especially with regard to subjects with left hemisphere damage, which may have skewed the self-report data.

Finally, damage to subcortical regions may play a key role in determining the presence or absence of affective disturbance following brain injury (Sackeim et al, 1982). Since lesion location was not precisely mapped for the patients in the present study, those with right hemisphere injuries may have had more extensive subcortical involvement.

4.7 Limitations of the Current Study and Directions for Future Research

Several factors may have influenced the outcome of these experiments.

1) Though all CVA subjects met clinical and CT scan criteria for admission into this study, the four groups (male; left and right, female; left and right) were not matched for extent, severity, or site of injury. Rostral/caudal and cortical/subcortical differences are of particular interest in this regard. Planimetric measurement of lesion size and location on CT scan would aid in addressing this issue, but this technique was beyond the scope of this dissertation.

2) As described above, analysis of the facial emotion paired comparison data resulted in more significant differences for the male than the female subjects. The task was designed to divide the sexes and avoid possible biases via separate stimuli. Unfortunately, this duplicate effort reduced the sample sizes by half.

3) Many of the stroke patients (but none of the controls) were receiving various medications at the time of their testing. This was especially true for those examined during the acute phase of their CVA. While some were receiving drugs to control symptoms that resulted from their CVA,

others were receiving medicine to alleviate other age-related disorders such as hypertension. Because various medications are well-known to affect cognitive functioning in the elderly, it is possible that they also biased the outcome of this study.

4) In order to place the emotion effects within a context of other cognitive abilities, all subjects received a thorough neuropsychological assessment. For these cognitive tests, the large number of dependent variables and resulting comparisons increase the risk that some of the statistically significant inter-group findings occurred by chance.

Despite these obstacles, inter-group differences for the perception of positive and negative emotions emerged for the facial emotion tasks, and for the measures of mood. Future studies with adults call for larger subject pools, with equivalent distributions of male and female patients with lateralized stroke. Better control of variables such as medication and lesion location should be exerted, and a well-defined observation time window (e.g., no more than 3-6 months post-stroke) should be maintained. Also, the use of more potent emotional stimuli, such as evocative videotapes, might enhance and extend the effects seen in this study.

The increased availability of physiological imaging hardware and techniques, such as Positron Emission

Tomography (PET), regional Cerebral Blood Flow (RCBF) and echo-planar Magnetic Resonance Imaging (functional MRI) also offers the promise for linking emotion processing with activation of discrete brain regions. These in vivo methods provide an opportunity to observe directly the effects of behavioral manipulation on brain activity, rather than speculate about possible mechanisms.

If indeed specialized neuroanatomical structures exist for the perception of emotion, and they are differentially lateralized for positive and negative stimuli, then fundamental questions arise regarding the development and maturation of these brain regions. These questions are best addressed through studies of pediatric rather than adult populations. Studying young children also circumvents the need to control effects of social learning on emotion perception and expression. Research to date has clearly indicated developmental staging for the expression of emotion, processing of emotionally laden information, and regulation of mood (Sackeim and Weber, 1984). Insights into the functional brain asymmetries underlying these skills are gradually establishing developmental sequences for this affective lateralization. Sex differences for these abilities are also emerging, and appear to parallel findings among adult subject populations. Future studies with children would enhance our understanding of the basic cerebral architecture of emotion processing, and its

relationship to other cognitive abilities.

4.8 Concluding Comment

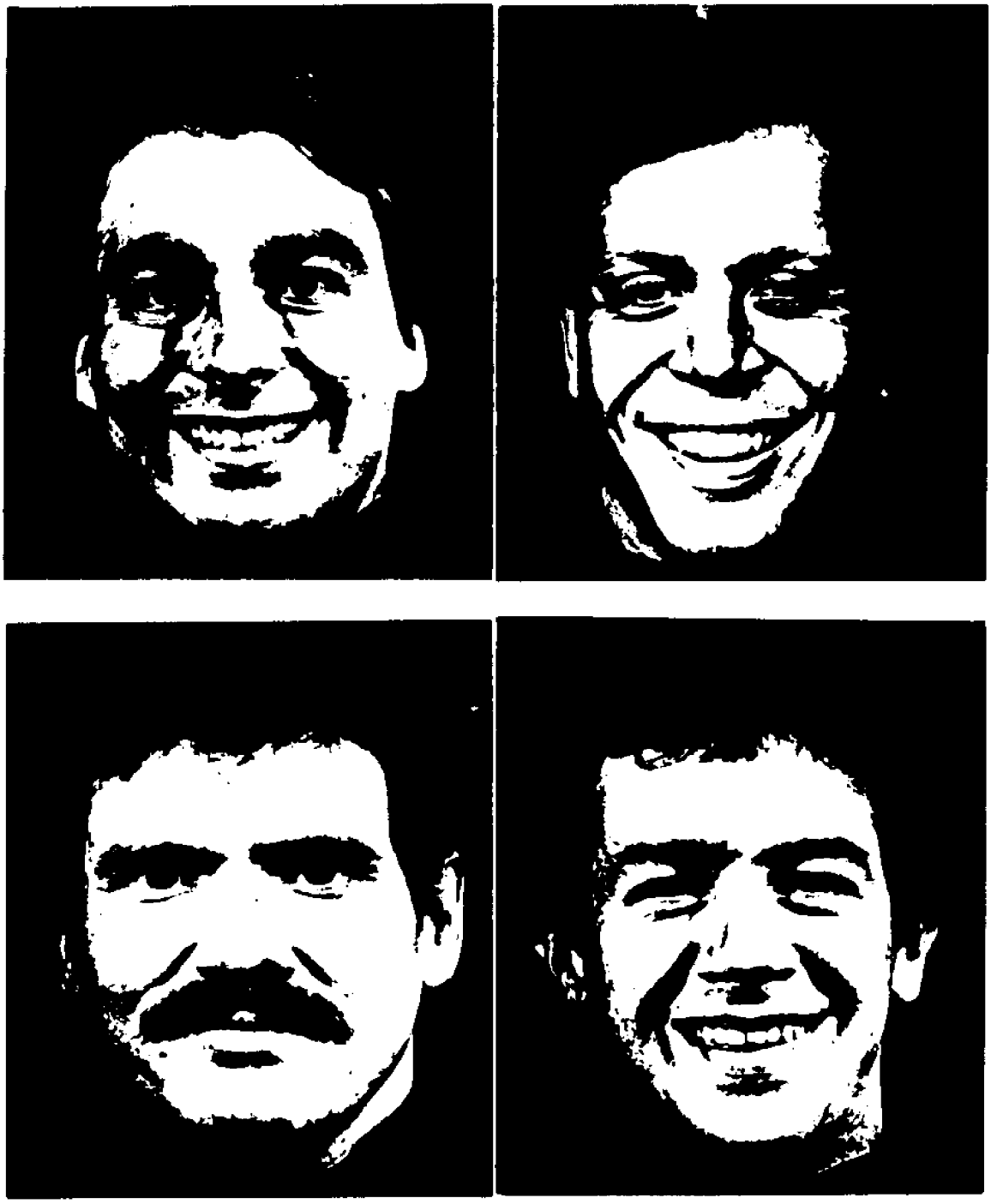
An abundance of tests is now available to assess various domains of cognitive functioning. There is also general acceptance of overlapping and hierarchical associations between cognitive spheres. For example, tests of verbal memory cannot be adequately interpreted without knowledge of language abilities. Despite widespread acknowledgement of an integral and interdependent relationship between emotions and cognition, no generally accepted measures for the accurate appraisal of emotion processing exist. This can be attributed to difficulties in quantifying elusive emotional states and isolating individual components of emotional experiences. The eventual development of a test battery to address this deficiency will augment routine evaluations of cognitive skills and assess the integrity of emotion expression and perception. This will expand our understanding of the complex associations of emotion and cognition, and allow us to determine how deficiencies in one sphere affect performance in the other. Ultimately, effective assessment of emotion perception deficits could lead to data-based rehabilitation strategies. Since cross-cultural studies have demonstrated a core number of universally recognized facial expressions of emotion, such measures could also be added to the armamentarium of

culturally unbiased tests.

The results of this study are compatible with those obtained from previous research involving normal subjects or patients experiencing a wide variety of neurologic or psychiatric disturbances. Like most of the investigations examining cerebral lateralization for emotion, the findings are subtle but consistent. The data provided by this study refine the hemispheric specialization hypothesis by showing that emotion communication difficulties due to brain damage not only occur across emotions, but also within specific emotions.

Appendix I

Photocopies of Facial Emotion Recognition Test stimuli:
Male Happy faces



Appendix I, continued

Photocopies of Facial Emotion Recognition Test stimuli:
Male Happy faces

Appendix I. continued

Photocopies of Facial Emotion Recognition Test stimuli:
Male Sad faces

Appendix I. continued

Photocopies of Facial Emotion Recognition Test stimuli:
Male Sad faces

Appendix I. continued

Photocopies of Facial Emotion Recognition Test stimuli:
Male Neutral faces

Appendix I, continued

Photocopies of Facial Emotion Recognition Test stimuli:
Male Neutral faces

Appendix I, continued

Photocopies of Facial Emotion Recognition Test stimuli:
Female Happy faces

Appendix I, continued

Photocopies of Facial Emotion Recognition Test stimuli:
Female Happy faces

Appendix I, continued

Photocopies of Facial Emotion Recognition Test stimuli:
Female Sad faces

Appendix I. continued

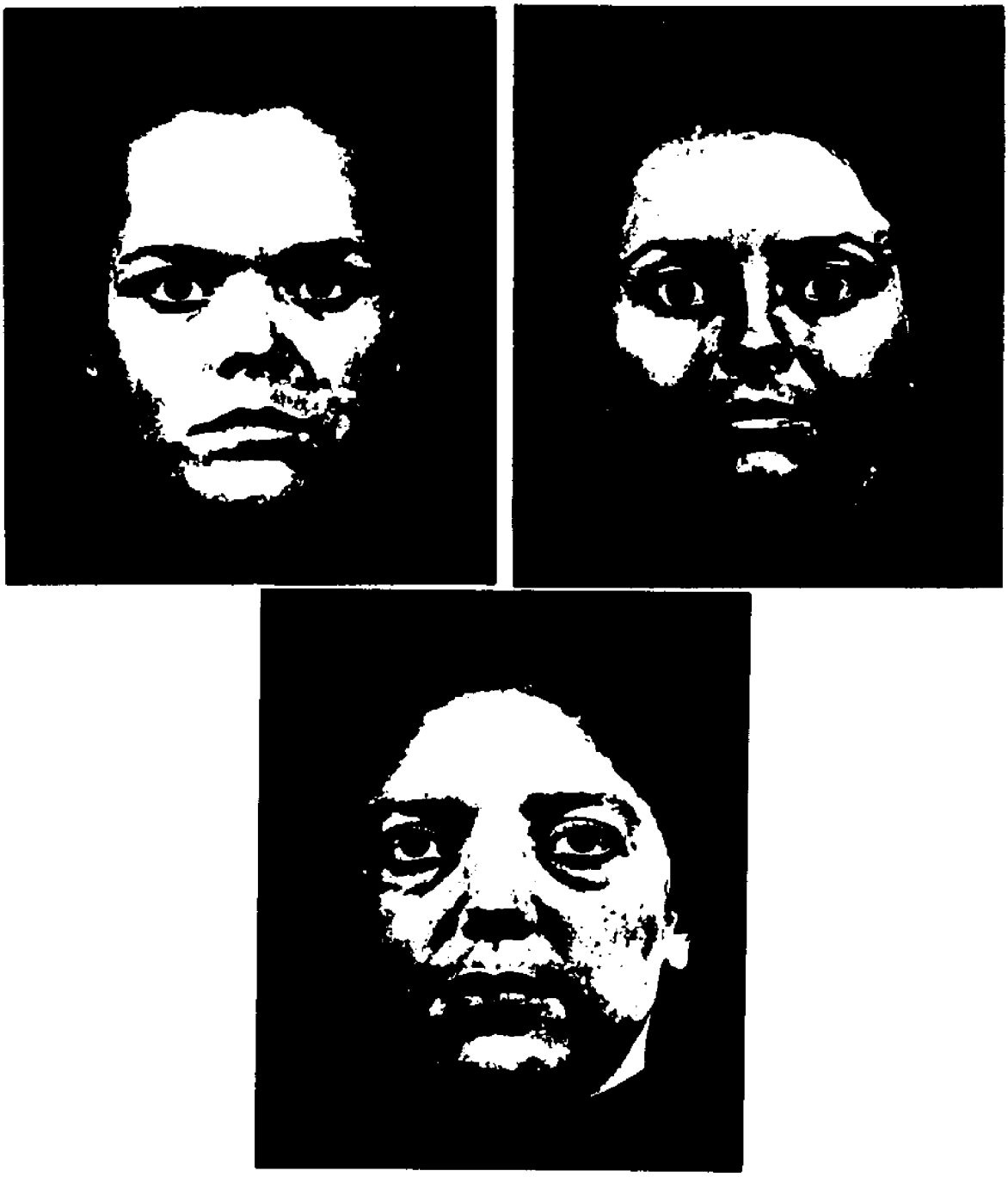
Photocopies of Facial Emotion Recognition Test stimuli:
Female Sad faces

Appendix I, continued

Photocopies of Facial Emotion Recognition Test stimuli:
Female Neutral faces

Appendix I, continued

Photocopies of Facial Emotion Recognition Test stimuli:
Female Neutral faces



Appendix II

Facial Emotion Perception Test data coding sheet

Name: _____ Date: _____

D.O.B.: ___/___/___ Age: _____ Educ.: _____

Laterality: Hand-____Foot-____Eye-_____

Occup.: _____

Diagnosis: _____

Counterbalanced Face Presentation Orders

SAD				HAPPY			
Order	Response	RT	Rank	Order	Response	RT	Rank
1. FG				1. DB			
2. AF				2. FA			
3. AB				3. GC			
4. CF				4. FC			
5. EG				5. CB			
6. DE				6. EC			
7. CD				7. FB			
8. DG				8. GF			
9. CE				9. EA			
10. BE				10. EB			
11. BD				11. BA			
12. CG				12. GE			
13. AD				13. ED			
14. AC				14. CA			
15. BC				15. FE			
16. EF				16. GB			
17. DF				17. GA			
18. BG				18. FD			
19. AE				19. DC			
20. BF				20. GD			
21. AG				21. DA			

NEUTRAL (HAPPY)				NEUTRAL (SAD)			
Order	Response	RT	Rank	Order	Response	RT	Rank
1. FG				1. DB			
2. AF				2. FA			
3. AB				3. GC			
4. CF				4. FC			
5. EG				5. CB			
6. DE				6. EC			
7. CD				7. FB			
8. DG				8. GF			
9. CE				9. EA			
10. BE				10. EB			
11. BD				11. BA			
12. CG				12. GE			
13. AD				13. ED			
14. AC				14. CA			
15. BC				15. FE			
16. EF				16. GB			
17. DF				17. GA			
18. BG				18. FD			
19. AE				19. DC			
20. BF				20. GD			
21. AG				21. DA			

Appendix III

Maximum likelihood estimation in the Bradley-Terry model is based on maximizing the log-likelihood function

$$L = \Sigma a_i \ln(\pi_i) - \Sigma\Sigma n_{ij} \ln(\pi_i + \pi_j)$$

where the first sum is over i=1, ..., K and the second sum is over $1 \leq i < j \leq K$. In this notation, $a_i = \Sigma a_{ij}$ $(i \neq j)$ which is simply the number of times that object i was chosen. Bradley (1976, p. 217) gives an iterative scheme for estimating the π_i's. Let p_i denote the maximum likelihood estimate of π_i and let $p_i^{(k)}$ be the kth iterative step in computing p_i.

Step 0: For all i=1,...K, set $p_i^{(0)}=1/K$.
Step 1: Set $p_i^{*(k)} = a_i/\Sigma(n_{ij}/(p_i^{(k-1)}+p_j^{(k-1)}))$ $(j \neq i)$
Step 2: Set $p_i^{(k)} = p_i^{*(k)}/\Sigma p_i^{*(k)}$
Step 3: Choose ϵ, e.g. 0.001. Compute $\Delta = \max(|p_i^{(k)}-p_i^{(k-1)}|)$, over i = 1, ..., K. Stop when $\Delta < \epsilon$, otherwise return to step 1.

This algorithm was programmed in FORTRAN and found that when $\epsilon = 0.001$, it never failed to converge to the maximum likelihood estimates $p_1, \ldots, p_K$. With $\epsilon = 0.0001$, there were some cases in which convergence was not reached at 100 iterations, although the final Δ was about 0.0003 or 0.0004. On an 80386/33 Mhz MS/DOS machine, the program runs in a few seconds. Within-group and between-group hypotheses about the paired comparison experiment all may be tested using various features of this model.

Appendix IV

Individual sex x diagnosis calculations of estimated preference probabilities, whose order implies an order for the emotion photographs. Key: diagnosis (dx) 1=right stroke, diagnosis 2=left stroke and diagnosis 3=control. Sex 1=male and sex 2=female. Results of the chi-square tests of the within-group hypotheses are displayed: a) the null hypothesis, that all selections are equally likely (always rejected), and b) the hypothesis that the Bradley-Terry model fits these data (always strongly accepted).

```
  happy          sex 1 diagnosis 1
  101 max delta 0.0004 p_new: 0.9560 0.0000 0.0173 0.0000
0.0103 0.0061 0.0103
 log likelihood   -7.920
 chi-square test of = selection:  42.384( 6)
 chi-square test of fit         :   1.978(15)

  happy          sex 2 diagnosis 1
41 max delta 0.0001 p_new: 0.0223 0.3544 0.4771 0.0526
0.0526 0.0164 0.0246
 log likelihood  -76.535
 chi-square test of = selection:  79.827( 6)
 chi-square test of fit         :  13.537(15)

  happy          sex 1 diagnosis 2
15 max delta 0.0001 p_new: 0.1527 0.0624 0.2592 0.0057
0.2592 0.1080 0.1527
 log likelihood  -41.774
 chi-square test of = selection:  32.900( 6)
 chi-square test of fit         :  17.427(15)

  happy          sex 2 diagnosis 2
62 max delta 0.0001 p_new: 0.0058 0.2950 0.5974 0.0363
0.0363 0.0058 0.0234
 log likelihood  -15.591
 chi-square test of = selection:  27.043( 6)
 chi-square test of fit         :  14.546(15)
```

```
  happy          sex 1 diagnosis 3
24 max delta 0.0001 p_new: 0.1969 0.0444 0.1607 0.0000
0.1230 0.0938 0.3812
 log likelihood  -97.355
 chi-square test of = selection: 125.525( 6)
 chi-square test of fit        :  10.157(15)

  happy          sex 2 diagnosis 3
60 max delta 0.0001 p_new: 0.0110 0.5411 0.3592 0.0303
0.0391 0.0032 0.0162
 log likelihood  -53.240
 chi-square test of = selection:  97.305( 6)
 chi-square test of fit        :  20.117(15)

  sad            sex 1 diagnosis 1
101 max delta 0.0006 p_new: 0.0007 0.9374 0.0586 0.0007
0.0003 0.0007 0.0017
 log likelihood  -12.423
 chi-square test of = selection:  33.379( 6)
 chi-square test of fit        :   5.438(15)

  sad            sex 2 diagnosis 1
16 max delta 0.0001 p_new: 0.1090 0.0630 0.1366 0.1854
0.1090 0.3034 0.0936
 log likelihood -107.042
 chi-square test of = selection:  18.814( 6)
 chi-square test of fit        :   6.458(15)

  sad            sex 1 diagnosis 2
29 max delta 0.0001 p_new: 0.0405 0.3203 0.4090 0.0620
0.0000 0.0758 0.0923
 log likelihood  -32.330
 chi-square test of = selection:  51.788( 6)
 chi-square test of fit        :   7.537(15)

  sad            sex 2 diagnosis 2
12 max delta 0.0001 p_new: 0.0944 0.0944 0.0689 0.2373
0.1732 0.2373 0.0944
 log likelihood  -26.741
 chi-square test of = selection:   4.741( 6)
 chi-square test of fit        :  14.667(15)

  sad            sex 1 diagnosis 3
101 max delta 0.0002 p_new: 0.0097 0.8275 0.1285 0.0142
0.0024 0.0121 0.0057
 log likelihood  -84.547
 chi-square test of = selection: 151.141( 6)
 chi-square test of fit        :   9.346(15)
```

sad sex 2 diagnosis 3
27 max delta 0.0001 p_new: 0.0626 0.1002 0.1330 0.1780
0.0377 0.4420 0.0465
log likelihood -82.493
chi-square test of = selection: 38.800(6)
chi-square test of fit : 19.362(15)

happy/neutral sex 1 diagnosis 1
101 max delta 0.0004 p_new: 0.0112 0.0112 0.0047 0.0000
0.0112 0.0029 0.9590
log likelihood -12.260
chi-square test of = selection: 33.704(6)
chi-square test of fit : 5.112(15)

happy/neutral sex 2 diagnosis 1
25 max delta 0.0001 p_new: 0.0326 0.0836 0.3803 0.2960
0.0226 0.0924 0.0924
log likelihood -75.915
chi-square test of = selection: 51.956(6)
chi-square test of fit : 12.395(15)

happy/neutral sex 1 diagnosis 2
53 max delta 0.0001 p_new: 0.0401 0.1909 0.0947 0.0040
0.0323 0.0130 0.6251
log likelihood -32.329
chi-square test of = selection: 51.791(6)
chi-square test of fit : 10.674(15)

happy/neutral sex 2 diagnosis 2
30 max delta 0.0001 p_new: 0.0612 0.0612 0.3852 0.3852
0.0951 0.0000 0.0120
log likelihood -13.648
chi-square test of = selection: 30.928(6)
chi-square test of fit : 10.660(15)

happy/neutral sex 1 diagnosis 3
19 max delta 0.0001 p_new: 0.3135 0.2535 0.1159 0.0165
0.0286 0.1317 0.1404
log likelihood -117.322
chi-square test of = selection: 85.590(6)
chi-square test of fit : 11.378(15)

happy/neutral sex 2 diagnosis 3
32 max delta 0.0001 p_new: 0.0638 0.1159 0.2198 0.4791
0.0577 0.0214 0.0425
log likelihood -75.858
chi-square test of = selection: 52.069(6)
chi-square test of fit : 9.383(15)

```
  sad/neutral   sex 1 diagnosis 1
69 max delta 0.0001 p_new: 0.0143 0.0143 0.0823 0.5953
0.0040 0.2899 0.0000
 log likelihood   -9.992
 chi-square test of = selection:  38.240( 6)
 chi-square test of fit         :  11.666(15)

  sad/neutral   sex 2 diagnosis 1
22 max delta 0.0001 p_new: 0.0645 0.0945 0.0430 0.0386
0.3547 0.1521 0.2525
 log likelihood  -81.810
 chi-square test of = selection:  40.166( 6)
 chi-square test of fit         :   9.356(15)

  sad/neutral   sex 1 diagnosis 2
82 max delta 0.0001 p_new: 0.0209 0.0117 0.0438 0.7861
0.0209 0.1023 0.0143
 log likelihood  -38.236
 chi-square test of = selection:  39.976( 6)
 chi-square test of fit         :  12.757(15)

  sad/neutral   sex 2 diagnosis 2
48 max delta 0.0001 p_new: 0.0481 0.0682 0.0147 0.0336
0.0972 0.0972 0.6410
 log likelihood  -21.001
 chi-square test of = selection:  16.223( 6)
 chi-square test of fit         :  22.593(15)

  sad/neutral   sex 1 diagnosis 3
26 max delta 0.0001 p_new: 0.0402 0.0458 0.2712 0.4011
0.1153 0.0709 0.0554
 log likelihood -126.918
 chi-square test of = selection:  66.398( 6)
 chi-square test of fit         :  15.393(15)

  sad/neutral   sex 2 diagnosis 3
17 max delta 0.0001 p_new: 0.1021 0.0622 0.0288 0.0365
0.2828 0.2049 0.2828
 log likelihood  -78.346
 chi-square test of = selection:  47.094( 6)
 chi-square test of fit         :   9.802(15)
```

References

Aggleton, J.P., and Mishkin, M. (1986) The Amygdala: Sensory Gateway to the Emotions. In R. Plutchik, and H. Kellerman, (Eds.) Emotion Theory,Research, and Experience, Vol. 3: Biological Foundations of Emotion. New York: Academic Press. 281-299.

Agresti, Alan (1990, preprint) Analysis of ordinal paired comparison data.

Beaton, Alan (1985) Left Side, Right Side: A Review of Laterality Research. New Haven: Yale University Press.

Beck, A., Ward, C., Mendelson, M., Mock, J., and Erbargh, J. (1961) An Inventory for Measuring Depression. Archives of Psychiatry, 4, 561-567.

Benson, D. Frank, (1973) Psychiatric Aspects of Aphasia. British Journal of Psychiatry, 123, 555-566.

Benton, Arthur L. (1980) The Neuropsychology of Facial Recognition. American Psychologist, 35 (2), 176-186.

Benton, A.L., Hamsher, K.deS., Varney, N.R., and Spreen, O. (1983) Contributions to Neuropsychological Assessment. New York: Oxford University Press.

Benton, Arthur L. (1986) Reaction Time in Brain Disease. Cortex, 22 (1), 129-140.

Berrios, G.E., and Samuel, C. (1987) Affective Disorder in the Neurological Patient. The Journal of Nervous and Mental Disease, 175 (3), 173-176.

Borod, J.C., Koff, E., and White, B. (1983) Facial Asymmetry in Posed and Spontaneous Expressions of Emotion. Brain and Cognition, 2, 165-175.

Bradley, R.A. (1976) Science, statistics, and paired comparisons: an invited paper with discussion, Biometrics, 32, 213-240.

Bradley, R.A. & Terry, M.E. (1952) The rank analysis of incomplete block designs, I. The method of paired comparisons, Biometrika, 39, 324-345.

Bryden, M.P., and Ley, R.G. (1983) Right-Hemispheric Involvement in the Perception and Expression of Emotion in Normal Humans. In K.M. Heilman and P. Satz (Eds.) Neuropsychology of Human Emotions. NY: Basic Books. 6-44.

Bruyer, Raymond (Ed.) (1986) The Neuropsychology of Face Perception and Facial Expression. NJ: Erlbaum Press

Clarke, M., and Fiske, S. (Eds.) (1982) Affect and Cognition (17th Annual Carnegie Symposium on Cognition), NJ: Erlbaum Press.

Coslett, H.B., Bowers, D., and Heilman, K.M. (1987) Reduction in Cerebral Activation after Right Hemisphere Stroke, Neurology, 37 (6), 957-62.

Damasio, A.R., Damasio, H., and Van Hoesen, G.W. (1982) Prosopagnosia: Anatomical basis and Behavioral Mechanisms. Neurology, 32, 331-41.

Darwin, Charles (1965) The Expression of the Emotions in Man and Animals. Chicago: University of Chicago Press (originally published in 1872).

Davidson, R.J., Mednick, D., Moss, E.M., Schaffer, C.E., and Saron, C. (1987) Ratings of Emotion in Faces are Influenced by the Visual Field to which Stimuli are Presented. Brain and Cognition, 6, 403-411.

Davidson, R.R. & Farquhar, P.H. (1976) A bibliography on the method of paired comparisons, Biometrics, 32, 241-252.

Ekman, P., and Friesen, W.V., (1975) Unmasking the Face. New Jersey: Prentice-Hall, Inc.

Ekman, P., and Friesen, W.V., (1978) Facial Action Coding System, California: Consulting Psychologists Press.

Etcoff, Nancy (1985). The Neuropsychology of Emotional Expression. To appear in G. Goldstein and R.E. Tarter (Eds.) Advances in Clinical Neuropsychology (Vol. 3). New York: Plenum Press.

Finkelstein, S., Benowitz, L.I., Baldessarini, R.J., Arana, G.W., Levine, D., Woo, E., Bear, D., Moya, K., and Stoll, A.L. (1982) Mood, Vegetative Disturbance, and Dexamethasone Suppression Test After Stroke. Annals of Neurology, 12, 463-468.

Flor-Henry, P., Koles, Z.J., Howarth, B.G., and Burton, L. (1979a) Neurophysiological Studies of Schizophrenia, Mania, and Depression. In J. Gruzelier and P. Flor-Henry (Eds.) Asymmetries of Function in Psychopathology, New York: Elsevier/North-Holland Biomedical Press.

Flor-Henry, P., and Yeudall, L.T. (1979b) Neuropsychological Investigation of Schizophrenia and Manic-Depressive Psychoses. In J. Gruzelier and P. Flor-Henry (Eds.) Hemisphere Asymmetries of Function in Psychopathology, New York: Elsevier/North-Holland Biomedical Press.

Folstein, M.F., Maiberger, R., and McHugh, P.R. (1977) Mood Disorder as a Specific Complication of Stroke. Journal of Neurology, Neurosurgery, and Psychiatry, 40, 1018-1020.

Freeman, R.L., Galaburda, A.M., Cabal R.D., and Geschwind,N. (1985) The Neurology of Depression: Cognitive and Behavioral Deficits with Focal Findings in Depression and Resolution after Electroconvulsive Therapy. Archives of Neurology, 42, 289-291.

Frijda, Nico (1988) The Laws of Emotion. American Psychologist, 43(5), 349-358.

Gainotti, Guido (1969) Reactions "Catastrophiques" et Manifestations d'Indifference au cours des Atteintes Cerebrales. Neuropsychologia, 7, 195-204.

Gainotti, Guido (1972) Emotional Behavior and Hemispheric Side of Lesion. Cortex, 8, 41-55.

Gur, Raquel (1979) Hemispheric Overactivation in Schizophrenia. In J. Gruzelier and P. Flor-Henry (Eds.) Hemisphere Asymmetries of Function in Psychopathology, New York: Elsevier/North- Holland Biomedical Press.

Gur, R.E., Skolnick, B.E., Gur, R.C., Caroff, S., Rieger, W., Obrist, W.D., Younkin, D., and Reivich, M. (1983) Brain Function in Psychiatric Disorders: I. Regional Cerebral Blood Flow in Medicated Schizophrenics. Archives of General Psychiatry, 40, 1250-1254.

Gur, R.E., Skolnick, B.E., Gur, R.C., Caroff, S., Rieger, W., Obrist, W.D., Younkin, D., and Reivich, M. (1984) Brain Function in Psychiatric Disorders: II. Regional Cerebral Blood Flow in Medicated Unipolar Depressives. Archives of General Psychiatry, 41, 695-699.

Gur, R.E., Gur, R.C., Skolnick, B.E., Caroff, S., Obrist, W.D., Resnick, S., and Reivich, M. (1985) Brain Function in Psychiatric Disorders: III. Regional Cerebral Blood Flow in Unmedicated Schizophrenics. Archives of General Psychiatry, 42, 329-334.

Gur, R.C., Gur, R.E., Obrist, W.D., Skolnick, B.E., and Reivich, M. (1987) Age and Regional Cerebral Blood Flow at Rest and During Cognitive Activity. Archives of General Psychiatry, 44, 617-621.

Gur, R.C. et al (1991) in process.

Harnad, S., Steklis, H., and Lancaster, D. (Eds.) (1976) Origins and Evolution of Language and Speech. Annals, New York Academy of Sciences, vol. 280, New York: New York Academy of Sciences.

Hays, William, L. (1963) Statistics. New York: Holt, Rinehart and Winston.

Heilman, K., Bowers, D., Speedie, L., and Coslett, B. (1984) Comprehension of Affective and Nonaffective Speech. Neurology, 34, 917-921.

Hewes, Gordon W. (1976) The Current Status of the Gestural Theory of Language Origin. In Harnad, Steklis, and Lancaster (Eds.) Origins and Evolution of Language and Speech. Annals, New York Academy of Sciences, 280, 482-504.

Johnson, W.F., Emde, R.N. Scherer, K.R., and Klinnert, M.D. (1986) Recognition of Emotion from Vocal Cues. Archives of General Psychiatry, 43, 280-283.

Kelly, A.E., and Stinus, L. (1984) Neuroanatomical and Neurochemical Substrates of Affective Behavior. In N. Fox, and R.J. Davidson (Eds.) The Psychobiology of Affective Development. New Jersey: Erlbaum Press. 1-75.

Koella, Werner P. (1982) The Functions of the Limbic System - Evidence from Animal Experimentation. Advances in Biological Psychiatry, 8, 12-39.

Korner-Bitensky, N., Mayo, N.E., and Kaizer, F. (1990) Change in Response Time of Stroke Patients and Controls during Rehabilitation, American Journal of Physical Medicine and Rehabilitation, 69 (1), 32-8.

Krishnan, K.R.R., Goli, V., Ellinwood, E.H., France, R.D., Blazer, D.G., and Nemeroff, C.B. (1988) Leukoencephalopathy in Patients Diagnosed as Major Depressive. Biological Psychiatry, 23, 519-522.

Lazarus, Richard S. (1982) Thoughts on the Relations Between Emotion and Cognition. American Psychologist, 37, 1019-24.

Lee, G.P., Loring, D.W., Meador, K.J., Flanigin, H.F., and Brooks, B.S. (1988) Severe Behavioral Complications Following Intracarotid Sodium Amobarbital Injection: Implications for Hemispheric Asymmetry of Emotion. Neurology, 38, 1233-1236.

Lipsey, J.R., Robinson, R.G., Pearlson, G.D., Rao, K., and Price, T.R. (1984b) Nortriptyline Treatment of Post-Stroke Depression: A Double-Blind Study. The Lancet, February 11, 297-300.

MacLean, Paul D. (1954) Psychosomatic disease and the "visceral brain", recent developments bearing on the Papez theory of emotion. Psychosomatic Medicine, 11, 338-353.

MacLean, Paul D. (1973) A triune concept of the brain and behavior, Lecture I. Man's reptilian and limbic inheritance, Lecture II. Man's limbic brain and the psychoses, Lecture III. New trends in man's evolution. In T. Boag and D. Campbell (Eds.), The Hincks Memorial Lectures (p. 6-66). Toronto: University of Toronto Press.

Malatesta, C., and Izard, C. (1984) The Ontogenesis of Human Social Signals: From Biological Imperative to Symbol Utilization. In N. Fox, and R.J. Davidson (Eds.) The Psychobiology of Affective Development. New Jersey: Erlbaum Press. 161-206.

Milner, B., and Petrides, M. (1984) Behavioural Effects of Frontal Lobe Lesions in Man. Trends in Neurosciences, 7(11), 1-5.

Milner, Brenda (1967) Discussion of the paper: Experimental Analysis of Cerebral Dominance in Man. In C.H. Millikan and F.L. Darley (Eds.) Brain Mechanisms Underlying Speech and Language. New York: Grune and Stratton.

Moscovitch, M., Strauss, E., and Olds, J., (1981) Handedness and Dichotic Listening Performance in Patients with Unipolar Endogenous Depression who Received ECT. American Journal of Psychiatry, 138, 988-990.

Nauta, Walle J. H. (1971) The Problem of the Frontal Lobe: A Reinterpretation. Journal of Psychiatric Research, 8, 167-187.

Nelson, Hazel (1976) A Modified Card Sorting Test Sensitive to Frontal Lobe Defects. Cortex, 12, 313-324.

Newcombe, F., de Haan, E.H., and Young, A.W. (1989) Face Processing, Laterality, and Contrast Sensitivity. Neuropsychologia, 27 (4), 523-38.

Papanicolaou, A.C., Levin, H.S., Eisenberg, H.M., and Moore, B.D. (1983) Evoked Potential Indices of Selective Hemispheric Engagement in Affective and Phonetic Tasks. Neuropsychologia, 21 (4), 401-405.

Papanicolaou, A.C., Moore, B.D., Deutsch, G., Levin, H.S., and Eisenberg, H. (1988) Evidence for Right Hemisphere Involvement in Recovery from Aphasia. Archives of Neurology, 45, 1025-9.

Papez, P.W. (1937) A Proposed Mechanism of Emotion. Archives of Neurology and Psychiatry, 38, 725-744.

Ploog, Detlev (1989) An Outline of Human Neuroethology. Human Neurobiology, 6, 227-238.

Ploog, Detlev (1986) Biological Foundations of the Vocal Expressions of Emotions. In R. Plutchik, and H. Kellerman, (Eds.) Emotion Theory,Research, and Experience. Vol. 3: Biological Foundations of Emotion. New York: Academic Press. 173-197.

Plutchik, R., and Kellerman, H. (Eds.) (1986) Emotion Theory, Research, and Experience, Vol. 3: Biological Foundations of Emotion. New York: Academic Press.

Plutchik, Robert (1984) Emotions: A General Psychoevolutionary Theory. In K.P. Scherer, and P. Ekman, (Eds.) Approaches to Emotion. New Jersey: Erlbaum Press. 197-219.

Price, Thomas R. (1987) Depression and Stroke. In R.E. Dunkle, and J.W. Schmidley, (Eds.) Stroke in the Elderly: New Issues in Diagnosis, Treatment, and Rehabilitation. New York: Springer Publishing Co. 162-168.

Rinn, William E., (1984) The Neuropsychology of Facial Expression: A Review of the Neurological and Psychological Mechanisms for Producing Facial Expressions. Psychological Bulletin, 95 (1), 52-77.

Robinson, R.G., and Szetela, B. (1981a) Mood Change Following Left Hemispheric Brain Injury. Annals of Neurology, 9, 447-53.

Robinson, R.G., and Benson, D.F., (1981b) Depression in Aphasic Patients: Frequency, Severity, and Clinical-Pathological Correlations. Brain and Language, 14, 282-291.

Robinson, R.G., Kubos, K.L., Starr, L.B., Rao, K., and Price, T.R. (1984) Mood Disorders in Stroke Patients: Importance of Location of Lesion. Brain, 107, 81-93.

Robinson, R.G., Lipsey, J.R., Bolla-Wilson, K., Bolduc, P.L., Pearlson, G.D., Rao, K., and Price, T.R. (1985) Mood Disorders in Left-handed Stroke Patients. American Journal of Psychiatry, 142 (12), 1424-1429.

Robinson, R.G., Bolla-Wilson, K., Kaplan, E., Lipsey, J.R., and Price, T.R. (1986a) Depression Influences Intellectual Impairment in Stroke Patients. British Journal of Psychiatry, 148, 541-547.

Robinson, R.G., Lipsey, J.R., Rao, K., and Price, T.R. (1986b) Two-Year Longitudinal Study of Poststroke Mood Disorders: Comparison of Acute-Onset with Delayed-Onset Depression. American Journal of Psychiatry, 143 (10), 1238-1244.

Rossi, G.F., and Rosadini, G. (1967) Experimental Analysis of Cerebral Dominance in Man. In C.H. Millikan and F.L. Darley (Eds.) Brain Mechanisms Underlying Speech and Language. New York: Grune and Stratton.

Ruckdeschel-Hibbard, M., Gordon, W.A., and Diller, L. (1986) Affective Disturbances Associated with Brain Damage. In S.B. Filskov and T.J. Boll (Eds.) Handbook of Clinical Neuropsychology: Vol. II. NY: Wiley,Interscience. 305-37.

Sackeim, H.A., Greenberg, M.S., Weiman, A.L., Gur, R.C., Hungerbuhler, J.P., and Geschwind, N. (1982) Hemispheric Asymmetry in the Expression of Positive and Negative Emotions: Neurological Evidence. Archives of Neurology, 39, 210-218.

Sackeim, H.A., and Weber, S.L. (1984) The Development of Functional Brain Asymmetry in the Regulation of Emotion. In N. Fox, and R.J. Davidson, (Eds.) (1984) The Psychobiology of Affective Development. NJ: Erlbaum Press. 325-351.

Schaffer, C.E., Davidson, R.J., and Saron, C. (1983) Frontal and Parietal EEG Asymmetry in Depressed and Non-depressed Subjects. Biological Psychiatry, 18, 753-762.

Scherer, Klaus (1979) Non-linguistic Vocal Indicators of Emotion and Psychopathology. In C. Izard (Ed.) Personality and Psychopathology. New York: Plenum Press.

Scherer, K.P., and Ekman, P., (Eds.) (1984) Approaches to Emotion. New Jersey: Erlbaum Press.

Schlanger, B.B., Schlanger, P., and Gerstman, L.J. (1976) The Perception of Emotionally Toned Sentences by Right Hemisphere-Damaged and Aphasic Subjects. Brain and Language, 3, 396-403.

Schulz, R., Tompkins, C.A., and Rau, M.T. (1988) A Longitudinal Study of the Psychosocial Impact of Stroke on Primary Support Persons. Psychology and Aging, 3 (2), 131-141.

Searleman, Alan (1983) Language Capabilities of the Right Hemisphere. In A.W. Young (Ed.) Functions of the Right Cerebral Hemisphere. New York: Academic Press. 87-111.

Shinar, D., Gross, C.R., Price, T.R., Banko, M., Bolduc, P.L., and Robinson, R.G. (1986) Screening for Depression in Stroke Patients: The Reliability and Validity of the Center for Epidemiologic Studies Depression Scale. Stroke, 17(2), 241-245.

Shipley-Brown, F., Dingwall, W.O., Berlin, C.I., Yeni-Comshian, G., and Gordon-Salant, S. (1988) Hemispheric Processing of Affective and Linguistic Intonation Contours in Normal Subjects. Brain and Language, 33, 16-26.

Sinyor, D., Jacques, P., Kaloupek, D.G., Becker, R., Goldenberg, M., and Coopersmith, H. (1986) Poststroke Depression and Lesion Location: an Attempted Replication. Brain, 109, 537-546.

Spielberger, C.D., Gorsuch, R.L., and Lushene, R.E. (1970) Manual for the State-Trait Anxiety Inventory, Palo Alto, CA: Consulting Psychologists Press.

Stafford, J.L., Albert, M.S., Naeser, M.A., Sandor, T., and Garvey, A.J. (1988) Age-Related Differences in Computed Tomographic Scan Measurements. Archives of Neurology, 45, 409-415.

Starkstein, S.E., Robinson, R.G., Berthier, M.L., Parikh, R.M., and Price, T.R. (1988) Differential Mood Changes Following Basal Ganglia vs Thalamic Lesions. Archives of Neurology, 45, 725-730.

Suberi, M., and McKeever, W.F. (1977) Differential Right Hemisphere Memory Storage of Emotional and Non-emotional Faces. Neuropsychologia, 15, 757-768.

Tartaglione, A., Oneto, A., Manzino, M., and Favale, F. (1987) Further Evidence for Focal Effect of Right Hemisphere Damage on Simple Reaction Time, Cortex, 23 (2), 285-92.

Tranel, D., and Damasio, A.R. (1985) Knowledge Without Awareness: An Autonomic Index of Facial Recognition by Prosopagnosics. Science, 228, 1453-1454.

Tranel, D., Damasio, A.R., and Damasio, H. (1988) Intact Recognition of Facial Expression, Gender, and Age in Patients with Impaired Recognition of Face Identity. Neurology, 38, 690-696.

Tucker, D.M., Watson, R.T., and Heilman, K.M. (1977) Discrimination and Evocation of Affectively Intoned Speech in Patients with Right Parietal Disease. Neurology, 27, 947-950.

Tucker, Don M. (1981) Lateral Brain Function, Emotion, and Conceptualization. Psychological Bulletin, 89 (1), 19-46.

Tucker, D.M., Stenslie, C.E., Roth, R.S., and Shearer, S.L. (1981) Right Frontal Lobe Activation and Right Hemisphere Performance. Archives of General Psychiatry, 38, 169-174.

Tucker, Don M. (1986) Neural Control of Emotional Communication. In Blanck, Buck, and Rosenthal (Eds.) Nonverbal Communication in the Clinical Context. State College: The Pennsylvania State University Press.

Waber, D.P. (1977) Biological Substrates of Field Independence: Implications of the Sex Difference. Psychological Bulletin, 84(6), 1076-1087.

Wallace, J.L., (1984) Wechsler Memory Scale. International Journal of Clinical Neuropsychology, 6(3, Suppl.) 216-226.

Watson, D., and Tellegen, A. (1985) Toward a Consensual Structure of Mood. Psychological Bulletin, 2, 219-235.

Weintraub, S. Mesulam, M-M, and Kramer, L. (1981) Disturbances in Prosody - A Right Hemisphere Contribution to Language. Archives of Neurology, 38, 742-744.

Wolf, P.A., Kannel, W.B., and McGee, D.L. (1986) Epidemiology of Strokes in North America. In H.J.M. Barnett, B.M. Stein, J.P. Mohr and F.M. Yatsu (Eds.) Stroke (Vol. I): Pathophysiology, Diagnosis, and Management. New York: Churchill Livingstone Press.

Zaidel, E. (1978) Auditory language comprehension in the right hemisphere following cerebral commissurotomy and hemispherectomy: A comparison with child language and aphasia. In A. Caramazza and E.B. Zurif (Eds.) Language Acquisition and Language Breakdown: Parallels and Divergences. Baltimore: Johns Hopkins Press.

Zajonc, Robert B. (1980) Feeling and Thinking (Preferences need no Inferences). American Psychologist, 35(2),151-75.

Zajonc, Robert B. (1984) On the Primacy of Affect. American Psychologist, 39(2), 117-123.

Zung, W.K. (1965) A self-rating depression scale. Archives of General Psychiatry, 12, 63-70.