HEMISPHERIC AND AUTONOMIC LATERALITY: EFFECTS OF UNILATERAL REPETITIVE ACTIVATION

by

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DISSERTATION

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ABSTRACT

The purpose of the study was to compare the ability of the left and right hemispheres of the human brain to control autonomic variables. The variable of interest was the amounts of time to recover from startle induced elevation in bilateral skin conductance levels and heart rate. The methodo1ogy used, called Unilateral Repetitive Activation, is based on a hypothesis which suggests a decrease in contralateral interference when one hemisphere is repeatedly presented with information known to be processed more efficiently in that hemisphere. One group of 24 right handed adult female subjects received right hemisphere activation by watching a moving light line produced by a kinescope and by listening to music. A second matched group of 23 received left hemisphere activation by reading from a screen and listening to a tape of the readings. Results showed that the right hemisphere activation group recovered faster suggesting that the left hemisphere dominated autonomic control.

A second purpose of the study was to evaluate effects of hemisphere activation on verbal and spatial task performance. After six 45 minute sessions of left or right hemisphere activation, subjects were given three verbal and three spatial tasks. No significant differences were found between the groups.

Additional analysis suggested a probable relationship between the left hemisphere and the sympathetic nervous system and a possible relationship between the right hemisphere and the parasympathetic nervous system.

Implications were discussed in terms of relationship to stress related disorders and application to education and psychotherapy.

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INTRODUCTION

The two hemispheres of the human brain and other paired organs of the body tend to be slightly asymmetrical. Diligent structural measurements of the hemispheres reveal small morphological differences but fail to account for functional dissimilarities. It is generally agreed that in right handed people, language and arithmetic processing are served by the left hemisphere, and that the right hemisphere is specialized for spatial relations.

The evolution of hemispheric specialization is not well understood. Language development is the most obvious distinguishing characteristic, but why it lateralized left is speculative. Once the relationship between each hemisphere and contra lateral sensor motor control was well established, so was a possible link between right handedness and left hemisphere dominance for speech because theorists began to hypothesize , some relationship between increased manipulation of the environment with the right hand and reinforcement of the development of symbol formation in the left hemisphere. This interdependent Loop is feasible, but why the right hand more than the left and why only the human species? Answers are not definite, but evidence suggests genetic as well as environmental influences in determination of lateral laterality dominances, with somewhat more weight placed on the former from an evolutionary standpoint.

Most of the information about hemispheric laterality comes historically from differential symptoms produced by brain damage and from extensive study following surgical separation of the halves of the brain. Neuropsychological assessment in brain damaged patients has provided the basis for much of what is known about tae brain and behavior, but those data are not as pertinent to hemispheric specialization research as are the results of severance of relatively undamaged brains. Although slit brain patients appear normal on casual inspection, controlled lateralized testing indicates independent, sometimes simultaneous, and even antagonistic processing within the hemispheres. The modes of processing appear to be quite different. The left is verbal, analytical, and logical while the right is nonverbal, gestaltic, and intuitive. A mutual interference is evidenced by depressed scores when both verbal and nonverbal perceptual functions develop in the same hemisphere or when one hemisphere attempts a task usually mediated by the other.

In the normal intact brain, a presumed cooperation occurs between the hemispheres as they share information via the corpus collosum. Several possibilities are hypothesized to explain the apparent integration necessary to behave in a coherent unified manor. Either the hemispheres altercate between modes or they process independently in parallel, each contributing elements to the final behavior. Evidence suggests that in either case, conflict can occur and one hemisphere gains control of shared functions to dominate overt behavior. Because language functions have had such high survival value for humans, the hemisphere dominant for speech usually controls when conflict exists. Full integration and cooperation, on the other hand, has been associated with creativity.

The concept of laterality extends from the brain to the peripheral nervous system as well. Besides contralateral tomatosensory control, current research suggests a relationship between cortical function and autonomic behavior change. The extent to which the cerebrum participation in visceral activity and whether one of the hemispheres is more specialized in this area are not known. Clinical reliance on the validity of the relationship between the brain and autonomic systems is evidenced by the successful use of cognitive techniques such as visual imagery and autogenic verbal exercises to aid relaxation.

Proponents of hemispheric specialization report significant bilateral peripheral asymmetries during performance of verbal and spatial tasks, but applications in educational, medical, and psychotherapeutic settings are unclear. Since the nondominant hemisphere is implicated in emotionality and the autonomic responses to emotional stimuli are well documented, it is possible that the right hemisphere is specialized for autonomic regulation. However the left hemisphere, by virtue of more active lifelong reinforcement as language develops and verbal skills improve, tends to control output channels most of the time. Therefore, the hemisphere dominant for speech could also be the dominant influence in autonomic control.

Assuming a cortico-visceral relationship, which hemisphere more efficiently aids in regulation of autonomic variables? Is there a methodology by which each hemisphere can be tested for autonomic control? Does systematic manipulation of hemispheric processing modes have post-treatment effects on verbal and spatial task performance? Answers to these questions were sought in the study which follows.

The issues of laterality are timely. Current research results suggest applications to enhance treatment of psychosomatic disorders, to improve teaching techniques, and to understand psychodynamics. More divergent theorists suggest that exploration of the minor hemisphere will lead to explanations for phenomena such as altered states of *consciousness, bursts* of human creativity, and even psychic healing. Therefore, further knowledge of hemispheric and autonomic asymmetries of function is of benefit in treatment of human pathology as well as generalized enhancement of the quality of life.

CHAPTER 2

REVIEW OF THE LITERATURE

Nature effects a Paradoxical balance in the human brain by designating a contralateral control system, whereby the right side of t-he body is primarily controlled by the left brain with comp complementary activity from right brain to left body. The left hemisphere is generally considered rational, propositional, and analytical, while the right hemisphere is considered more intuitive, appositional and gestaltic (Bennett, 1970; Bogen, DeZure and Tenhouten, 1972; Bocen,1969; and Dimond, 1972). The following review will consider hemispheric laterality in five aspects: a historical perspective, genetic and environmental influences, split brain studies, intact hemisphere studies, and psycho physiological laterality studies.

<u>Historical perspective.</u> An evolutionary explanation of bilaterality assumes some adaptive survival value. In reference to the brain, perhaps an attack from a beast on one side could also be anticipated from the other if the information were laid down in mirror-image fashion in the other hemisphere (Corballis & Beale, 1971, 1976). Based on, the fact that the neurological structure necessary for speech exists without apparent use in the minor hemisphere, Jaynes (1976) hypothesizes a former function for this area prior to the cultural pressure which forced the learning of consciousness as a human trait some 3000 years ago. The suggested function is described as the equivalent of auditory hallucinations telling ancient man how to respond to danger, stress, or novelty.

Jaynes calls this early internal dialogue processing system the bicameral mind.

The brains of lower primates appear to be more functionally equivalent than the human brain, probably due to absence of language development (Milner, 1971; Steklis & Harnad, 1975; Warren & Nonneman 1976). This difference alone did not satisfy Young (I962) who speculated about an original nervous system which operated by means of a map-like analog system. As humans evolved they became less dependent upon mapping, but the question of why two brains has not been completely answered. Young further offers the visual system as a possible precursor to cerebral laterality. Since visual inversion by the lens requires correction, the optic chiasm gained a prime function. It is suggested that this mechanism in turn determined all the other crossings in the brain. Whatever the process, two functionally asymmetrical hemispheres of the human brain evolved.

Functional differences' appeared in the literature in 1836 when Dax reported thirty years of observations relating speech problems to hemiplegia of the right side of the body (Neilsen, 1938). In 1865 Broca formally published this relationship stating that in right handed people, language is a function of the left hemisphere. Ten years later Jackson confirmed Broca`s findings, but disagreed that this relationship was contra laterally true for left handed individuals. Jackson called the lent the leading hemisphere and added the possibility that the right might be involved in visual ideation due to observed imperception in patients with right brain damage. In 1880 Jackson reported aphasia in a left-handed person with right brain damage. Wernicke (1874) contributed information suggesting that aphasia also occurs with auditory comprehension deficits. Additional historical presentations are available from several sources (Benton, 1976; Goodglass & Quadfasel 1954; Milner, 1971; and Zangwill, 1960).

At the turn of the century ideas suggesting hemispheric specialization were quite novel, for little had been done since the ventricle theory which appeared during the first century A.D. until Gall's 1812 phrenology publications (Blakemore, 1977) . Yet no real impact was made until after World War II when large numbers of head wounds and their resultant problems were studied. Of particular interest were the left-handed patients. Ten years of study provided shaky confirmation that left-handedness and dominance for speech are frequently disassociated. Bramwell (1899) wrote about several cases of crossed aphasia in which left-handed persons with left brain lesions developed aphasia, but this phenomenon was still considered an exception to the contra lateral rule. By mid-twentieth century no doubt remained that cerebral dominance for left-handers varies unpredictably (Hecaen & Piercy, 1950) and that in the vast majority of right-handed individuals the left hemisphere is dominant for speech.

A great deal of attention has been given to attempts to explain functional differences by dissimilar structural characteristics of the hemispheres. Length, width, height, depth, volume, specific gravity, skull dimension, gray versus white matter, and sizes of all the various parts of the brain have been measured extensively (Geschwind, 1972; Hoadley & Pearson, 1929; and von Bonin, 1962) Nothing conclusive has been found. Geschwind and Levitsky (1968) recently reported small differences in the temporale planum, a part of Wernicke's area, with 65% of the brains studied measuring larger on the left side. Brain samples have been homogenized and deproteinized in amino acid analyses of speech areas to no avail (Hansen, Perrv, & Wada, 1972). Using ophthalmodynamometry the systolic blood pressure was found to be lower in the left carotid artery in right handed people suggesting a more favorable metabolic condition for acquisition of speech in the left hemisphere (Carmon & Gombos, 1970). To date no morphological differences have been found large enough to account for the functional differences.

Other structures of the brain have been studied for correlation to dominance and laterality. For example, the occipital horns of the lateral ventricles are asymmetrical in about 70% of neurological patients with the left horn longer five times more often in right handed patients (McRae, Branch, & Milner, 1968). Since the horns can be visualized via cerebral pneumography, the probability of relatively noninvasive determination of dominance for speech increases. However, the technique has not been confirmed by the more valid method of sodium amytal in intracarodid artery injection developed by Wada in 1949 (Wada & Rasmussen, 1960). The latter technique involves the chemical immobilization of one or the other hemisphere. Dominance for speech is determined when the patient is unable to speak. Effects are short-lived, relatively safe, but reserved for medical crises (Terzian, 1960). The difficulties inherent in establishing valid relationships between structures such as the occipital horns and brain functions are obvious. Another structure which has received considerable attention, without conclusive results regarding function, is the corpus callosum, which corrects the two hemispheres.

Until the late 1800's, the corpus callosum was considered a connective, supportive structure of little import. Today it is known to be a sophisticated communication system by which each half of the brain finds out about the other's activities. Coding for transfer of such information and the extent of connections are not fully known. (Akelaitus, 1941; Gumming, 1970; Ebner-& Myers, 1962; Ettlinger, 1962; Geschwind, 1965; Hewitt, 1962; Myers, 1962; Proctor, 1965; Sperry, 1962; and Trevarthen, 1965) . A few cases of congenital agenesis of the corpus callosum have been reported with impairment varying from very mild to severe with most cases undiagnosed until after puberty (Ettinger, Blakemore, Milner, & Wilson, 1972; Jeeves & Rajalakshmi, 1964; McQ. Reynolds & Jeeves, 1970) . Conclusions suggest alternative pathways connecting the hemispheres which compensate to some degree for the absent callosum.

Among mammals, the development of the corpus callosum is proportional to the development of the neo-cortex (Myers, 1965). Humans, therefore, exhibit the highest degree of callosal complexity. Improper development is difficult to detect, but some researchers suggest abnormalities in structure or function when behavioral assessment shows results not otherwise explainable. For example, an interesting observation has been noted by Blau (Note 1). Children who exhibit torque, drawing clockwise circles, are often socially deficient, have academic difficulties, and are more vulnerable to schizophrenia at maturity. The suggested explanation lies in a neural integrative defect of the corpus callosum with subsequent mixed cerebral dominance accompanied by interference with development of cognitive, language, and social skills. The implication is that mixed dominance due to improper communication between the hemispheres can result from unclear division of duties with potential pathological manifestations. What Goodglass anal Quadfasel (1954) refer to as cerebral ambilaterality describes a similar type of mental organization in which neither hemisphere functions optimally due to continuous interference from the other. Both seem to be trying to do the same job at the same time. No structural or psychological abnormality is suggested, but such individuals are described as particularly vulnerable to stress due to an inborn temperamental instability. With favorable circumstances, development is usually normal. If stressed, complications can lead to educational and even psychiatric casualties (Zangwill, 1900). Both torque and cerebral ambilaterality occur more frequently in left handed people.

The search to explain the relationship between handedness and hemispheric dominance has paralleled the cerebral laterality literature (Hecaen & deAjuriaguerra, 1964). With rare exception dextrals are left dominant for speech as are more than half the sinstrals, with ambidextrous persons equally divided (Annett, 1974; Bakan, Dibb, &. Reed, 1973; Barnsley & Rabinovitch, 1970; Bo, 1972; Chesser, 1936; and Milner, Branch, & Rasmussen, 1966). Specialization is not limited to the hands, but extends to the feet, the eye, and possibly the mandible (Seth, 1975) .

The vast bulk of research has attempted to find body-brain relationships by the study of dysfunction. Clinical and experimental neuropsychologists test to find lateralization and localization of brain lesions, noting details of observed behavioral and cognitive impairment (Lezak, 1976; Luria & Majovski, 1977; Reitan, 1959; Satz, 1973; Satz, Fennell, & Jones, 1969; and Heilman, Note 2). Crossed aphasia occurs occasionally and is usually presented as a case study (Weschler, 1976). In this condition, right handed individuals develop aphasia following injury to the right hemisphere, and left handed people are severely impaired after insult to the left side of the brain. The type of aphasia is closely related to the degree of dominance for speech which exists at the time of brain damage. Apparently, the less complete the cerebral lateralization, the better the prognosis for partial or full recovery from aphasia. Left handed aphasics and crossed aphasic dextrals usually regain speech function following left brain damage (Brown, 1976)

Since the work of Broca, most research effort has been exerted in studying speech related functions of the left hemisphere, while the role of the right brain until recently was virtually ignored

(Henschen, 1926; Piercy & Smyth, 1962; and Rubino, 1970). Sensory and motor maps are clearly localized, but occupy only about one fourth of the cortex with different capacities represented is the right and left hemispheres (Lucia, 1976). Although each sensory motor system controls primarily the contralateral body functions, some ipsilateral control is also evidenced. The left-brain operates focally; the right seems to be more diffuse. This led Semmes (1965) to propose a differential integration and specialization for the two hemispheres. Namely, the left, because of the focal capabilities, is better at directing fine sensorimotor tasks as needed in manual skills or speech and favors the processing of similar units of information input. The right, then, specializes in multimodal coordination, such as spatial tasks, with capabilities to process dissimilar units. This proposition is like recent suggestions by Wada and Davis (1977) that the hemispheres differ in a broader sense than verbal-spatial. The left handles data for which there already exists relevant reference material for comparison, while the right deals with input for which there is no previous reference. Thus, optimally efficient functioning in the intact human brain is dependent on cooperative transcallosal exchange of information.

Zangwill (1961) also reveals several differences in the hemispheres which are unrelated to speech. Neglect, constructional apraxia and poor pictorial representation are found more frequently in right hemisphere damage (Hecaen, Penfield, Bertrand, & Malmo, 1956)

Considering known aspects of functional asymmetry, two modes of thought are hypothesized: propositional and appositional. Propositional processing refers to an analytic, logical, step by step mode of thought, while appositional modes are comparative, intuitive, and holistic. Good propositional skills, or a well developed left hemisphere, would be manifested in high literary and mathematical abilities. Likewise, proper appositional development might be observed in artistic, creative endeavors involving affective expression. Sperry (1968a) goes so far as to suggest that if either of these activities is not exercised, the neurons may regress, leaving profound functional deficiencies. Thus, a balance is necessary. There appears to exist a subtle antagonism between proposition and apposition with the former being more reinforced in western cultures. If the development of both is to be enhanced, methods must be devised whereby each can be functionally explored in the normal brain.

Genetic and developmental influences. Another of laterality's unanswered questions is whether sidedness is transmitted genetically. Porac and Coren (1976) say no familial influence can be determined for eye, ear, and foot preference. However, children tend to have the same handedness as the mother. Speculation as to why this should be so ranges from intrauterine asymmetric development of the ova to behavioral training by the mother. Suter, Krone, and Mathews (Note 3) eliminate any subject from laterality research who has a history of left handedness among parents or siblings, suggesting definite hereditary ties and differential performance in weak right handers as well as left handed individuals. Other researchers propose a genetic model of inheritance for handedness and hemispheric dominance determined by two alleles (Annett; 1964; and Levy & Nagylaki, 1972). Homozygotic combination of the alleles would result in more rigid lateralization while heterozygotes would be more plastic. Satz, Fennell and Jones (1969) support this theory, stating that the later combination is an unstable genotype with incomplete lateralization leading to possible disturbances in motor and language development. Anett (1974) reported that handedness in children of two left handed parents appeared to be determined by accidental variation. That is, approximately the same number of left and right handed children were observed, showing the absence of bias toward dextrality found in the general population.

To support the hypothesis that cerebral asymmetries are predisposed and usually, but not necessarily, related to language, infants have been studied (Cernacek & Podivinsky, 1971). Wada and Davis (1977) presented clicks and flashes to infants assuming the former to be a structured auditory stimulus as contrasted with an unstructured visual stimulus. The hypothetical relationship between clicks and flashes and left and right hemisphere function respectively was supported. Preverbal lateralization for speech, implying genetic programming, was also found in infants showing greater auditory evoked responses to speech from the left temporal region than from the right. Nonspeech stimuli elicited greater responses in electroencephalogram amplitude from the right (Molfese, Freeman, Jr., & Palermo, 1975; Molfese, Nunez, Seibert, & Ramanaieh,. 1976) . Such asymmetries decrease with age, suggesting more communication between the hemispheres by increased myelination. Morse (1972) found that infants as young as forty days old could discriminate acoustic cues for intonation and place. Differences in the non-nutritive conjugate sucking responses to non-speech stimuli led Morse to conclude that infants respond in a linguistically relevant manner. These findings are in accord with evidence of speech perception in infants found by Eimas, Sigueland, Jusczyk, and Vigorito (1971) . Left and right peripheral sensitivity also appears to differ in infants as measured by heart rate changes to facial stimulation. Right face touching accelerated the heart more than touch to the left face (Hammer & Turkewitz, 1974)

As might be expected, the search for a structural explanation of functional differences accompanied the infant findings. From the twenty-ninth week of gestation to adulthood the planum temporale measures increasingly larger on the left (Geschwind & Levitsky, 1963; Wada, Clarke, & Hamm, 1975; and Witelson & Pallid, 1373) . The general conclusion to be drawn is a biological predisposition to left dominance for speech with increasing lateralization. However, the argument for equipotentiality for language development in the hemispheres continues despite indications for predisposition. Lenneberg (1966) suggests a broad but critical period for language lateralization between. the ages of two and twelve, after which speech gradually and irreversibly lateralizes left. Prior to age two, either hemisphere can take over language functions. The process, as well as the structural differences are apparently unique to humans. No such asymmetries have been observed in brains of anthropoid apes, rhesus monkeys, or baboons despite display of paw preferences (Corballis & Beale, 1976; and Warren & Nonneman, 1976).

Human developmental studies show decreasing left-right hand confusion by age seven and stable hand preference is demonstrated by age nine. Lags in these areas have been related to personality and emotional disorders which are explained vaguely as a disturbance of neurological organization (Belmont & Birch, 1963). Exactly why lags in left right differentiation occur is not clear. It. has been shown that normal children between the ages of four and eleven have visuospatial abilities some years before they can verbalize similar tasks (Williams & Jambor, 1964) . Likewise, the right brain perceives nonverbal auditory information better than the left brain perceives verbal information during these years (Bakker, 1967, 1963; and Knox & Kimura, 1970) .

In addition to maturational factors, laterality research is further complicated by sex differences. Hobson (1947) reported that males and females differ in primary mental abilities. More recent literature does not support overall intellectual differences as measured by intelligence quotient test but rather hemispheric specialty differences are noted. Specifically, males perform better on non-verbal tasks and females score higher in verbal performance.

(Macoby & Jacklin, 1972). During early childhood, differences are not as marked as during pubescence. Paradoxically, by age forty the differences decrease (Helmchen, Kanowski, & Kunekl, 1967) . In a sample ranging upward to age sixty, Sutar, et al, (Note 3) found males superior in regulation of left hemisphere alpha waves and females better able to control right-side alpha activity.

In summary, it appears that genetic influences are apparent at an early age, but environmental factors became more powerful later in life. Sinistrality has formulated covert social attitudes exhibited in such ways as forced use of the right hand in naturally left-handed children. Such cultural interference has been correlated with disturbances of emotion and speech, particularly stuttering (Blakemore, 1977). Most everyday appliances, utensils, and sports equipment are designed for the dextral. Only recently have left-handed desks, for example, been standard orders for classrooms. A similar undefined attitude shrouds the right hemisphere. Formal education, especially higher education, in almost every culture emphasizes factual knowledge appropriate for the left hemisphere with extracurricular or incidental teaching to the right. Thus, society is reinforcing to this cycle by holding left hemisphere graduates in high esteem. An effort to change this trend has begun (Ornstein, 1972). Caution, however, is imperative with the need for empirical research at the forefront (Harnad, 1972).

Split brain studies. In 1937 t he first report of partial severance of one hemisphere from the other by cutting the corpus callosum was reported (Trescher & Ford, 1937). The rationale for such drastic measures was intractable epilepsy in which convulsions spread from one hemisphere to the other via the corpus callosum in severe enough proportions to endanger life. Surgery proved therapeutic in that seizures were confined to one side of the body and were reduced in frequency and intensity (Bogen & Vogel, 1963).

A somewhat philosophic debate regarding unity of consciousness has been prevalent in psychology for over a century. Fechner, in 1860, argued that if consciousness were a property of the brain, then splitting the brain would split the consciousness. The counterpoint made by McDougall in 1911, stated that the mind could not be split. Surgical severance of the corpus callosum renewed the question and provided unique research opportunities to test both views: If giving a verbal account of experience defines consciousness, then only the left hemisphere is conscious; but if responding in a highly organized manner and use of the results of past experience is also considered consciousness, then split brain patients have multiple consciousnesses (Geschwind, 1965a; Rosadini & Rossi, 1967; Serafetinides Hoare, & Driver, 1965). Trevarthen (1965) reasoned that since no ability is actually lost due to corpus callosum section because each hemisphere still maintains immediate control over the contralateral side of the body, and since ipsilateral control. is too inefficient to be feasible, somehow communication still occurs, perhaps via sub-cortical structures. He further speculates that since each hemisphere could acquire separate, even conflicting memories simultaneously, maybe lower centers eliminate conflicting commands before they release a response. Sperry (1968a, 1973) boldly states that commissurotomized patients have two separate brains with two streams of consciousness. He reviews visual, tactual, and auditory tests in support of his position and attributes unifying, factors to sharing one body and having common experiences via motor control.

Preliminary split brain research was conducted on animals. With few exceptions this discussion will be limited to humans. One, classic cat study should be mentioned, however, because of the impact on the scientific community. Myers and Sperry, (1953) sectioned the optic chiasm, the anterior commissure and the corpus callosum of a cat. With a patch over one eye at a time, the recovered cat was unable to perform tasks learned by one hemisphere when the untrained side was in control. No gross behavioral changes were observed and each brain showed comparable, but separate learning curves.

Prior to Myers and Sperry's work. human' studies had been done, but of the twenty-six split-brain patients reported by Akelaitis (1941, 1944), only one had both the corpus callosum and the anterior commissure severed. Briefly, Akelaitis reported bilaterally similar abilities in visual perception, recognition of colors, relative orientation, and size of objects. Apparently, communication still occurred between the hemispheres. By the mid 60's commissurotomy

Case studies were prevalent in the literature. Left and right somatosansory information was markedly separate (Gazzaniga, Bogen, & Sperry, 1965), and the disconnexion syndrome was established in support of, or disagreement with most known neuropsychological abnormalities (Geschwind, 1965b). Two years post operation, testing revealed normal ordinary behavior, overall intelligence unchanged, and slightly increased ipsilateral motor control (Bogen, Fisher, & Vogel, 1965). The left hand did consistently well on spatial tasks such as block design, but the right hand could hardly do the simplest ones (Bogen & Gazzaniga, 1965) . A twenty-seven year follow-up stir revealed defects in transfer of information suggesting no major functional reorganization had taken place (Goldstein & Jogut, 1969). The major difference between human and animal total hemisphere disconnection was that somehow the human brain continued to share information.

A possible explanation for the apparent communication was discovered in the form of cross cuing (Gazzaniga, 1967). For example, if the right brain saw a red light on a red-green discrimination task and heard the left brain say "green", it knew the answer was wrong which resulted in a frown or head shake. This response cued the left to correct itself, which it did if given another chance. More cross cuing is suggested by a blush and giggle response to a nude photograph presented to the right hemisphere, yet the subject cannot say why. Similar tactics are reported in cases of congenital agenesis of the corpus callosum. These patients, however, display less overall impairment, indicating more cross cuing, than patients with surgically severed hemispheres (Saul & Sperry, 1963) .

As knowledge increased prediction of the general disconnexion syndrome, researchers began to look for more detailed differences in split brain people. Olfactory recognition was confined to the ipsilateral hemisphere (Gordon & Sperry, 1969), temperature stimuli presented to the left body was reported accurately by the left brain, but whether the right brain also had access to right body temperatures could not be determined (Levy & Sperry, 1970) . The right brain has some language capability in that it can identify nouns but not verbs, negatives but not plurals, nor could it differentiate between active and passive voice (Gazzaniga, 1971) . Neither could the right hemisphere speak nor do higher math than add single digits (Gazzaniga, 1970; Gazzaniga & Hillyard, 1971). When one fourth of the corpus callosum was left intact, the disconnexion syndrome did not occur (Gordon, Bogen, & Sperry, 1971). Some evidence exists that the independence of separated hemispheres is not fully complete. When the left brain was solving a problem, finger tapping with the left hand was disrupted. Similar interference and competition for attention has also been exhibited when simultaneous tasks are required of split brain patients, and the right brain's limited speech capabilities are further lessened by confabulation and preservation (Tong & Sperry, 1973).

In 1969 Bogen began a more intensive study of right hemisphere functions, calling it the other side of the brain. He concluded that the informational capacity of the right hemisphere is just as great as the left and it is working just as hard and intricately as the side which does the talking. Nebes (1973) found right brains superior to left brains in forming a whole concept from incomplete, fragmented information. The minor hemisphere also performs better at tactile pattern-recognition tasks (Milner & Taylor, 1972) and the perception of bilateral chimeric figures (Levy, Trevarthen, & Sperry, 1972) . Empirical demonstration of a link between meditation and the nondominant hemisphere associates the right brain with processes involved in altering consciousness (Pagano & Frumkin, 1977).

Clinical and educational applications utilizing suggested capacities of the right hemisphere are appearing in current literature. Successful results include weight control, improved self concept, more rapid foreign language acquisition and a teaching tool for art (Budzinski, Note 4; Edwards, Note 5; and Wickramsekera, Note 6). In cooperation with Bogen, a neurosurgeon who has performed many commisurotomies, Hoppe (1977) did psychoanalytic studies on twelve split brain patients. Impoverished dream material, poor gestalt perception, and deficits in creativity were strikingly similar to studies of many psychosomatic patients. Furthermore, both split brain patients and psychosomatic patients exhibit alexithymia, the marked inability to describe feelings. Hoppe suggests that psychosomatically ill patients have created a functional commisurotomy in which interhemispheric processing is disrupted. Specifically, emotional expression is decreased or blocked, then somaticized.

A few problems in unitary motor control have been related by split brain people when emotionality is a contributing factor (Gazzaniga, 1970). For example, one hand might try to pull pants down, but the other hand might pull upward. Another bizarre incident was reported in which a patient said that during an argument with his wife his left hand attacked her, and his right hand came to her rescue. These reports stand in contrast to the theoretical position that two brains are better than one, in that, when freed from the job of listening to the other and keeping up to date, each hemisphere could work in parallel at full capacity.

Besides superior spatial task performances and relationship to emotionality, other possible functions are suggested for the intact minor hemisphere. Gazzaniga (I970) suggests one of the most important functions might be to allow more time for processing incoming information. Split brain people use fewer "buts" and "howevers", suggesting that a connected right hemisphere might act as a qualifier, listening to the left and deciding what to qualify or modify. On the other hand, it could be just more processing and storage space. Further research is needed for intact functional definition, especially for the right hemisphere.

<u>Intact hemisphere studies</u>. Three frequently used methods for intact hemisphere comparisons are dichotic listening, visual field, and reaction time studies. Dichotic listening refers to the

simultaneous presentation of different information to each ear. It has been established electrophysiologically that auditory information is processed in the ccntralateral hemisphere (Rosenzweiz, 1951). Haaland (1974), using EEG, confirmed these results by showing that the ipsilateral pathways from the right ear to the right brain are inhibited in dichotic listening verbal tasks. Since humans tend to exhibit selective perception, hearing only one thing at a time, whatever is attended to and recalled when two stimuli are presented would indicate the more efficient site for processing that particular kind of information (Broadbent, 1976). Kimura (1961) showed that the dominant temporal lobe is the site for processing spoken digits or other verbal material, and that dichotic listening techniques are effective only when a competing stimulus is presented to the other ear. Palmer (1964) confirmed this latter observation in an unsuccessful attempt to replicate Kimira's study using monaurally presented speech. However, Bakker (1969) did achieve significant monaural results when the stimuli were ordered rather than randomly presented, and found (Bakker, 1970) that retention in monaural stimulation is related to length of series of digits presented. Retention decreases as length increases but not in a linear manner. Perl (1970) added white noise as the contralateral competing stimulus and equated other dichotic listening results. Structured syntax also aids accuracy of recognition (Zurif & Sait, 1970).

Kimura (1964) found the left ear superior for detection of melodies, concluding that music is a right hemisphere function. This concurs with Milner (1962), who found decrements in perception of music after right temporal lobectomy. Shankweiler (1960) and Gordon (1970) also confirmed Kimura's results relating music to the right hemisphere. Dominance for voice recognition was determined by dichotic listening to be a left hemisphere function (Doehring & Bartholomeus, 1971) while emotional tone of voice was better recognized by the right (Carmon & Nachshon, 1973; Haggard & Parkinson, 1971; King & Kimura, 1972) . In 1963 Bryden performed a dichotic listening test, after which subjects could more accurately choose with the right hand the stimulus which had been presented to the right ear.

With repeated confirmation of the technique of dichotic listening, Kimura (1967) suggested the method as a valid means for broader study of hemispheric specialization. Many supportive dichotic listening studies ensued which varied the types of stimuli, related findings to handedness, and explored problems associated with laterality (Curry, 1967, 1968; Dobie & Simmons, 1971; Knox & Boone, 1970; Murphy & Venables, 1971; Netley, 1972; Satz, Achenbach, Pattishall, & Fennell, 1967; Satz, 1963; Schulhoff & Goodglass, 1969; Screen, Spellacy, & Reid, 1970; and Zurif & Bryden, 1969).

Learning disabilities have been related to laterality problems such as left-right hand confusion and mixed hand eye preference (Chap & Mirsky, 1978). Confirmation of hemispheric involvement was produced using dichotic listening techniques. For example, dyslexics often perform backward on dichotic listening tasks, i.e., they more accurately report verbal material delivered to the left ear than to the right ear (Zurif & Carson, 1970) . With other explanations ruled out, a strong possibility is suggested for a developmental lag in cerebral lateralization (Whitelson, 1977). Differential diagnostic indicators are needed along with research to develop educational plats for compensation based remediation.

Kimura has continued to search for simpler means of determining dominance. In1973 she reported increased activity of the hand opposite the hemisphere controlling speech as the subject talked. Other behavioral indications of hemispheric activity include direction of head or eye turning, classroom seating, and writing postures (Gur, Gur, & Marshalek, 1975; Kinsbourne, 1972; Levy & Reid, 1976; and Sackheim, Packer, & Gur, 1977). Confirmation of such observations would enhance' research in naturalistic settings.

Visual field procedures are less reliable indicators of asymmetry than dichotic listening (Hines & Satz, 1974). The method involve presenting stimuli with a tachistoscope to the left or right of a central visual fixation point. Generally, letters of the alphabet and words are identified better when presented in the right visual field and non-alphabet material recognition is more accurate from the left field (Fontenot & Benton, 1972; Goodglass & Barton, 1963; Hines & Satz, 1971; Hines, Satz,& Clementino, 1973; Kershner & Jeng, 1972;. Kimura, 1961, 1966, 1969; McKeever & Hulling, 1971a, I971b; Olson, 1973) . Buchsbaum and Fedio, (1970) confirmed dissimilar occipital cortical activity in the EEG to visual verbal and nonsense stimuli.

Agreement that verbal information is more efficiently processed when presented to the right visual field, and thus the left hemisphere, is consistent across the visual field literature. However, many studies fail to confirm the left visual field, right hemisphere, superiority for nonverbal stimuli (Bryden, 1960, 1973; Buffrey, 1967). Several possible explanations are offered for this failure. Perhaps tachistoscopic procedures fail to tap the relevant site in the right hemisphere. Since visual perception takes place in the occipital and posterior parietal regions, which are less related to speech lateralization than the temporal lobes, asymmetries are not. as marked as in dichotic listening tasks (Bryden, 1965; Zurif & Bryden, 1969).

As early as 1957, superiority of the right visual field for verbal information was demonstrated with the suggested explanation of directional scanning of eye movements when reading English (Heron, 1957). White (1969) lent support to this position by presenting rows of digits and letters across the whole visual field and finding better recall for those in the left field. When the stimulus is a single letter, however, scanning is not as important as differential hemispheric dominance for verbal and spatial information (Bryden, 1960) . Both scanning and a general dominance of the master hemisphere for all verbal material was rejected by Goodglass and Barton (1963) when the left visual field was found superior for vertically printed words. Caution is recommended in visual verbal tasks, since matching words, rather than simple recognition, elicits higher scores for words presented to the left visual than to the right field. When procedures are varied in this manner, words might not be exclusive for left hemisphere processing since some spatial strategy is probably used (Gibson, Dimond, Gazzaniga, 1972).

Further attempts to delineate functional differences between the hemispheres have used reaction time as the variable of interest. The assumption underlying such studies is that if one hemisphere is specialized for a certain kind of information processing, and if such information is presented to the other hemisphere, then response will be delayed as the data is transferred via the corpus callosum to the appropriate hemisphere. Studies using verbal and spatial information have confirmed this assumption. Faces of pictures presented in the left visual field were recognized faster than when they were presented in the-right field. The converse was true for words (Klatsky & Atkinson, 1971; Rizzolatti, Ultima, & Berlucci, 1971).

Efron (1963) suggests that sensory stimuli from both sides of the body are processed in the left hemisphere if the subject is required to report time of occurrence of the stimuli. Davis and Schmit (1971) found no differences between the hemispheres when two stimuli were presented to the same hemisphere requiring a same or different discrimination response. However, it took longer to make the judgment when the stimuli were presented to the same side than when they were separately presented to each hemisphere. McKeever, Gill, and VanDeventer (1975) failed to show left or right visual field differences in reaction time to dot detection, a spatial task, but did confirm right field superiority for letters. Another assumed spatial variable, line orientation, was more accurately judged by the right hemisphere when the task was difficult. Easy discriminations were performed better by the left hemisphere (U1tima, Rizzolati, Marzi, Zamboni, Franzini, Camarda, & Berlucchi, 1974) .

The use of different processing strategies is suggested by Seamon & Gazzaniga (1973) . Two instructional sets were used to measure verbal versus visual coding. Two word stimuli were presented with instructions to subvocally rehearse the words or to visualize a scene which included a picture of the words. The latter, called relational strategy, elicited faster reaction times when presented again to the left visual field, while verbal rehearsal was more efficient for the right field presentations. Differential performance when strategy is manipulated suggests confirmation of what Averback (1963) called sequential and parallel processing as descriptive of left and right hemisphere function respectively. Averback also tested the number of independent inputs which could be processed simultaneously. When the numbers were fewer than six, accuracy was high and reaction time fast indicating parallel processing; with greater than six, serial processing was suggested by slower response. Clinical application of hemispheric differences and the reaction time procedure was attempted by Clooney & Murray (1977).

Hypothesizing that schizophrenics might have dysfunctional left hemispheres, they expected better performance by the right. However, the results led to rejection of the hypothesis because no differences were found. These findings are in conflict with results obtained from schizophrenic populations by Gruzelier and Hammond (1976) who reported reduced verbal IQ relative to spatial performance indicating weak nervous system dynamics in the dominant hemisphere.

To summarize briefly, methods used to study hemispheric differences in the intact, non-damaged human brain include dichotic listening, visual field, and reaction time. Greatest asymmetries were observed in dichotic listening studies with low correlation to visual field differences, although the classic left-verbal, right-spatial hypothesis is generally supported by both, as well as by the majority of reaction time studies. As in the split brain research, different modes of processing are suggested for left and right hemispheres. One of the primary weaknesses of the non-surgica1 procedures is the lack of determination of dominance for speech. Most, but not all, right handed people have left speech dominance and many left handers have right dominance (Branch, Milner, & Rasmussen, 1964; and Ettlinger, Jackson, & Zangwill, 1956) .

Subject selection based on handedness is understandable, however, since valid evaluation of dominance for speech is obtainable only via the invasive technique of intracarotid artery injection of sodium amytal (Pierria, Rosadini, & Rossi, 1961; Pratt, Warrington, & Halliday, 1961; and Warrington & Pratt, 1973). A second criticism concerns wide procedural differences among the comparable studies which could account for the divergent and sometimes conflicting results (Harnad & Steklis, 1976) .

Psychophsiological laterality studies. When psychophysiological data, particularly EEG, is measured or manipulated in laterality research, confirmation of the above results for verbal and spatial tasks is usually obtained. In general, high frequency, low voltage electrocortical activity is measured over the left hemisphere when language materials are processed (Cohn, 1971; Matsumiya, Tagliasco, Lombrosco, & Goodglass, 1972; Morrell & Salamy, 1971; and Wood, Goff, & Dap, 1971). Differences have been reported between the EEG from each hemisphere while verbal and non-verbal tasks are being performed (Buchsbaum & Fedio, 1969; Davis & Wada, 1974; Fedio & Buchsbaum, 1971; Galin & Ornstein, 1972; Klove, 1959; Lifshitz, 1960; and Morgan, McDonald, & McDonald, 1971). Interpretations of the differences, however, are varied since the tasks selected as representative of verbal and spatial measures have questionable inter relationships. In addition, transducer placement varies from study to study and the exact nature of brainwave activity during hemisphere specialized tasks has not been clearly defined. Surer, Griffin, Smallhouse, and Whitlock (Note 7) report that some individuals can identify lateral shifts in temporal alpha suggesting conscious correlates of left and right differential activation.

Awareness of differential variation in activity of the two hemispheres implies usable knowledge available to the individual. . According to information theory, knowledge about a variable increases the probability of control of that variable. Individuals, therefore, should be able to modify left or right hemisphere activity voluntarily. Kamiya (1963, 1969) has shown that self-control of brain waves is possible with training. Indications are positive for the ability to lateralize control. Peper (1972) found that subjects could learn to maximize the condition under which asymmetrical activity occurs. Such control of left and right output was further demonstrated as subjects received feedback in the form of a moving line on a screen (Pay, Freudian, & Harman, 1977). Movement was controlled via computer by differential integrated output from the hemispheres. Successful subjects reported a reasonable facsimile to verbal and spatial mental activity to accomplish this feat but, paradoxically effectiveness of the strategies decreased rapidly. Conclusions suggest that control is possible, but difficult to maintain, and that wide individual differences are evident.

Patterson (Note 8) attempted to account for variance in EEG biofeedback trainability by grouping subjects according to cognitive style. Based on extreme scores on cognitive preference questionnaires, subjects were classified as spatial-intuitive or verbal-analytic. Training in the preferred hemisphere resulted in more rapid and more stable learning. Implications for more efficient clinical and educational application of biofeedback techniques were strongly suggested. For example, severe performance IQ depression, relative to verbal IQ, is indicative of right hemisphere dysfunction. Murphy, Darwin, and Murphy (Note 9) found correspondingly marked high frequency EEG baseline readings on

the right relative to the left in one learning disabled student who displayed this discrepancy. Training to reduce frequency on the right resulted in increased performance IQ scores and overall academic improvement. Similarly, training via left hemisphere feedback for left dysfunction resulted in significant improvement in arithmetic achievement (Cunningham & Murphy, Note 10). Thus, treatment affecting a whole hemisphere allowed improvement in tasks mediated by that hemisphere. One possible interpretation is that the manner by which a task is processed is more important for hemispheric function research than the task itself.

Intuitively, EEG asymmetries would seen to be the best measure of hemispheric asymmetries. While electrocortical activity is invaluable information, other viewpoints suggest that peripheral autonomic variables reflect activity in the cortex not reached by EEG (Galin, 1974; and. Galin & Ornstein, 1972) . Differential psychophysiological response patterns have been studied extensively in attempts to explain neurologically the body's reaction to emotion and stress (Ax, 1953; Funkenstein, 1955; Lacey, 1950; Schacter & Singer, 1962; and.Wenger,1941, 1948, 1957,3966). Central neural involvement is evidenced when electrical stimulation of the brain elicits responses described by individuals as similar to feelings (Penfield & Rasmussen, 1950).

Both laterality differences in the autonomic response and laterality of feedback have been considered in psychophysiological research. Response differences have generally shown slightly more reactivity on the dominant side of the body (Fisher, 1958) and learning appears to be enhanced when feedback is given from the dominant side (Surwit, Note 11 ; Keen & Montgomery, Note 12). A relationship has been noted between peripheral responses and scales which measure hemisphericity, or a tendency to rely on one hemisphere more than the other. Electromyogram (EMG) levels were lowered significantly more by spatial-intuitive groups than by verbal-analytic groups in Patterson's study (Note 8) . Furthermore, asymmetrical electrodermal activity has been recorded during verbal and spatial tasks (Myslobodsky & Rattok, 1975), although these. results have been disputed (Ketterer & Smith, 1977). The classical study by Miller and DiCara (1968) showing that differential vasomotor responses can be instrumentally conditioned in the left and right ears of rats paved the way for current autonomic laterality research. Similar results were obtained by training temperature differences in the earlobes of humans (Steptoe, Mathews, & Johnston, 1974). Bilateral differences have been shown repeatedly in skin resistance and cardiovascular activity (Gruzelier & Hammond, 1976; and Varni, Doerr, & Franklin, 1971) with patterns of EEG monitored for cortical correlations (Davidson & Schwartz, 1976).

In reference to laterality of feedback, placement on left or right side has been shown to affect learning in auto regulation of peripheral autonomic variables. Bilateral EMG feedback resulted in ability to control the left and right masseter muscles independently (Rugh, Note 13). Surwit (Note 11) found that feedback from the dominant hand produced greater effects than feedback from the nondominant hand in thermal training. These results were supported by Keen and Montgomery (Note 12) who reported significant increases in pulse amplitude with transducer placement on the dominant hand as compared with placement on the nondominant hand in right handed subjects. Of particular interest was the unexpected finding that right ear feedback produced greater ability to increase heart rate than left ear feedback (Greenstadt, Schuman, & Shapiro, 1978).

Cortical involvement in peripheral functions, other than contralateral sensory motor connections, are obviously present but are not yet clearly understood. Traditionally, autonomic control centers are shown to be located in subcortical and spinal areas (Hess, 1954). Cortical involvement is inferred by techniques such as the clinical use of mental imagery as an aid in achieving relaxation or by the knowledge that a distressful thought can result in measurable peripheral changes indicative of arousal. Luthe (1976) states that high tension levels accompany left hemisphere functioning.

Monitoring skin temperature over the external carotid arteries has shown relative warming on the left during verbal tasks and on the right during spatial tasks (Suter, Beatty, & Strickler, Note 14). The increase in temperature indicates increase in flow of blood, suggesting differential lateral cardiovascular changes as different cognitive processes occur in the corresponding hemispheres. Since vasodilation is autonomically controlled, these results establish a stronger link between hemisphere specific tasks anal the autonomic system. Biofeedback research in general is based on the premise that voluntary control over functions previously thought to be involuntarily regulated is possible. Human volition originates in the cortex, but whether the hemispheres share autonomic autoregulation or whether specialization for particular control has evolved remains an outstanding question.

In conclusion, hemispheric laterality research over the past century supports definite functional differences between the hemispheres which are not explainable by known structural dissimilarities. The evidence is sound for left and right hemisphere specialization in processing of verbal and spatial information respectively. Broader specialties are suggested, but few are yet substantially supported. For example, creativity and tranquility are associated with the right hemisphere while executive intention and stress are related to the left (Bogen & Bogen, 1969; Doyle, Ornstein, & Galin, 1974; Luthe, 1976; Marshall, 1973; Oldfield, 1969; Edwards, Note 5).

One of the difficulties inherent in the study or hemispheric function comes from a lack of knowledge about the corpus callosum, the connecting and communicating structure between the halves of the brain. Whether all information is shared all the time, how the information is coded for transfer; and whether interhemispheric processes facilitate or interfere with efficient cognitive function are some of the unanswered questions regarding the corpus callosum.

Drawn from the interference hypothesis, which suggests mutual inhibition during activation of either hemisphere, Kinsbourne (1970) theorizes an attentional model for hemispheric asymmetries of function.

Differences arise when activation of one hemisphere biases attention to the contralateral side. Empirical test of the model showed activation to be a function not only of the nature of the task, but also of subject expectancy. For example, if the subject expects verbal input, the left hemisphere activates in anticipation of the stimulus. If demands of the experimental situation constrain activation to one hemisphere, what happens in the other hemisphere?

Budzinski (Note 4) believes that if the activating stimulus is repeatedly presented, the processing hemisphere is "tied up" and, therefore, inhibited from interfering with activity in the opposite hemisphere. The hemisphere which is not being systematically activated loses interest in the repetitive task performance of its neighbor and is free to perform some concomitant task. For example, in Twilight Learning, random numbers are presented to the left hemisphere, while weight control suggestions are presented, and sometimes sung, to the right hemisphere. Wickramsakera (Note 6) follows a similar paradigm to improve self esteem. Luthe (1976) and Edwards (Note 5) use a somewhat different method based on the same general principle. They attempt to bypass left hemisphere interference by requiring a response too fast for logical, analytic processing to take place. Results have been positive for creativity mobilization, improved artistic work, and to a lesser degree in acquisition of foreign languages. The underlying suggestion is that each hemisphere functions more efficiently if interference from the other is decreased.

The following study attempted to minimize hemispheric interference through the use of a new methodology called Unilateral Repetitive Activation (URA). Repetitive spatial or verbal stimuli were presented to different groups of subjects over several sessions. Visual and auditory input channels were used in each condition in order to increase the probability of total hemispheric activation. Such activation, in turn, serves to inhibit interference with contralateral processing. This methodology differs from dichotic listening and visual field techniques in that no attempt is made to limit input to one hemisphere. Rather, it is assumed that with repeated presentation of very similar information known to be mediated by one hemisphere, the contralateral hemisphere will, at first, exhibit an orienting response, or a "what's that?" reaction, but with repeated presentations will habituate, in essence, an "oh, that again" reaction. Whereas, the activated hemisphere is obliged to continue to process the unavoidable information.

The primary purpose of the study was to assess the effects of repetitive activation of each hemisphere on selected autonomic variables and on post experiment verbal and spatial task performance. Immediate autonomic effects of URA were tested during activation and longer lasting effects were assessed after repeated exposure to the activating stimulus. During the first phase of the experiment, the ability of each hemisphere to decrease induced arousal in the autonomic nervous system was tested. If either hemisphere is specialized for autonomic control, it should be reflected in shorter recovery times while that hemisphere is free to perform the task. Because of suggestions in the literature that the left hemisphere more easily gains control of undesignated or shared functions, it was predicted that the group whose right hemispheres were activated, freeing the left, would recover more rapidly.

After treatment, effects of URA were tested by performance on verbal and spatial tasks. Expectations were that subjects whose right hemispheres have been repeatedly activated would score higher on spatial tasks and, conversely, subjects whose left hemispheres had been activated would perform better on verbal tasks. These expectations were based on a facilitation effect due to repeated use of the hemisphere.

Specifically, two hypotheses were tested: 1) Individuals whose right hemispheres are being activated by the processing of repetitive spatial information should demonstrate shorter recovery following induced arousal than individuals whose left hemispheres are being activated by repetitive verbal information; 2a) Individuals whose left hemispheres have been repeatedly activated should score higher on post treatment verbal tasks; and 2b) Individuals whose right hemispheres have been repeatedly activated should score higher on post-treatment spatial tasks.

CHAPTER 3

METHODOLOGY

Subjects. Forty-seven right handed female subjects between the ages of 20 and 40 who had no immediate family history of left-handedness or epilepsy were selected from a population of volunteers and randomly assigned to one of two conditions as follows:

Group 1: Right hemisphere activation (RHA), N=24

Group 2: Left hemisphere activation (LHA), N=23

All were screened by interview against major medical or emotional problems. Prior to participation each subject signed an informed consent form. Sex limitations were placed on subject selection because of conflicting reports regarding the degree of lateralization and, therefore, functional differences between males and females (Buffery, 1971c; Davidson & Schwartz, 1976; Ketterer & Smith, 1977; Liberson & Liberson, 1975; and Surwit,.Shapiro, & Feld, 1976). Age was limited because of possible decreases or shifts in lateralization above age 40 (Helmchen, Kanowski, & Kunkel, 1967).

Dependent Variables

In order to test the hypotheses, the dependent measures were selected for the following characteristics:

1. Bilateral skin conductance level (SCL) was selected because electrodermal activity is completely under the control of the sympathetic nervous system and has been.

used extensively in psycho physiological research as a nonspecific measure of arousal (Edelberg, 1972). In addition, asymmetrical electrodermal responses from the right and left hand have been reported during performance of verbal and spatial tasks. During verbal tasks larger responses were recorded from the right hand and during visual imagery larger responses were recorded from the left hand (Myslobodsky & Rattok, 1975) . These results were not supported however, by Ketterer and Smith (1977). Bilateral differences in skin resistance have also been attributed to differential vasomotor activity and to increased awareness of the dominant side of the body (Fisher, 1958; Varni, Doerr, & Franklin, 1971; and Varni, Doerr, & Varni, 1975). Based on pilot data the values for SCL phasic reaction to noise, light, movement, and touch disruption lie between 0.1 and 5 micromho/cm^2. Reaction time appears to be between 1.5 and 2.5 sec. with recovery in 1 to 5 min. The SCL recovery time score was determined by the average of three recovery from startle times. Recovery time was defined as the number of seconds from presentation of the stimulus until the last pre-stimulus SCL measure was recovered. If baseline was not recovered in 5 min., 300 was considered the maximum score indicating incomplete recovery. A SCL score was obtained. in three of the six sessions. Palmar surfaces of the second joints of the index fingers were used for placement.

2 Heart rate (HR) was selected because an increase occurs with the orienting response to a new stimulus and is considered an informative indicator of arousal (Germany & Klein, 1962; Gunn, Wolf, Block, & Person, 1972; Magoun, 1963; and Siminov, 1975). The heart is innervated by both sympathetic and parasympathetic branches of the autonomic nervous system. The right vagus affects heart rate while the left vagus affects strength of contraction with similar asymmetry for sympathetic control. HR recovery time score in seconds was determined by a counter which was activated by a Schmidt trigger when the HR increased one beat above the pre-startle measure and deactivated when the HR returned to the pre-startle level.

3 The Closure Flexibility Scale (Form A) is a measure of the ability to hold a configuration in mind despite distraction. Since the process involved is visuo-spatial, this score reflected right hemisphere sphere capabilities, specifically, the second closure factor in perception (Thugstone & Jeffrey, 1905) .

4 The Gestalt Perception Test was used to assess the ability to construct a whole figure from incomplete parts. This process is also a right hemisphere function (Nebes, 1973; Neilsen, 1938; Street, 1931).

5 Stroops Color Word Test measures the effects of perceptual interference. Randomized color words were printed in some color other than the color it names. The test has been used successfully in neuropsychological assessment (Nehemkis& Lewinsohn, 1972; Stroop, 1935; and Talland, 1965).

6. The Controlled Word Association Test reflects verbal fluency, a left hemisphere function (Lezak, 1976)

7. Anagram solution times were also used as a measure of left hemisphere efficiency (Jones & Barnes, Note 15) . Words were selected of equal difficulty and frequency of use.

8. An arithmetic problem solving task consisting of 15 problems was used as the final left hemisphere task.

9. Pencil balancing on the index finger is reportedly a difficult task to perform during right hemisphere activation. Right and left hand ability was tested on all subjects. The number of tries to successful balance was used as a measure of behavioral capability during right and left hemisphere activation to assess the degree of interference in fine sensorimotor control.

10. Finger tapping has been reported at lower rates during left hemisphere activation than during right processing (Kreuter, Kinsbourne, & Travar then, 1972) . The number of taps in one minute was used to assess interference in fine sensorimotor behavior of each hand under both conditions.

<u>Independent variables</u>. The independent variables were treatment and sessions in which recovery scores were calculated. Treatment consisted of right hemisphere activation for one group and left activation for another.

Apparatus. SCL was bilaterally monitored using two Conductron 330 instruments manufactured by Enting. The instruments digitally display SCL as an integrated average over the last 64 seconds. Heart rate was measured from the left radial pulse and displayed on a Cyborg Pulse Wave Velocity and Heart Rate Instrument. The digital read out represented a running average over the last five heart beats. A standard audio cassette tape plaver and stereo headphones were used to present auditory stimuli. Verbal material to be read was displayed from a slide projector onto a 38" x.48" screen. A finger oscillation counter was used to count the number of taps during the second behavioral task.

Right hemisphere activation was elicited by a Kinoscope (Wilson, Note 16). The Kinoscope is a rotatable cylinder with a stationary light in. the center. The cylinder is opaque, but it has a slanting slit cut across it, following a line which would be defined by a plane having passed diagonally through it. The cylinder is powered by an electric motor with a variable speed transformer which allows rotation. speeds from zero to approximately five per minute. The visual effect is a slow upward, downward movement of the light line with each rotation of the cylinder. This optical illusion resembles the sine wave of an oscilloscope. Differential responses to light stimulation suggest that this procedure is adequate for activation of the right hemisphere (Kamphuisen, 1969; Kamphuisen & van Leeuwen, 1968;.Lansing & Thomas, 1964; Montagu, 1967; Spehlmann, 1965; and Van den Tweel & Lunel, 1965). The entire apparatus was encased in blue tinted Plexiglas. The cylinder was 2' high with a 20" diameter and was positioned approximately 12' in front of the subject in a darkened room. Rotation speed was timed to complement light classical melodies.

Psychometric instruments (described above) included the Closure Flexibility Scale (CF) , Stroops Color Word Test (SCW) a Gestalt Completion Test (GC), Controlled Word Association Test (CWA), Arithmetic problem Solving Task (AR) , Anagrams (AN) , the Edinburgh Handedness Scale (EH) , Hemisphericity Scale (HS) , the Time Allocation Sample Key (TASK), and a State and Productivity Graph (SAP). The Edinburgh Scale is a measure of handedness and was used to rule out ambidexterousness; the HS is an experimental instrument; the TASK and SAP Graph were used to check for daily routine chances and mood swings in order to rule out confounding variables of ongoing life outside the laboratory.

<u>Procedure</u>. One week prior to the beginning of treatment each subject was given odd pages from CF; CWA using letters F, L, and T, the EH, HS, TASK, and SAP. Each subject came to the laboratory three times a week for two weeks for a total of six sessions. SCL and HR were monitored for the entire 45 minutes of each session with time samples recorded every minute for each variable. The first 15 minutes of each session was a stabilization period. During sessions two, four, and six, three disruptions were randomly presented to elicit a startle response, allowing at least five minutes for recovery from each of nine disruptions. Visual startle consisted of turning on an overhead light; auditory startle was elicited by hitting a metal file cabinet with a hammer; and touch startle consisted of two taps on the right forearm by the experimenter. Time for recovery to baseline was noted in seconds. Based on pilot data, surprise did not appear to be a necessary element to elicit the

response. Therefore, subjects were informed that interruptions would occur (See Appendix). In addition, two behavioral tasks were performed. Namely, each subject was asked to balance a pencil on the index finger of the right hand for one minute as activation continued after session three. The procedure was repeated using the left hand. After session five, one minute of finger tapping with first the right index finger, then the left index finger was performed, as activation continued.

Subjects in Group 1 received Kinoscope and music for activation of the right hemisphere. Group 2 received readings from Clinical Applications Of Biofeedback: A Procedural Manual (Gaarder & Montgomery, 1977) for activation of the left hemisphere. Habituation to repetitious stimulation of the autonomic nervous system is well documented (Garcia-Austt, Bocacz, & Vanzulli, 1964;.and Lacey, 1959). Arousal decreases with repeated exposures. However, habituation apparently did not occur in the activated hemisphere for two reasons. First, the nature of the activating stimulus was not completely monotonous and secondly, during, activation startle responses were elicited which functioned as a new stimulus to dishabituate (Garcia-Austt, et al., 1964).

Immediately following the sixth session the following tasks were administered: SCW, AR, CF, AN, GC, and CAA. Order of presentation was randomized.

Follow-up was conducted at two weeks during which SCL and HR were monitored following treatment procedures. At follow-up sessions, one startle response was elicited with recovery to baseline time noted.

CHAPTER 4

RESULTS

A multivariate analysis of variance (MANOVA) revealed no significant differences between the groups based on age or the following scores obtained prior to treatment: hemisphericity scale (HS), Edinburgh Handedness Scale (EH), Controlled Word Association Test (CWA), and Closure Flexibility Test (CF). Table 3.1 displays the means from this analysis.

TABLE 3.1

Mean Age and Pre-Test Scores

Group[a]		Variables[b]				
		Age	HS	EH	CWA	CF
RHA	Mean	28.3	59.5	96.9	17.0	47.7
	SD	5.5	11.3	5.7	3.9	6.4
LHA	Mean	29.9	57.5	97.9	16.6	50.1
	SD	5.8	15.3	4.3	3.9	6.9

RHA, N = 24
LHA, N = 23
[a] RHA = Right hemisphere activation; LHA = left hemisphere activation
[b] HS = Hemisphericity Scale; EH = Edinburgh Handedness; CWA = Controlled Word Association; and CF = Closure Flexibility

In addition, a multivariate repeated measures analysis (MRM) was performed on pretreatment physiological data collected during the stabilization period. The groups were not significantly different on left skin conductance level (LSCL), right skin conductance level (RSCL), or heart rate (HR) before treatment. The means for these measures were, for PHA and LHA, respectively: for LSCL, RSCL, and HR.: 3, 6, 3, 5, mMho; 4.5, 4.1 mMho; 70, 68 BPM. Apparently random assignment was successful.

As predicted in the first hypothesis, the right hemisphere activation (RHA) group recovered significantly faster from startle than the left hemisphere activation (LHA) group, F (3, 43) = 20.80, p<.001 as determined by a MRM analysis. Table 3.2 presents the mean recovery times for each group on the three physiological variables measured.

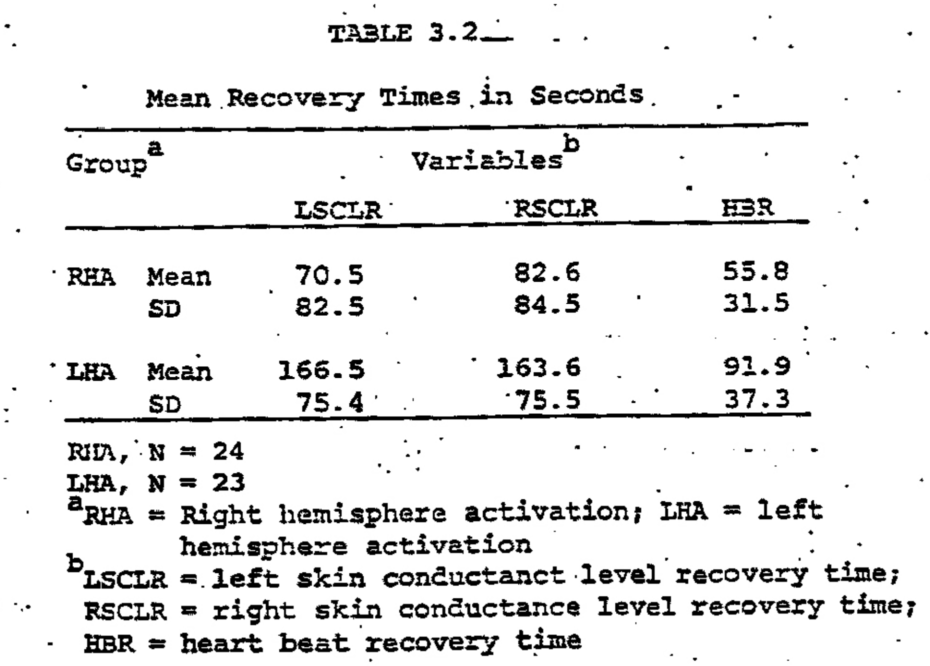

TABLE 3.2

Mean Recovery Times in Seconds

Group[a]		Variables[b]		
		LSCLR	RSCLR	HBR
RHA	Mean	70.5	82.6	55.8
	SD	82.5	84.5	31.5
LHA	Mean	166.5	163.6	91.9
	SD	75.4	75.5	37.3

RHA, N = 24
LHA, N = 23
[a] RHA = Right hemisphere activation; LHA = left hemisphere activation
[b] LSCLR = left skin conductanct level recovery time; RSCLR = right skin conductance level recovery time; HBR = heart beat recovery time

A significant multivariate group x session interaction was also found, F (6, 176) = 3.75, p< 01. Subsequent univariate tests for each variable showed significant group x session interaction effects for LSCL, F = 11.82, p<.001, and RSCL, F = 7.39; p<.01, but not for HR. Figure 3.1 presents the significant interactions.

The amplitude of response for physiological variables was evaluated using MRM analyses. Overall differences were found, F (3, 43) = 6.30, p < .0l. However upon inspection of univariate tests only HR response amplitudes were significantly different between the groups; F (3, 43) = 16.64, p<.001, but no significant differences were found for the amplitudes.

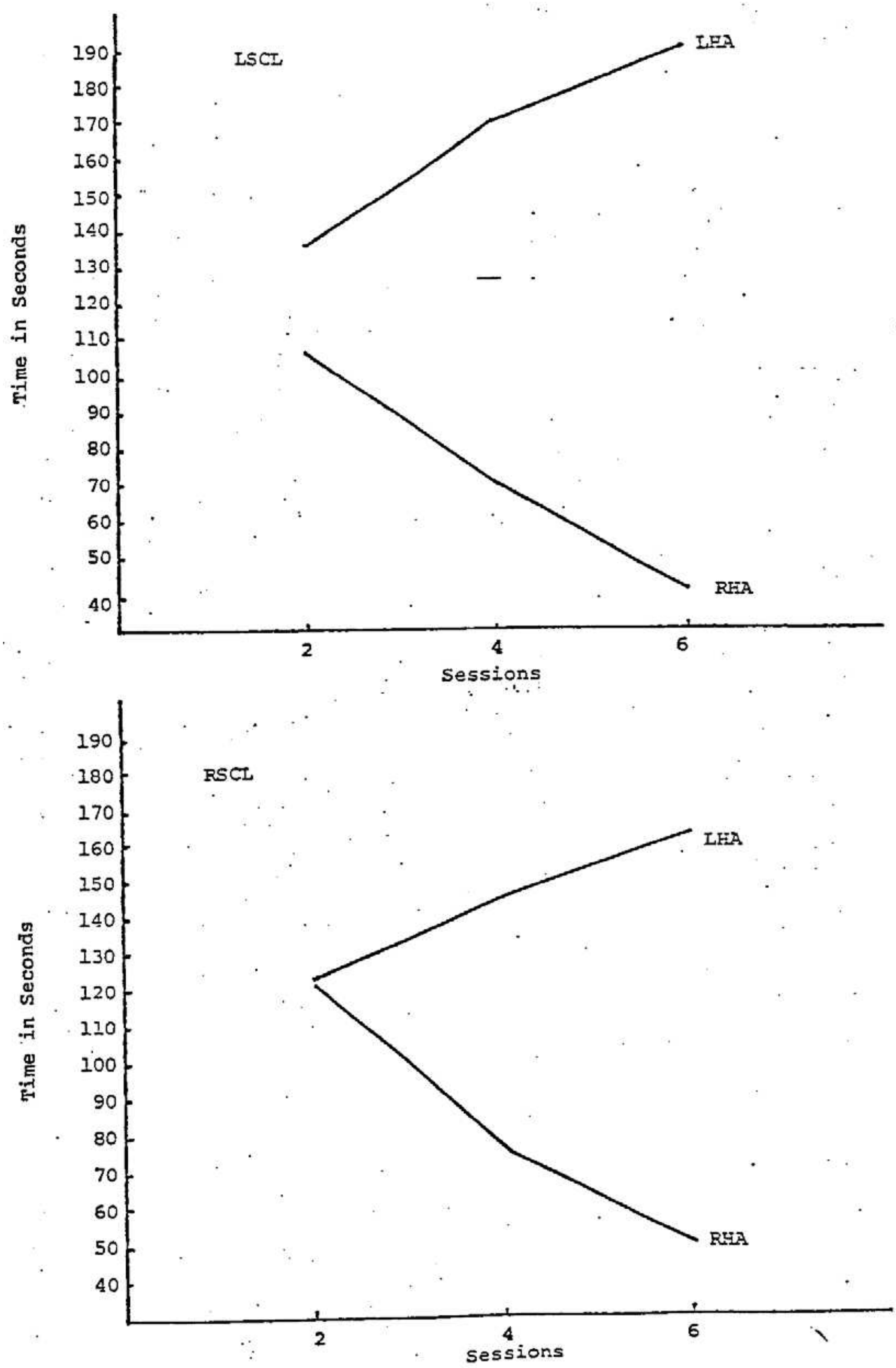

Figure 3.1. Recovery time across sessions (LHA = left hemisphere activation group, N = 24; RHA = right hemisphere activation group, N = 23; LSCL = left skin conductance level; RSCL = right skin conductance level)

Figure 3.2

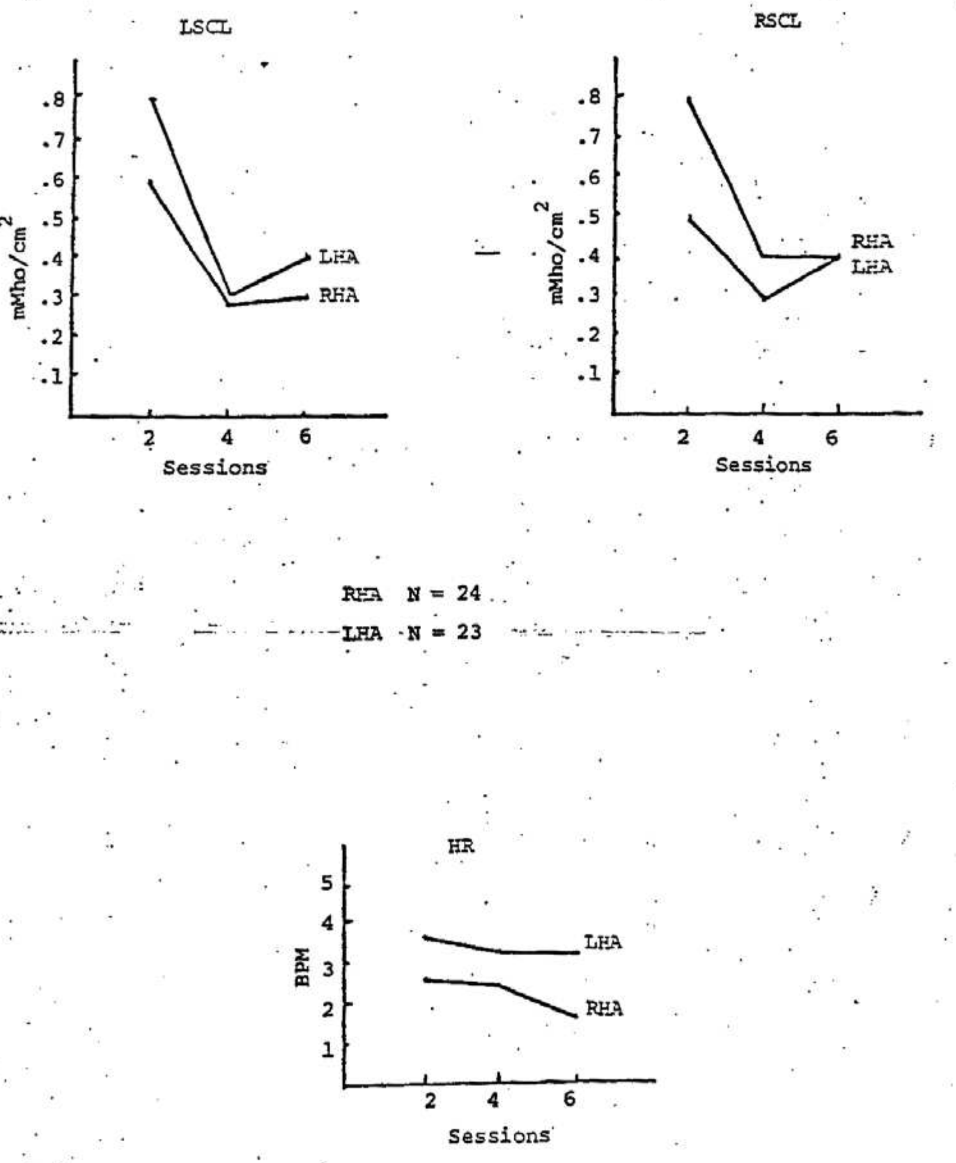

Figure 3.2. Amplitude of response to startle. (LHA = left hemisphere activation; RHA = right hemisphere activation; LSCL = left skin conductance level; RSCL = right skin conductance level; mMho/cm^2 = micromhos per centimeter squared; BPM = beats per minute

of response of LSCL and RSCL (see Figure 3.2) . The relationship between recovery time and amplitude of response was further explored by canonical correlation analysis. As shown in Table 3.3, intercorrelations between the two variable sets indicate a strong positive relationship.

TABLE 3.3

Intercorrelations Between Recovery Time and Amplitude of Response for All Subjects

			Amplitude[a]	
		LSCLA	RSCLA	HRA
Recovery[b]	LSCLR	.5860	.5539	.2003
	RSCLR	.5922	.5819	.2187
	HRR	.3997	.4072	.6060

N = 47

[a]LSCLA = Amplitude of response for left skin conductance level; RSCA = amplitude of response for right skin conductance level; HRA = amplitude of response for heart rate

[b]LSCLR = Recovery time for left skin conductance level; RSCLR = recovery time for right skin conductance level; HRR = recovery time for heart rate.

Two of three factors extracted were significant as follows: Factor 1, chi sq (5) = 26.43, $p<.001$ and Factor 2 chi sq (3) = 14.69, $p<.01$. Factor structures are presented in Table 3.4. Clearly, Factor 1, accounting for 26.9% of the redundancy in recovery time and 33% of the redundancy in amplitude, shows most subjects' recovery time and amplitude responses increase together. However, Factor 2, accounting for 9.4% and 7.0% of the redundancy in recovery time and amplitude respectively, describes a secondary relationship in which skin conductance levels and heart rate vary inversely.

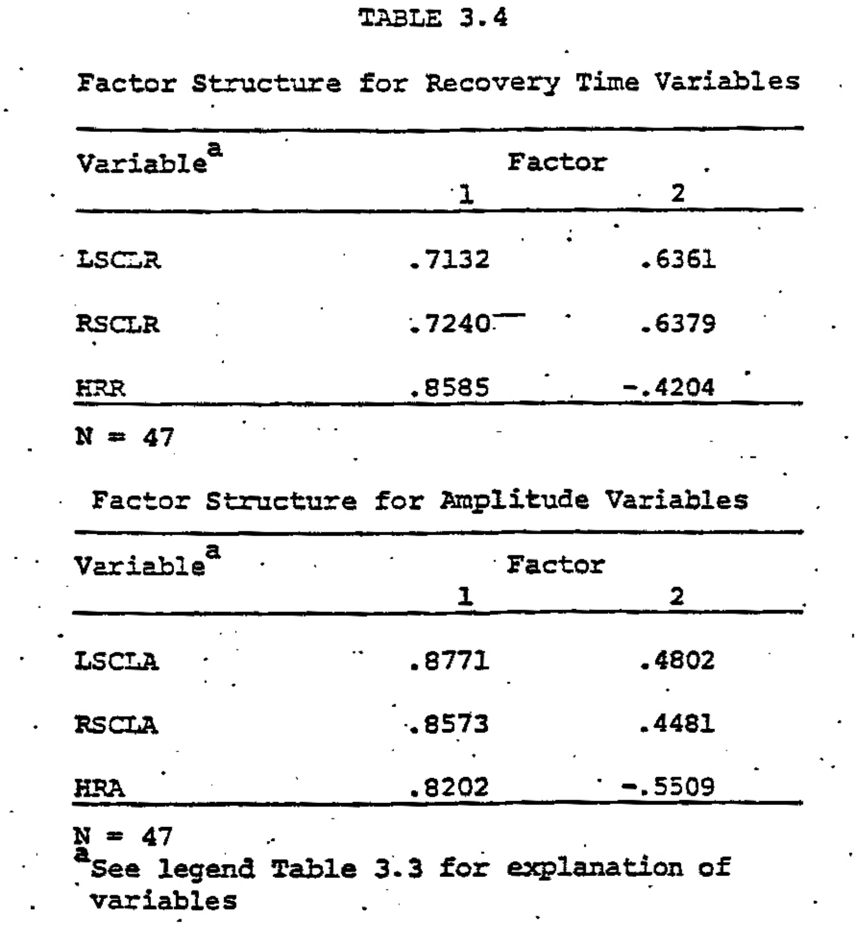

TABLE 3.4

Factor Structure for Recovery Time Variables

Variable[a]	Factor 1	Factor 2
LSCLR	.7132	.6361
RSCLR	.7240	.6379
HRR	.8585	-.4204

N = 47

Factor Structure for Amplitude Variables

Variable[a]	Factor 1	Factor 2
LSCLA	.8771	.4802
RSCLA	.8573	.4481
HRA	.8202	-.5509

N = 47

[a] See legend Table 3.3 for explanation of variables

The second hypothesis predicted differential performance on posttreatment verbal and spatial tasks. Specifically, the LHA group was expected to score higher on verbal tasks and the RHA group was expected to score higher on spatial tasks. A MANOVA revealed that the hypothesis was not supported, F (1, 45) =, 0.49, p = .83. Figure 3.3 displays the mean scores obtained by each group on each test.

The two behavioral tasks, balancing a pencil and finger tapping, were analyzed using a MANOVA. The differences between the group means were not significant, F (1, 44) = 0.48, p = .75. Mean scores are presented in Figure 3.4.

Figure 3.3

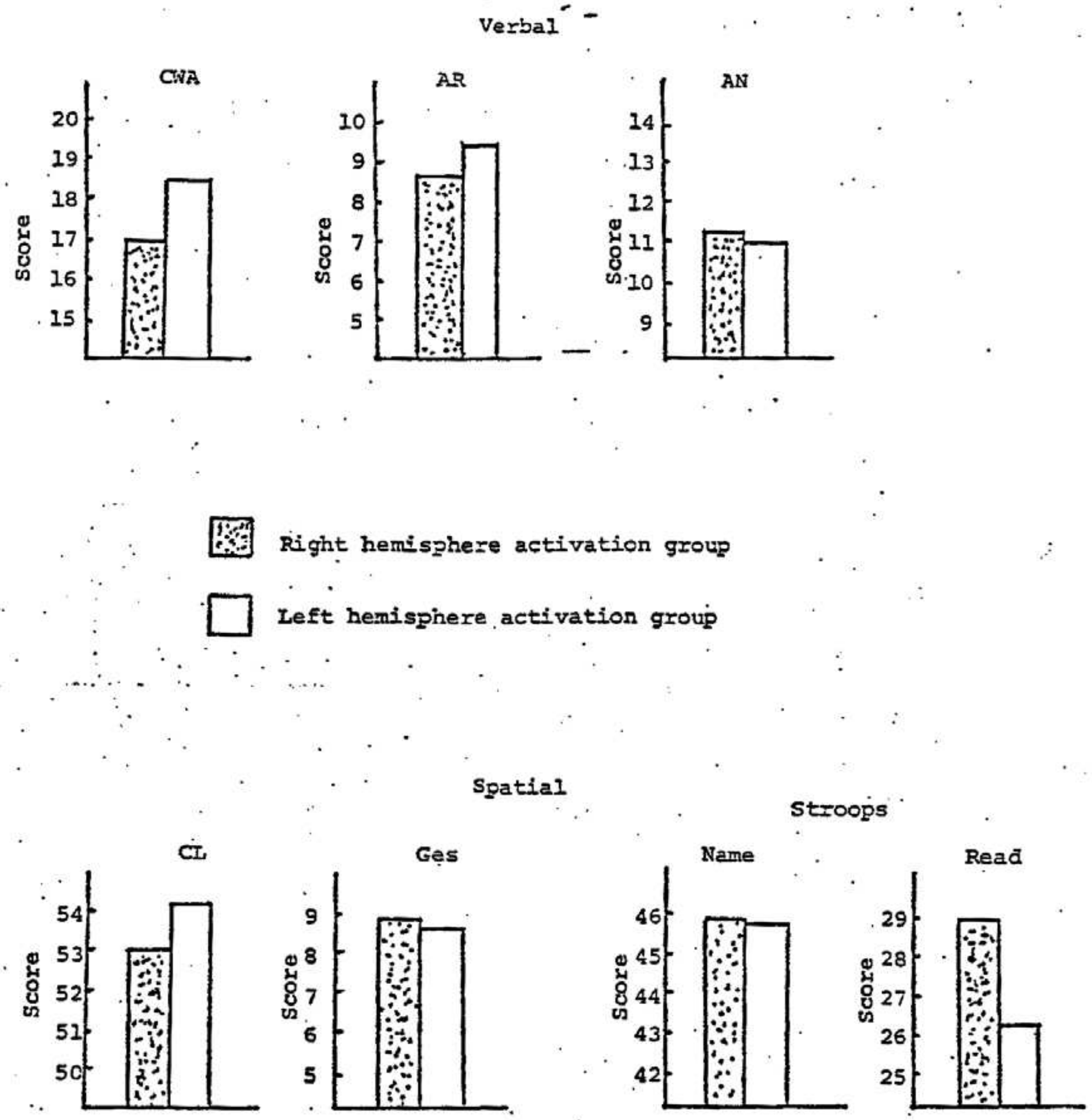

Figure 3.3 Post-test scores.
(CWA = Controlled Word Association, Score = No. words named in one min.;
AR = Arithmetic Problem Solving, Score = No. correct out of 15;
AN = Anagram Solutions Task, Score = No. correct out of 30;
CL = Closure Flexibility Test, Score = Standardized, norm = 61;
Ges = Gestalt Perception Test, Score = No. correct out of 13;
Stroops - name = naming colors; score = no. seconds;
Stroops - read = reading color words, score = no. seconds).

Figure 3.4

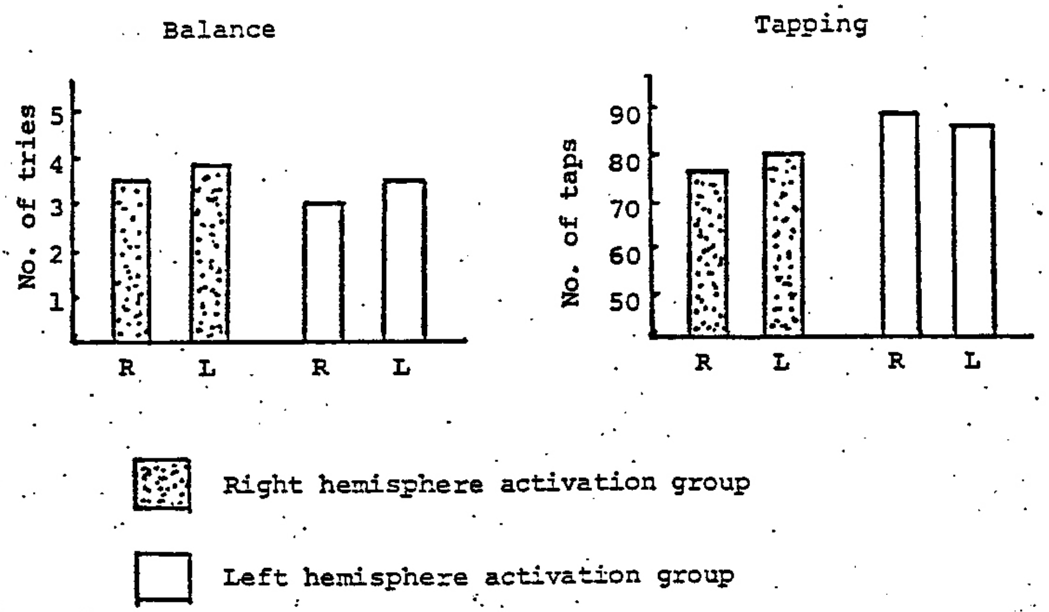

Figure 3.4. Behavioral task performance.
Balance = balancing a pencil on the index finger - measure used was the no. of tries to get it balanced.
Tapping = depressing a key with the index finger - measure used was the no. of taps in one minute.
(R = right hand; L = left hand)

Profiles were drawn for physiological variables across sessions and across trials, or minutes, within sessions. Differences in the profiles across sessions one, three, and five (non-startle sessions) during treatment are shown in Figure 3 .5. Levels during treatment in startle sessions (sessions two, four, and six) are presented for LSCL, RSCL, and HR in Figure 3.6.

Within sessions profiles were drawn for startle and non-startle sessions. The 45 minutes of each session were divided into 15 minute blocks of time for comparison of measures on LSCL, RSCL, and HR recorded each minute. The first 15 measures were taken before hemispheric activation began and the last 30 measures were taken during activation. LSCL, RSCL, and HR across -non-startle trials are shown in Figure 3.7. LSCL, RSCL, and HR across startle trials are presented in Figure 3.8.

The differences between left and right skin conductance levels under conditions of left and right hemisphere activation are of theoretical interest. Since limitations of the available local statistical libraries prevent thorough analysis of massive amounts of physiological data, difference scores and change scores were calculated in the following manner. For each minute of each session a difference score was obtained by subtracting RSCL from LSCL. Since RSCL was usually higher, most difference scores are negative. Change scores were then calculated across sessions by subtracting difference scores for any two sessions under consideration. A

Figure 3.5

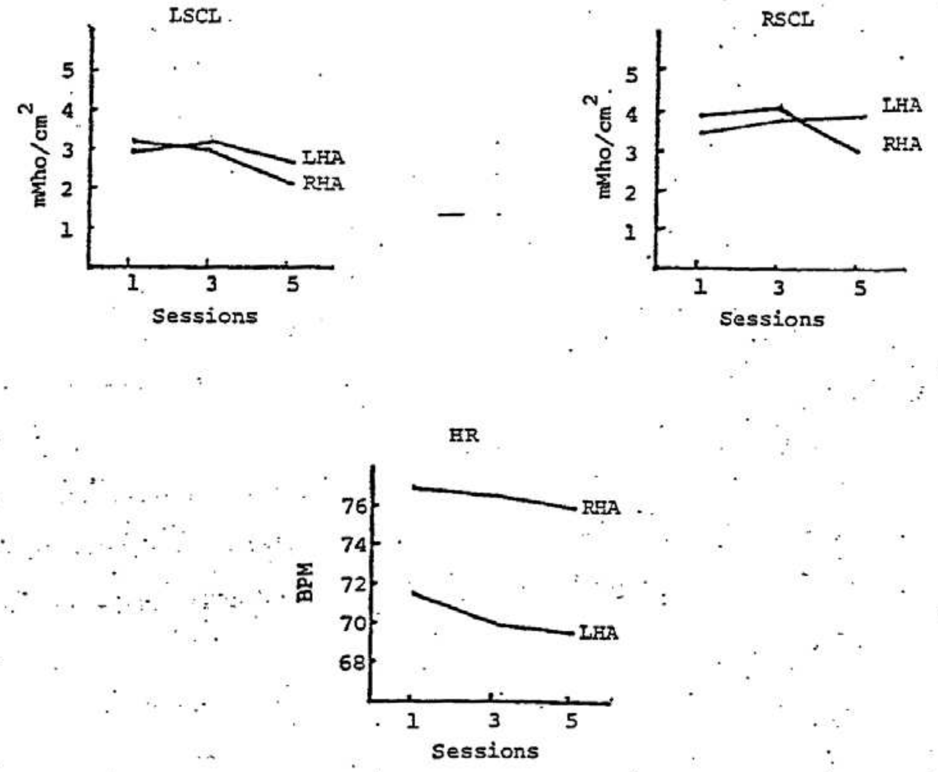

Figure 3.5. Profiles of physiological variables across non-startle sessions. (mMho/cm^2 = micromhos per centimeter squared; BPM = beats per minute; LSCL = left skin conductance level; RSCL = right skin conductance level; HR = heart rate; LHA = left hemisphere activation group; RHA = right hemisphere activation group.

Figure 3.6

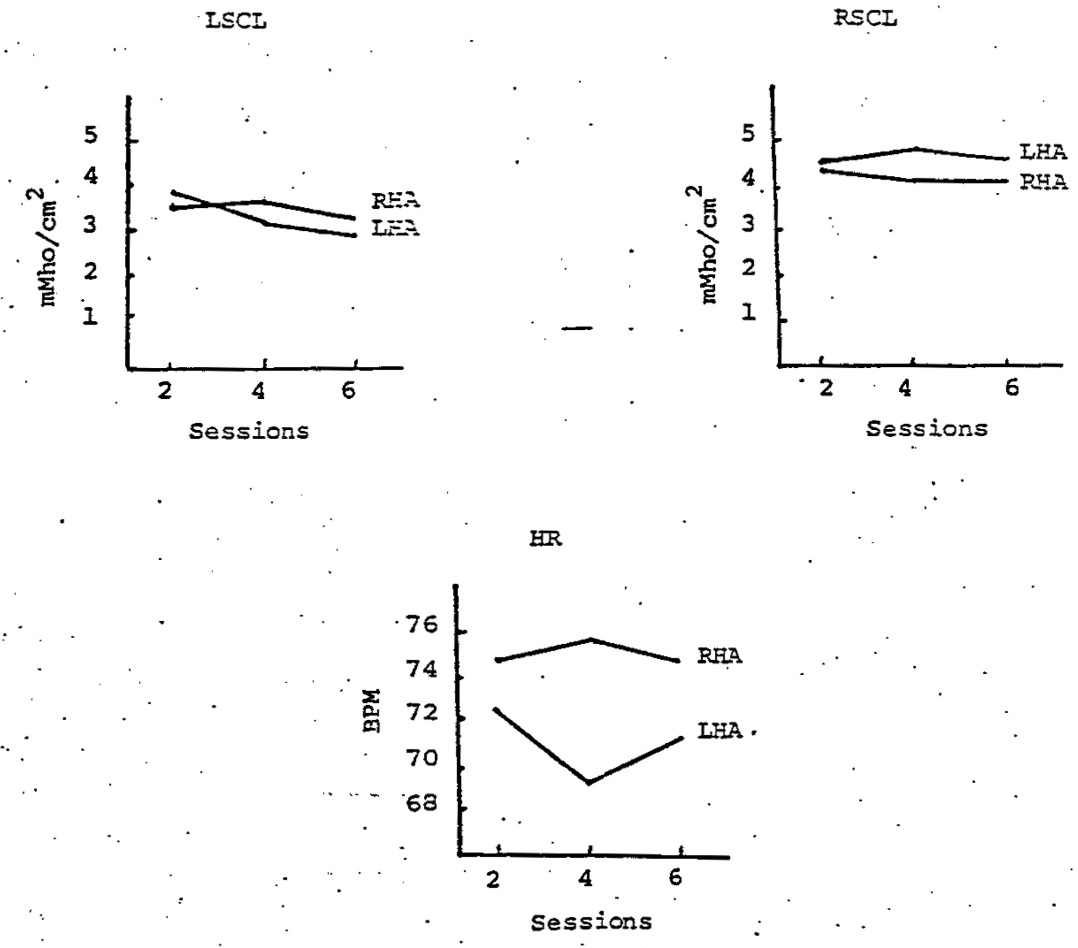

Figure 3.6. Profiles of physiological variables across startle sessions ($mMho/cm^2$ = micromhos per centimeter squared; BPM = beats per minute; LSCL = left skin conductance level; RSCL = right skin conductance level; HR = heart rate; LHA = left hemisphere activation; RHA = right hemisphere activation).

Figure 3.7

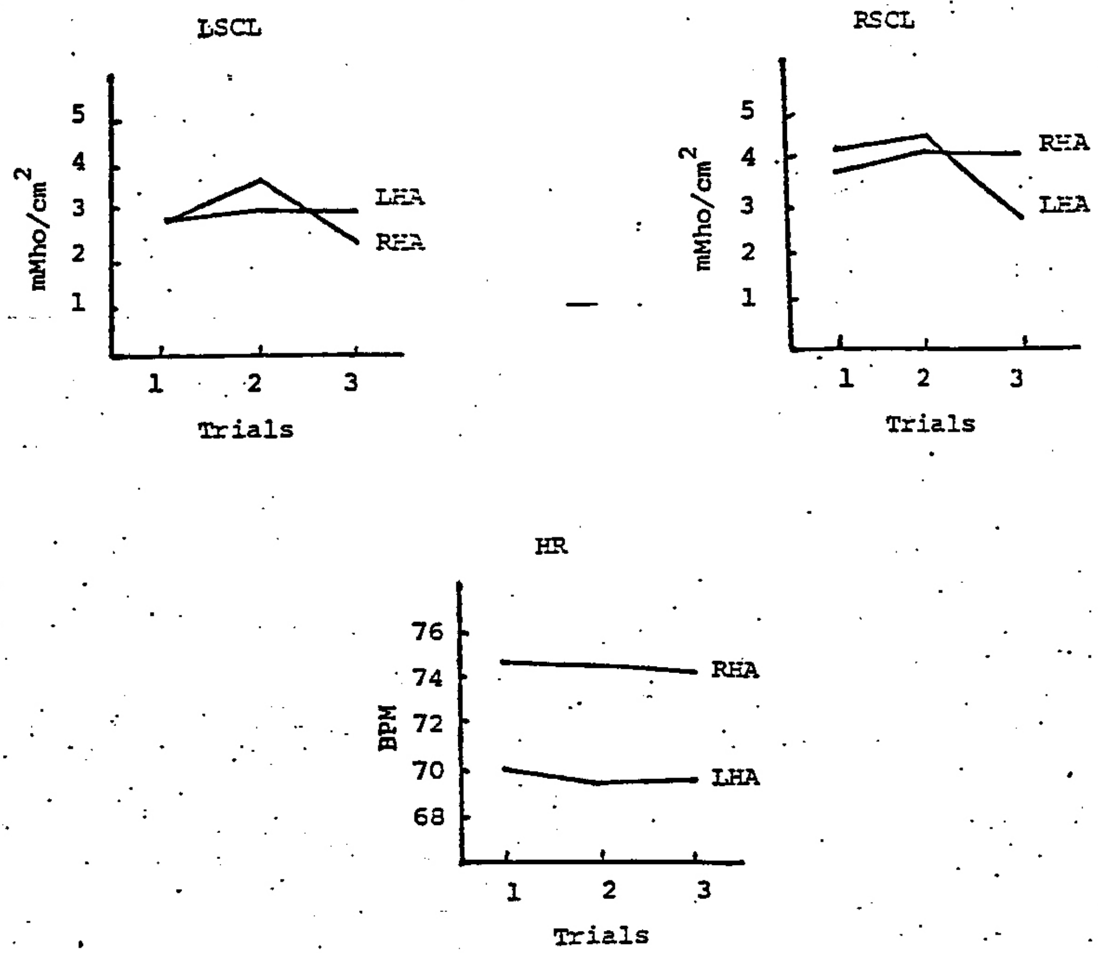

Figure 3.7. Profiles of physiological variables across non-startle trials (Trial 1 = mean of 1st 15 minutes - stabilization; trial 2 = mean of 2nd 15 minutes - during activation; trial 3 = mean of 3rd 15 minutes - during activation; mMho/cm^2 = micromhos per centimeter squared; BPM = beats per minute; LSCL = left skin conductance level; RSCL = right skin conductance level; LHA = left hemisphere activation; RHA = right hemisphere activation). Data include all three non-startle sessions.

Figure 3.8

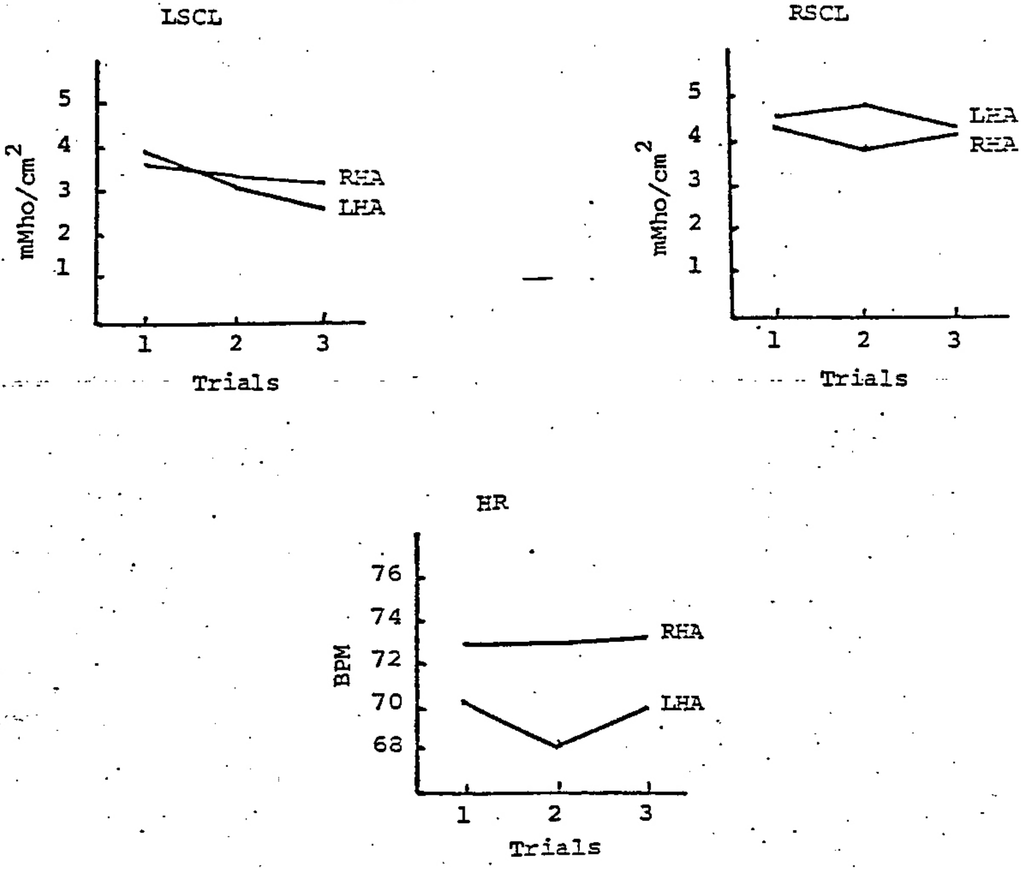

Figure 3.8. Profiles of physiological variables across startle trials (Trial 1 = mean of 1st 15 minutes - stabilization; trial 2 = mean of 2nd 15 minutes - during activation; trial 3 = mean of 3rd 15 minutes - during activation; mMho/cm^2 = micromhos per centimeter squared; BPM = beats per minute; LSCL = left skin conductance level; RSCL = right skin conductance level; LHA = left hemisphere activation; RHA = right hemisphere activation). Data include all three startle sessions.

positive change score is indicative of increased LSCL output relative to RSCL. With the knowledge that more appropriate analyses would have been desirable, comparisons are presented in Figure 3.9 in order to illustrate the contralateral effect on skin conductance level under left and right hemisphere activation.

The verbal and spatial tests administered before and after the experiment were submitted to a MRM which revealed a significant test of occasions effect, F (2, 44) = 15.5, p<.001. Further inspection of the univariate tests confirmed no differences at pre-testing but significant post test differences; F (2, 44) = 29.04, p<.001. The RHA group improved on the spatial test, but not the verbal one, and the LHA group improved on both tests (see Figure 3.10).

Eighty seven percent (N = 41) of all subjects returned for a follow-up session approximately two weeks after the last treatment session. On SCL recovery time the RHA group again recovered from startle significantly faster than LHA; F (3, 35) = 5.45, p < .01. Intermediately after the follow-up session, subjects were asked to rate their overall feelings about being a participant on a scale from 1 to 10, 10 being very positive, 1 very negative. Means for RHA and LHA groups were 8.44 and 7.50 respectively and were not significantly different.

Figure 3.9

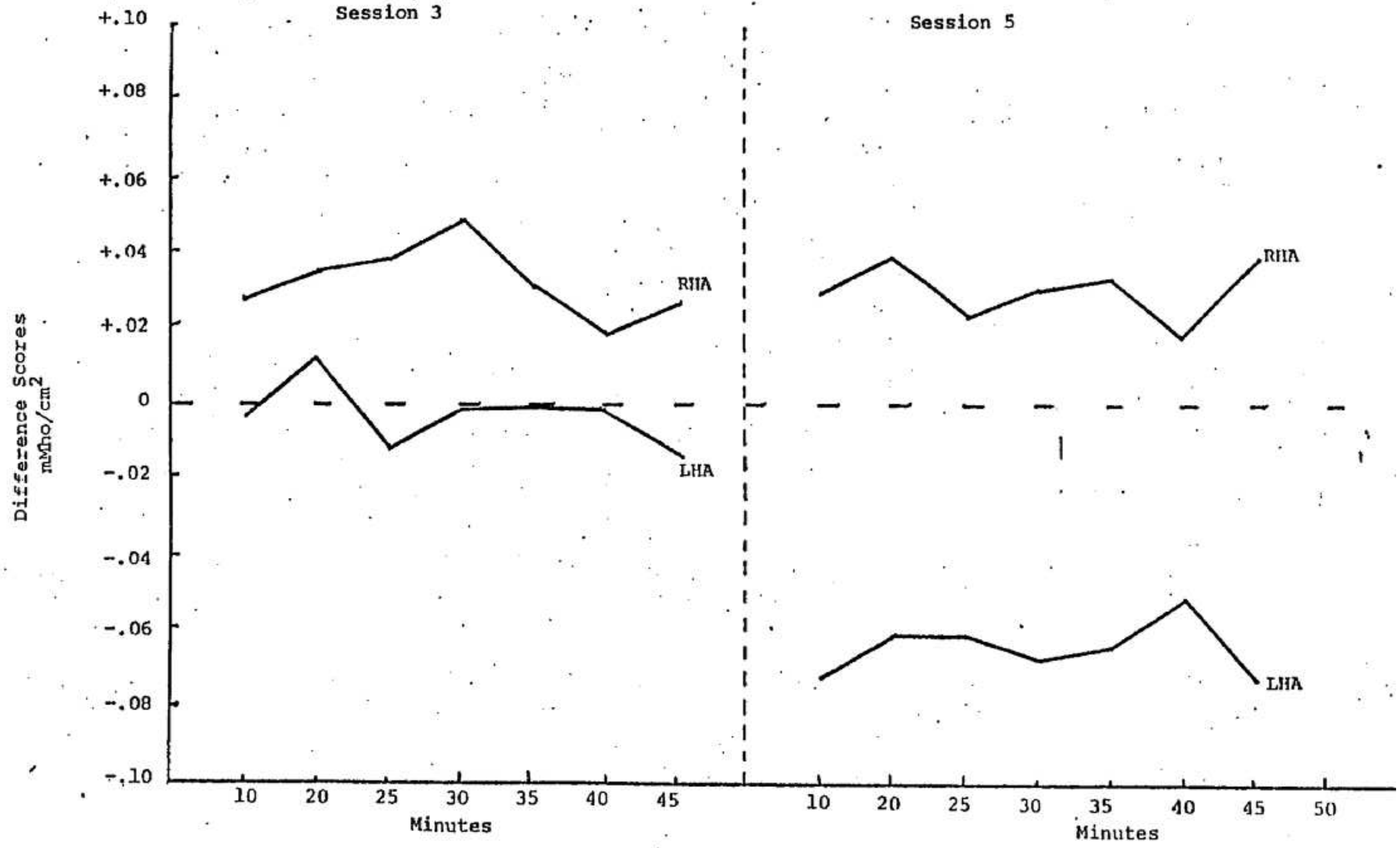

Figure 3.9. Skin conductance level differences between right and left hands from Session 1 to Session 3 and from Session 1 to Session 5. (RHA = right hemisphere activation group; LHA = left hemisphere activation group; minutes = "at minute 10," "at minute 20," etc. as compared between non-startle sessions.)

Figure 3.10

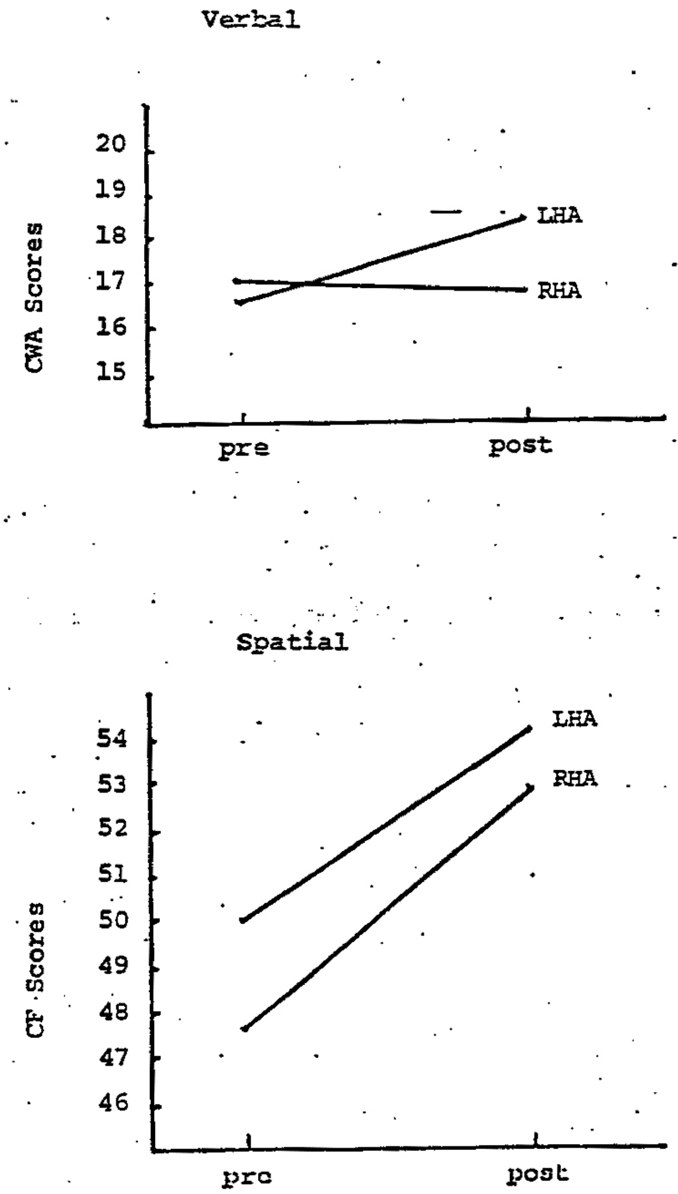

Figure 3.10. Pre - post Tests (CWA = controlled word association test; CF = closure flexibility test; LHA = left hemisphere activation group; RHA = right hemisphere activation group.

CHAPTER 5

DISCUSSION

The major finding is that elicited elevations in bilateral skin conductance levels and heart rate return to pre-startle baselines more rapidly under right hemisphere activation than when the left hemisphere is activated. This finding lends strong support, for the first hypothesis of the study. The predicted differences were based on the idea of interference between the hemispheres analogous to a competition to control various functions. Interference is decreased if one hemisphere is busy processing repetitive information mediated by that hemisphere. The data suggest that this phenomenon most probably accounts for the highly significant recovery time differences between the groups. When the right hemisphere was inhibited, or "tied up", processing the music and Kinoscope stimuli, the left more efficiently returned autonomic elevations to a homeostatic state than when the left was busy reading and the right was free to do the task.

Other interpretations are possible and should be considered. For example, higher amplitudes of response might logically account for longer recovery times. For SCL this possibility appears to be ruled out by the lack of significant amplitude response differences between the groups. A definite and positive relationship exists between amplitude of response and recovery time, but apparently not enough to explain why the groups differed so greatly.

A second consideration has to do with attentional factors. Ordinarily, reading rewires a sustained focused attention, whereas, watching a moving light line is more passive.

Therefore, interruption of the former behavior might have been more .frustrating for subjects since they had to resume a logical sequence. However, greater frustration should have been reflected in higher heart rate levels. The data show, however, that HR for the LHA group was lower. Furthermore, subjects in the right hemisphere activation group made more comments indicating task involvement than the left hemisphere activation group. For example, the music and kinescope group reported statements like, ".I really got into it", whereas, the reading group frequently expressed boredom. In addition, instructional sets for the groups were designed to allay any anxiety associated with the necessity to retain or recall information. In further support of the contention that differential attentiveness did not account for recovery time differences, heart rate of the RHA group were consistently higher than the LHA group during activation. According to Lacey, Kagan, Lacey, and Moss (1966) increase in heart rate is associated with increase in attention, which could be interpreted as meaning that the RHA group actually attended more closely to the activating stimulus yet still recovered faster.

Since subjects were not instructed to try to keep or bring levels down after startles, but rather to maintain attention on the stimuli when interrupted, it is not likely that either group perceived demands of the experimental condition as difficult.

Possibly, the re-establishment of lateral saccades necessary for the reading group was more difficult, but simultaneous auditory input made finding one's place easier. LHA subjects frequently expressed the feeling that they were passive recipients of words because the content of the readings were relatively meaningless to the majority.

Overall, then, it does not seem likely that attentional factors, frustration levels, or task difficulty can account for recovery time differences. The indications are in favor of left hemispheric specialization in control of skin conductance level. Since skin conductance level is controlled by the sympathetic branch of the autonomic nervous system, a link between sympathetic control and the left brain is suggested. Heart rate, on the other hand receives dual innervation from both sympathetic and parasympathetic systems as do most other autonomic variables. Since heart rate was higher while the right brain was inhibited from its control functions by activation, it is possible that a balance system was disrupted. Although inconclusive, the argument can be made for right hemisphere affiliation with the parasympathetic system.

For most subjects, recovery time and amplitude of response varied together for all three variables, but some subjects, scattered across both groups, displayed a different pattern. As skin conductance levels increased, heart rate decreased. Those two distinct patterns accounted for almost all the shared variance among the sets of variables when startles were presented. It would be interesting to collect personality and behavioral information for the two types of responders.

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To a lesser degree, an association is suggested between the left hemisphere and the sympathetic nervous system and between the right hemisphere and the parasympathetic system. If this is so, it would account for the ever increasing numbers of stress related disorders. The overactive left hemisphere might help to maintain an overactive sympathetic nervous system. Further work is necessary to verify this interpretation.

Application for this knowledge in education and psychotherapy are obvious. Reinforce the right hemisphere as well as the left in order to reinstate homeostasis. Trends among researchers and educators appear to be in this direction (Luthe, 1976; Budzinski, Note 4; Edwards, Note 5; and Wickramsekera, Note 6).

Because the sample of subjects in this study was very limited, more research is needed before a generalized statement can be made regarding relationships between hemispheric and autonomic laterality. Sex and age factors are particularly pertinent as well as differences between dextrals and sinistrals. In addition, the apparent learning effect in achieving shorter and shorter SCL recovery times across sessions for the right hemisphere activation group could be no more than adaptation to startle. However, why the converse occurred during left hemisphere activation is somewhat uncertain. Assuming the interpretation is correct, i.e., the right hemisphere is not as efficient at autonomic control as the left, why it should be less efficient at session six than at session two is difficult to explain. Replications in which hemispheric activation is verified electro physiologically might shed some light in this area.