THE EFFECTS OF ASYMMETRICAL SUB-FUNCTIONAL ELECTRICAL STIMULATION AND AUDITORY AMPLIFICATION ON SPATIAL DISORIENTATION IN LEFT HEMIPLEGIA

by Arthur S. Leonoff

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CURRICULUM STUDIORUM

Arthur Leonoff was born April 26, 1947, in Winnipeg, Manitoba. He received the Bachelor of Arts degree from the University of Manitoba in 1968, and the Master of Arts degree from the University of Ottawa, in 1971. The title of his thesis was Long-term Effects of Hemodialysis on Psychological Functioning in Chronic Renal Failure.

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INTRODUCTION

The human experience of spatial orientation reflects stabilized modes of control operating through and throughout the spatial system. These organismic controls provide the normal individual with workable behavioral strategies that have proven efficient in countless encounters with the environment.

Cerebral vascular disease resulting in occlusion of major arterial flow into the right hemisphere often leads to left hemiplegia and a concomitant disruption in stabilized spatial functioning. The left hemiplegic patient reveals a particular inability to maintain a consistent frame of reference or system of perceptual coordinates, and thus, no longer exists and acts in an expectable environment. Consequently, the left hemiplegic's opportunity for achieving independent daily living rests, to a considerable extent, on the residual spatial acuity he retains or the extent to which he can recover appropriate spatial responsiveness. That the majority of left hemiplegics do not attain independent status following rehabilitation indicates the gravity of the disorder and the depth of the problem for both patient and therapist.

Psychology, in this regard, has contributed extensively to the delineation of symptoms and syndromes and to the prediction of rehabilitation prognosis. However, beyond diagnosis and prediction lies the realm of remediation for the gross perceptual deficits that have been identified. It is only recently that this problem has been approached in question to left hemiplegia. This is in contrast to the considerable strides which have been made in re-training techniques for perceptual deficits in children. Thus, the conception that the role of psychology within physical rehabilitation must, in a coherent framework, focus beyond description towards treatment of psychophysiological defects in neurologically handicapping conditions, dominates the enquiry to follow.

The explicit goal of this study is the assessment of a physiological re-training strategy for spatial disorientation in left hemiplegia based on a specific model of disturbed cerebral regulation of spatial processes in this disorder.

The first chapter initially discusses the context in which spatial orientation is considered, and then presents literature on pertinent constituents of spatially oriented behavior. This is followed by a review of the spatial disorientation syndrome encountered in left hemiplegia and leads to a discussion of the neurodynamics underlying the disorder. The application of the dynamics to remediation are postulated and indicate the programmatic context of the succeeding chapters.

Chapter two presents the experimental design employed in the evaluation of the treatment paradigm and includes a discussion of the tools, population, and statistical methods utilized in the analysis of the data.

The third chapter presents the results of the study and endeavors to interpret them with respect to the model described in the first chapter. Suggestions for continued research are given at the conclusion of this discussion.

CHAPTER I

REVIEW OF THE LITERATURE

Hemiplegia is caused primarily by a progressive or sudden interruption of the arterial blood supply as a consequence of vascular occlusion. The resultant symptomatology, which may be massive in scope and severity, depends on the particular locus of lesion, the individual in question, and the demands and nature of the tasks used to assess the behavior.[1] In general, however, loss of function to the contralateral half of the body including paralysis or paresis, sensory diminution, visual field deficits, and neuropsychological syndromes comprise the clinical picture.[2]

In left hemiplegia due to cerebral vascular accident[3] the major area of psychological deficit involves non-verbal spatial skills in which some form of dysfunction in the synthesizing of multiple percepts occurs.[4,5]

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1 Maurice W. Van Allen, "Objectives Behavioral Assessment in Diagnosis and Prediction," presentation 16, in A.L. Benton (ed.), Behavioral Change in Cerebrovascular Disease, New York, Harper and Row, 1970 , p. 166-168.

2 A. Biemont, Brain Diseases, New York, Elsevier Publishing Co., 1970, p. 3-54.

3 Hereafter referred to as C.V.A.

4 L. Diller, "Brain Damage, Spatial Orientation, and Rehabilitation," in S. J. Freedman (ed.), The Neuropsychology of Spatially Oriented Behavior, Homewood, Ill., Dorsey Press, 1968, p. 265-279.

5 Walter Friedlander, "Anosognosia and Perception," American Journal of Physical Medicine, Vol. 46, 1967, p. 1394-1408.

REVIEW OF THE LITERATURE

The major purpose of this present investigation is to provide preliminary evaluation of a remediation model for spatially disoriented behavior in left hemiplegia. The literature, leading to the experimental treatment hypotheses, is presented under the following headings in the order described: (1) spatial orientation; (2) spatial disorientation in left hemiplegia; and (3) conclusions and hypotheses.

1. Spatial Orientation.

In order to explore the dynamics underlying spatially disoriented behavior due to right hemispheric dysfunction, a general overview of factors deemed important to spatial orientation is warranted in this regard. Thus, the following section first enumerates a theoretical position relevant to the thesis in question and proceeds to a discussion of major research trends in this area of investigation. Although this review is by no means exhaustive, it is intended as a precursor to the discussion and experimentation that follows.

A. Theoretical Overview

In the human organism, the neuromuscular control mechanisms maintain a normal or functional equilibrium between the body axis and external referents in a self-restoring manner so as to permit spatially accurate behavior. Adequate spatial functioning, then, implies a correlation or matching of the individual's repertoire of behaviors to the structures of the external world. Both the body's structures and its underlying physiology and the structures of the external world function within a given set of constraints and invariants, respectively, that provide order and predictability to spatial-perceptual functioning.[6] Gibson,[7] in this regard, refers to the "economy" of the orienting system which allows the individual to avoid distraction, identify what is essential from concurrent multi-sensorial information, and organize the entire spatial system for appropriate action.

In discussing spatial orientation, therefore, two components, the somatic and the environmental, may be considered as necessary dimensions functioning in interaction towards the expeditious maintenance of spatial behavior. Within their definition of human spatial orientation, Howard and Templeton include the above characteristics:

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6 I. P. Howard and W. B. Templeton, Human Spatial Orientation, New York, John Wiley and Sons, 1966, p. 533.

7 J. J. Gibson, "The Theory of Information Pickup," in J. J. Gibson (ed.), The Senses Considered as Perceptual Systems, Boston, Houghton-Mifflin, 1966, p. 266-286.

> Spatially coordinated behavior is construed as the development and maintenance of a repertoire of response patterns which are molded and conditioned by the spatial characteristics of the body and of the physical world in such a way that objectives may be rapidly and accurately achieved.[8]

Inasmuch as the body must retain a normal relationship with the ecological reality, an analysis of spatial mechanisms must begin with the physical nature of the human body itself.

All actions in space and upon the body schema are dependent on the symmetry of the body structures at least to the extent that they are all performed in directions relative to its central longitudinal or mid-body axis. Symmetry would appear to be one feature that is most characteristic of the human form. This inherent structural disposition, evidenced both externally and internally, is perhaps most conspicuous in the realm of body sensory equipment. Eyes, ears, hands, olfactory bulbs, sensory-topic representations, posterior columns and spinothalamic tracts are all present in symmetrical duplication. This anatomic redundancy led Sir Victor Horsley to note what he believed to be a fundamental truth: "We are not single animals: we are really two individuals joined together in the middle line."[9]

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8 Howard and Templeton, op. cit., p. 7.

9 V. Horsley, quoted in J. E. Bogen, "The Other Side of Brain II: and Appositional Mind," Bulletin of the Los Angeles Neurological Societies, Vol. 34, 1969, p. 153.

Sperry's[10] "split-brain" studies moved him to a similar conclusion that the human organism is composed of two independent minds with two separate realms of consciousness.

The functional significance of this double format in respect to spatial orientation has long been an issue although its prominence in theory and research has been undermined by the clinical discoveries of hemispheric functional differentiation. Somewhat prophetically, Hughlings Jackson wrote in 1874:

> That the nervous system is double physically is evident enough. This is a very striking fact, but one so well known that we are in danger of ceasing to think of its significance--of ceasing to wonder at it.[11]

Gooddy and Reinhold[12] focused their conception of the dynamics of spatial orientation on the symmetrical arrangement of the human anatomy whereby orientation is dependent upon the integration and complete synchronization of the sensory-motor system. In their deductions, proprioceptive, kinesthetic, and exteroceptive stimuli are in

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10 R. W. Sperry, "Cerebral Organization and Behavior," Science, Vol. 133, 1961, p. 1749-1757.

11 J. H. Jackson, Selected Writings, Vol. 2, James Taylor (ed.), London, Hodder and Stroughton, 1932, p. 129.

12 William Gooddy and Margaret Reinhold, "Some Aspects of Human Orientation in Space," Brain, Vol. 75, 1952, p. 472-509.

constant flux and so require an incessant integration and perception. Movement, the response component of the orientation system, is considered inseparable from sensation. All concurrent stimuli contribute to the maintenance of orientation although not all are perceived consciously at any one time. Orientation, then, becomes the preservation of a direct and constant relationship between ever changing fixed points in the environment and the mobile symmetrical human body.

The concept of an independent sensory system has been considered by Luria[13] who also denies its existence. Rather, he denotes the sensory system as being part of a larger sensory-motor cortex in which associational fibers provide rich communication. As will be discussed below, the functional importance of this unitary system can be readily observed from the neurodynamic consequences of posterior cerebral lesions involving the primary and secondary sensory cortex. Lesions in these areas appear to lead to a disorientation in spatial organization or to a disturbance in the schemata upon which the development of motor actions is built.[14] As Head[15] noted, the sensory memory

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13 A. R. Luria, Higher Cortical Functions in Man, New York, Basic Books, 1962, 490 p.

14 H. L. Teuber, "Perception," in Handbook of Physiology, Vol. 3, Section 1, Neurophysiology, Baltimore, Williams and Wilkins, 1960, p. 1595-1668.

15 Henry Head, Studies in Neurology, London, Oxford University Press, 1920, p. 786.

provides the kinesthetic base upon which controlled action can occur.

From this perspective, therefore, spatial orientation, the ability of an individual to relate himself to a point on his person or in external space, is a dynamic process based upon the integrity of a complex and inseparable sensory-motor process. It requires an on-going knowledge and integration of the status of the organism interacting with a particular and changing environmental input. It implicates the total organism and all its receiving modalities. Sensory-motor functioning refers to a particular and characteristic neuronal circuitry whereby the various modality inputs communicate intra- and interhemispherically and are coordinated with the intimately linked effector system. It may be said to describe a basic afferent-efferent relationship in which each subserves the other towards the organization and orientation of behavior so as to be, in essence, functionally one.

What is germane to this theory of orientation, then, is first the organism-environment relationship in which spatial thought, perception and motion are determined by the status of the organism in dynamic interaction with the surrounding stimulus array at any moment in time, and secondly, the complicity of the central nervous system as the focal source of knowledge (memory), comparison and judgment. To quote Gooddy and Reinhold:

> By this means a man is able to appreciate the form and position of his own body in relation to the outside world. He is able to judge direction and distance with reference to himself, and also the relative position of objects in the outside world to one another. As a result of learning, he is able to apply conceptual terms to direction and position, and to orient himself in an abstract or remembered environment not immediately perceived.[16]

The thesis that spatial orientation is tied inextricably to bilateral sensory-motor functioning, both developmentally and in terms of maintenance, is to perceive orientation as the psychological by-product of sensory-motor integration and processing. Hebb's[17] finding that disorientation was a primary resultant of sensory deprivation could logically be interpreted within this explanatory perspective. Developmentally, Piaget[18] has demonstrated that the child's ability to construct and act upon reality parallels his ability to attend to the higher order features of objects and to integrate his perceptions into adaptive spatially oriented response patterns (schemas). Research on young infants has found little evidence to reject the

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16 Gooddy and Reinhold, op. cit., p. 480.

17 D. O. Hebb, The Organization of Behavior, New York, John Wiley and Sons, 1949, 335 p.

18 Jean Piaget and B. Inhelder, The Child's Conception of Space, London, Routledge and Kegan Paul, 1956, 490 p.

hypothesis that basic sensory and perceptual processes such as scanning, form discrimination, three-dimensionality, and pattern recognition are present at infancy.[19] Rather, and in accord with Piaget, sensory development, post-natally, is typified by a progressive increase in capacity to integrate bilateral information arriving from all sensory modalities.[20] Luria[21] has equated this integrational differentiation with the physiological development of "secondary" and "tertiary" associative zones in the cerebral cortex.

It is perhaps noteworthy that a sensory-motor conceptualization of spatial orientation shares a basic commonality with Schilder's[22] delineation of body image development.. Schilder reasoned that the coordinated integration of exteroceptive input, vestibular and proprioceptive feedback, and dynamic control of muscle tone and motility (kinesthesias) resulted in a unified awareness of the body and permitted perception of objects, their boundaries and spatial

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19 Elizabeth K. Bond, "Perception of Form by the Human Infant," Psychological Bulletin, Vol. 77, 1972, p. 225-245.

20 David Warren and Herbert L. Pick, Jr., "Intermodality Relations in Localization in Blind and Sighted People," Perception and Psychophysics, Vol. 8, 1970, p. 430-432.

21 A. R. Luria, Human Brain and Psychological Processes, New York, Harper and Row, 1966, 587 p.

22 P. Schilder, The Image and Appearance of the Human Body, New York, International Universities Press, 1950, p. 83-152.

relationships. Accordingly, the clinical research of Gesell[23] and, more recently, Fish[24] has demonstrated that lack of response to proprioceptive stimuli in some infants antedated the apraxia, perceptual-spatial disturbance, and body image disorders observed during childhood.

In summary, the preceding discussion has attempted to introduce the concepts or postulates on which the following literature concentrates its enquiry. These are:

1. a correlative relationship, within the confines of human and environmental restraints, exists between the behavioral repertoire and the external world in which the individual operates;
2. the operations, which are spatially oriented or objectively sound, are related functionally to the symmetrical anatomy and physiology of the sensory-motor system;
3. the sensory-motor system, although duplicated in arrangement, is functionally unitary, and differentiates ontogenetically in respect to its integrational capacities.

B. Experimental Findings

Having defined and attempted to present a general hypothesis or context in which to view human orientation, it now remains to inspect the relevant literature with

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23 A. Gesell and C. S. Amatruda, Developmental Diagnosis, 3rd ed., New York, Harper and Row, 1965, 496 p.

24 B. Fish, "Involvement of the Central Nervous System in Infants with Schizophrenia," American Medical Association Archives of Neurology, Vol. 2, 1960, p. 115-121.

particular emphasis on the role of organismic processes in spatial orientation that has emerged from experimentation. Two major research directions may be identified and are discussed in the following order of presentation: (a) sensory-tonic relations, and (b) cybernetic relations.

(a) Sensory-tonic Relations

Werner and Wapner[25,26] were the first experimental psychologists to consider and operationally investigate spatial functioning from an organismic perspective in an attempt to reconcile the schools of sensory (Gestalt and Psychophysics) and motor psychology (Functionalism and Behaviorism).

They reasoned that stimulus organismic integration was not summative or parallel but "a total dynamic process" in which both factors contributed equivalently.[27] To capsulize this premise, they coined the term sensory-tonic in which perception is conceived in terms of a reciprocal interrelationship between any sensory input and the total state of the organism. The somatic status of the organism,

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25 Heinz Werner and Seymour Wapner, "Sensory Tonic Field Theory of Perception," Journal of Personality, Vol. 18, 1949, p. 88-107.

26 --------, "Experiments on Sensory-Tonic Field Theory of Perception: IV. Effect of Initial Position of Rod on Apparent Verticality," Journal of Experimental Psychology, Vol. 43, 1952, p. 66-74.

27 --------, op. cit., 1949, p. 91.

its tonus, included visceral factors, musculo-skeletal tension as well as proprioceptive and kinesthetic input at a particular point in time. Being dynamic in interaction, stimulus and organismic factors were recognized as being in natural constant flux with a biological tendency towards maintaining or re-establishing a stable relationship or equilibrium.[28,29,30]

As behavior was considered in relation to the context of total organismic activity, it followed that changes in perception could be induced as a function of change in either the organism or stimulus object polarity. Specifically, a change in the tonic equilibrium of the organism results in a new sensory-tonic relationship reflected in an altered perceptual experience.[31]

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28 Werner and Wapner, op. cit., 1949, p. 91.

29 --------, "Toward a General Theory of Perception," Psychological Review, Vol. 29, 1959, p. 324-338.

30 --------, "Sensory Tonic Field Theory of Perception: Basic Concepts and Experiments," Revista di Psicologia, Vol. 50, 1956, p. 315-337.

31 Seymour Wapner, "Some Aspects of a Research Program Based on an Organismic Developmental Approach to Cognition: Experiments and Theory," Journal of the American Academy of Child Psychiatry, Vol. 3, 1964, p. 192-212; 226-230.

Werner and Wapner's[32,33,34] first efforts to demonstrate this dynamic process concerned the perception of the subjective vertical. In these studies, the subject was requested to adjust a luminous rod in a dark room until it appeared vertical. This was done under various conditions, all of which disturbed through asymmetrical stimulation, the equilibrial status of the organism. Head tilt, body tilt, monaural stimulation, electrical stimulation to one side of the neck, rotary acceleration around the mid-body axis, and emotional stimulation such as fear to one-half of the body, all functioned in an equivalent manner in respect to the perceived vertical; the apparent vertical rotated in a direction relatively opposite to the side in which the stimulation was applied.

In respect to monaural stimulation, this result was replicated by Chandler.[35]

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32 Werner and Wapner, op. cit., 1949, p. 88-107.

33 S. Wapner, H. Werner and K. A. Chandler, "Experiments on Sensory Tonic Field Theory of Perception: I. Effect of Extraneous Stimulation on the Visual Perception of Verticality," Journal of Experimental Psychology, Vol. 42, 1951, p. 341-345.

34 H. Werner, S. Wapner and K. A. Chandler, "Experiments on Sensory-tonic Field Theory of Perception: II: Effect of Supported and Unsupported Tilt on the Visual Perception of Verticality," Journal of Experimental Psychology, Vol. 42, 1951, p. 351-357.

35 K. A. Chandler, "The Effect of Monaural and Binaural Tones of Different Intensities on the Visual Perception of Verticality," American Journal of Psychology, Vol. 74, 1961, p. 260-265.

A further series of experiments parallelled those on verticality by considering the judgment of eye level, this being that horizontal plane which passes through the pupil. Glick[36] observed that when a subject pressed down with his hands to force his head up against a spring, the apparent eye level shifted upwards, and when the subject pressed up to force his chin down against a spring, the apparent eye level was displaced downwards. Glick interpreted these results in respect to asymmetric body tonus although the grounds are tenuous since the experimental condition did not produce any shift in tonic symmetry. Utricular functioning may be influential in these results as illustrated by the perceived upward displacement of objects reported to occur in increased gravitational states.[37] Sziklai[38] also observed a shift in apparent eye level concomitant with alteration in proprioceptive conditions. Sziklai found that weighting the subject with a heavy vest caused a significant downward shift of the apparent eye level.

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36 J. Glick, The Effects of Static and Dynamic Extraneous Stimulation on the Apparent Horizon," unpublished Master's thesis, Clark University, 1959.

37 B. Clark, A. Graybiel and K. Maccorquodale, "The Illusory Perception of Movement Caused by Angular Acceleration and by Centrifugal Forces During Flight: II. Visually Perceived Motion and Displacement of a Fixed Target During Turns," Journal of Experimental Psychology, Vol. 38, 1948, p. 298-315.

38 C. Sziklai, Effect of Body Position and Muscular Strain on Space Localization as Measured by the Apparent Eye Level, unpublished Master's thesis, Clark University, 1961.

Under conditions analogous to those employed for exploration of verticality and eye level, the effects of tonic asymmetry on the median plance (straight ahead) have also been investigated. Werner, Wapner and Bruell[39] found that the apparent kinesthetic straight ahead shifted in a direction opposite to the side of head turn when the subjects were required to keep their eyes straight ahead. The angle of head turning was not specified, however, and one could question how they ensured that subjects' eyes were kept straight. Akishige[40] has also reported an increase in variability of judgment of the median plane with head tilting in the sagittal plane.

McFarland, Werner and Wapner[41] reported a shift in the apparent straight ahead in the opposite direction to head or head and body tilt. Subjects were asked to set a rod to the median plane with eyes closed under the two conditions of tilt.

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39 H. Werner, S. Wapner and J. G. Bruell, "Experiments on Sensory-tonic Field Theory of Perception: VI. Effect of Position of Head, Eyes, and of Object on Position of the Apparent Median Plane," Journal of Experimental Psychology, Vol. 46, 1953, p. 293-299.

40 Y. Akishige, "Experimental Researches on the Structure of the Perceptual Spaces," quoted in Howard and Templeton, op. cit., p. 288.

41 J. H. McFarland, H. Werner and S. Wapner, "The Effect of Postural Factors on the Distribution of Tactual Sensitivity and the Organization of Tactual-Kinesthetics Space," Journal of Experimental Psychology, Vol. 63, 1962, p. 148-154.

The position of the eyes has also been reported to affect the apparent position of the straight ahead. Goldstein and Riese[42] and Werner et al.[43] found that with eyes turned right, the apparent straight ahead is shifted in the same direction. In their conclusion to this report, Werner et al.[44] state that with eyes closed and deviated, the apparent median plane shifted in an opposite direction to that in which the eyes were turned.

A series of studies in this area by Werner and his associates pertained to the relationship between stimulus and apparent location of one's body under variations in body tilt.[45,46] In these experiments a luminous rod is adjusted to the perceived position of the longitudinal body axis. There is agreement that in this condition the apparent mid-body axis is over-estimated between one and seven degrees.

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42 K. Goldstein and W. Riese, "Uber Induzierti Veranderungen des Tonus: III. Blickrichtung und Zelgeversuch," quoted in Howard and Templeton, op. cit., p. 288.

43 Werner, Wapner and Bruell, op. cit., p. 293-299.

44 Ibid.

45 S. Wapner and H. Werner, "Experiments on Sensory-tonic Field Theory of Perception: V. Effect of Body Status on the Kinesthetic Perception of Verticality," Journal of Experimental Psychology, Vol. 44, 1952, p. 126-131.

46 M. Bauermeister, H. Werner and S. Wapner, "The Effect of Body Tilt on Tactual-kinesthetic Perception of Verticality," American Journal of Psychology, Vol. 77, 1964, p. 451-456.

McFarland _et al_.[47] and Bauermeister[48] also found that subjects showed an increasing displacement with the angle of body tilt. It is of interest that the average error factor in the extrapersonal judgment of rod verticality exceeds that of body verticality in conditions of body tilt.[49]

Although Werner and Wapner have contrasted the roles of visual and postural factors in perceptual experience, this phenomenon does not appear restricted to this one modality. Thus, Liebert and Rudel,[50] in a developmental study of seventy blind-folded subjects between five and seventeen years of age, observed that sound was localized towards the side of body tilt twenty-five degrees left and right of vertical.

A relevant contrast and prologue to these studies is an investigation by Freilicher[51] who induced symmetric

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47 J. H. McFarland, S. Wapner and H. Werner, "Relation between Perceived Location of Objects and Perceived Location of One's Own Body," _Perceptual and Motor Skills_, Vol. 15, 1962, p. 331-341.

48 M. Bauermeister, "Effect of Body Tilt on Apparent Verticality, Apparent Body Position and Their Relation," _Journal of Experimental Psychology_, Vol. 67, 1964, p. 142-147.

49 Wapner, _op. cit_.

50 R. S. Liebert and R. G. Rudel, "Auditory Localization and Adaptation to Body Tilt: A Developmental Study," _Child Development_, Vol. 30, 1959, p. 81-90.

51 J. Freilicher, _Effect of Symmetrical Extraneous Stimulation on the Position of the Apparent Median Plane_, unpublished Master's thesis, Clark University, 1963, 101 p.

muscular tonus in three ways: (1) two four-degree prisms were worn to increase eye convergence beyond that normally required for binocular vision; (2) seven-pound weights were held in each hand; and (3) the presence of a constant binaural tone. All three conditions caused a significant reduction in the variance of settings of a vertical line to the straight ahead position. The heightened organismic tonus was interpreted as providing increased proprioceptive cues and therefore decreasing fluctuation in performance.

The basic conclusion that may be drawn from these studies is that a change in the symmetry of body tonus results in an altered perceptual-motor experience reflected in a predictable displacement of spatial axes. This phenomenon appears to become apparent when the integration of the two halves of the body is altered or disturbed so as to render difficult tonic comparison of one side against the other. Unfortunately, such concepts as an emerging "tendency in the organism to change its state in the direction towards establishment of equilibrium between body and object" are considered explanatory but in fact are descriptive of the behavior observed.[52] Werner and Wapner and associates pay little heed to the complexities of the neuropsychological mechanisms involved and their procedures are vulnerable to

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52 Werner and Wapner, op. cit., 1952, p. 325.

contamination by other factors. What may be contributory to their findings, for example, is the increased arousal that would obviously accompany their experimental procedures. However, on an observable level, their research efforts do aid in highlighting a somesthetic component in spatial functioning.

(b) Cybernetic Relations

Spatially oriented behavior in the normal adult is, to a large extent, dependent on optic information. However, that blindness does not result in disorientation is certainly evidence to the fact that the visual array does not exhaust the information received by the individual; it is only the sense best understood by modern psychophysiology.[53] It would seem more reasonable on the basis of current information to accept human orientation as due to the integration of a multiplicity of cues arising both exteroceptively and within the organism itself. To suggest, as does Gibson,[54] that visual information, organized not by the central nervous system but inherent in the optic array, is sufficient for spatial-perceptual orientation, is to ignore that the organism also receives information about

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53 Warren and Pick, op. cit., p. 430-432.

54 Gibson, op. cit., p. 266-286.

its own activity and that this might have a direct effect upon spatial behavior.

The research generated by Werner and Wapner considered the relationship between exteroceptive stimuli (primarily optic) and somatosensory (tonic) factors in perception through the inducement of asymmetry. Other investigators have considered the role of optic and non-optic parameters by varying them either singly or in combination and observing the effect on perception. The basic issues in these studies are the conditions and central variables underlying spatially oriented behavior.

Cybernetic models of orientation again emphasize a bilaterally harmonious afferent-efferent relationship in which each subserves the other towards the organization and orientation of behavior.[55,56,57] Feedback, in terms of a multiple feedback system is considered the mediating mechanism that allows for on-going coordination and adjustments of spatially oriented behavior. Thus, Wiener states

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55 N. Wiener, Cybernetics, New York, John Wiley and Sons, 1948, 212 p.

56 J. Paillard, "The Patterning of Skilled Movements," in Handbook of Physiology, Vol. 3, American Physiological Society, Washington, 1960, p. 1679-1708.

57 K. Smith, J. Gould and L. Wargo, "Sensory Feedback Analysis in Medical Research. II. Spatial Organization of Neuro-behavioral Systems," American Journal of Physical Medicine, Vol. 43, 1964, p. 49-84.

the central concept common to all system or control models as follows:

> For effective action on the outer world it is not only essential that we possess good effectors--but that the performance of these effectors be properly monitored back to the central nervous system, and that the readings of these monitors be properly combined with other information coming in from the sense organs to produce a properly proportional output to the effectors.[58]

The neural processes involved in the interaction and coordination of temporal-spatial behavior are no doubt complex and models appear to be more abundant than established neurodynamics. In general, two basic types of servomechanisms appear to characterize these feedback systems.[59] Those directly related to the receptors in the muscle to be controlled and the adjacent joints and tendons are referred to as output-informed. An example of this first type of servomechanism, then, would be the gamma-afferent system which inputs information to the cerebellum and other central integrative centers to permit feedback control of individual muscular action.[60] The second class of servomechanism has been termed input informed and

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58 Wiener, op. cit., p. 114.

59 Paillard, op. cit., p. 1679-1708.

60 S. W. Kuffler and C. C. Hunt, "The Mamillian Small Nerve Fibres: A System for Efferent Nervous Regulation of Muscle Spindle Discharge," Research Publications of the Association of Nervous and Mental Diseases, Vol. 30, 1952, p. 24-47.

functions to mediate between central nervous system structures. The cerebral-cerebellar-cerebral circuit is probably an important component of this type of servomechanism. Ruch[61] considers the cerebellum analogous to the comparator of electromechanical servomechanisms. It compares the command of the cerebral cortex with feedback from the muscle spindles to arrive at modifications in cerebral output and peripheral muscle response in the service of precise movement.

The relationship between output-informed feedback and spatial functioning is, perhaps, within this context, illustrated by the research presented on sensory-tonic relations. Here, the role of proprioceptive cues in relation to body symmetry is delineated. However, the local or specific factors necessary for perception do not reveal the role that these elements play in the wholistic, organized process. To this end, the position of input-informed processes has assisted in the evolving conception of spatial behavior as an interaction between peripheral input and feedback, be they exteroceptive or proprioceptive (here used in the broadest sense), and central parameters.

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61 T. C. Ruch, "Motor Systems," in S. S. Steven (ed.), Handbook of Experimental Psychology, New York, John Wiley and Sons, 1952, p. 24-47.

Von Holst[62] was the first to postulate a direct hypothesis pertaining to the mutual involvement of peripheral and central factors that led to a greater understanding of the self-organization of the spatial process. To Von Holst, orientation requires the capacity to distinguish between changes in the external world (exafference) and sensory stimulation contingent upon self-produced movement (reafference). The organism is said to store efferent commands in the brain and compare the arising input with the 'efferent copy' of that command. Modification of behavior is then a function of discrepancy between input and 'efferent copy' of the behavior desired.

Von Holst and Mittelstaedt[63] performed a series of experiments with a fly to illustrate that the organism records relations between itself and the environment. The optic condition was held constant, a striated black and white cylinder. If the cylinder was rotated to the right, for example, the fly would track in the same direction due to the optokinetic reflex. This reflex is substantiated by tracking movements opposite to the movement of the cylinder

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62 E. Von Holst, "Relations between the Central Nervous System and the Peripheral Organs," British Journal of Animal Behavior, Vol. 2, 1954, p. 89-94.

63 E. Von Holst and H. Mittelstaedt, "Das Reaferenz Prinzip," Die Naturwissenshaften, Vol. 20, 1950, p. 464-476.

when the fly's head is surgically rotated 180 degrees in relation to the body. In this condition, the visual signals are reversed and 'interpreted' as such. In another experiment, a stimulus such as a smell was placed left of the fly with the cylinder stationary. The fly moved towards the smell, thus producing the same visual input as if the cylinder was moving to the right and the fly was stationary. In this situation, the fly does not perceive motion of the environment to the right as indicated by the lack of the tracking response. Von Holst and Mittelstaedt interpreted this result as indicating that the information gained from efference contributed to the 'interpretation' of the afferent input. To clarify this process, they again surgically rotated a fly's head. In this case there is the same afference but the reafference (that is movement of the visual field across the retina) is reversed. Thus, the fly begins towards the left (efference) and will continue to move in small circles until exhausted. They further showed that this only occurs in a textured environment and not in a visually homogeneous one. Thus, even at this low phylogenetic level, visually processed feedback contingent upon movement was shown to be essential for spatial guidance or orientation. Hence, in the final experiment there is efference as well as reversed and therefore contradictory reafference due to surgery leading to the disorientation of behavior and the perpetual non-adaptive circling.

The idea that the motion of an organism produces feedback that is centrally processed ('interpreted') and compared with the receptor input to guide movement was further explored by Sperry[64] who also observed repetitive circular activity in fish when an eye was surgically rotated 180 degrees. Sperry referred to this central relevant process as "a corollary discharge into the visual centers to compensate for the retinal displacement" occurring with "any excitation pattern that normally results in a movement that will cause a displacement of the visual image of the retina."[65] This is basically the same concept as Von Holst's efferent copy.

A further test of the role of the central nervous system comparison of afferent and efferent signals arises from experiments by von Helmholtz.[66] Von Helmholtz paralyzed the external rectus muscle of the eye so as to immobilize

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64 R. W. Sperry "Neural Basis of the Spontaneous Optokinetic Response Produced by Visual Inversion," Journal of Comparative and Physiological Psychology, Vol. 43, 1950, p. 482-489.

65 Ibid., p. 488.

66 H. Von Helmholtz, Treatise on Physiological Optics, Vol. 3 (3rd ed.), P.C. Southhall (ed and trans.), Optical Society of America, Menasha, Wisconsin, 1925.

its movement. It was found that on the command to look to the right, individuals perceived motion of the environment to the right. Thus, perception is clearly non-optically derived in this case. Since the efferent command to the eye to move to the right is normally followed by reafference due to that movement, the organism perceives a compensatory movement by the environment instead. Von Holst elaborated on this study by turning the subject's paralyzed eye to the right mechanically.[67] He stated that in this case there is no efference (central nervous system command) nor is there an efferent copy. There is, however, afference which is processed cortically without an efferent copy or reafference. As would be hypothesized from his theory, a compensatory movement of the environment to the left would be perceived, which was the case. However, when the command to move the eye is given under the same paralyzed condition, and the eye is moved mechanically, the normal situation is simulated and no environmental motion is perceived. This clearly demonstrates that perception of a stationary environment requires a voluntary organism-environment relationship; secondly, that a perceptual illusion will occur if the organismic output and feedback mechanism are shunted while retaining optic input. The

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67 Von Holst, op. cit., p. 89-94.

illusion is in essence a compensatory transfer to the environment of the motion of the organism and reflects the inseparable organism environment relationship in the perceptual process.

In general, the above studies seem to indicate the importance of the self-monitoring function of the central nervous system. Specifically, there is an on-going interaction of monitored behavior with exteroceptive input which is interpreted by some mechanism utilizing copy and comparison. This central system whereby an organism can be aware of its own activity may, as suggested by Konorski,[68] involve the cerebellum and its cortical-peripheral connections.

The role of self initiated movement in spatial orientation, which was stressed by Von Holtz and others[69,70,71] has been further elaborated by studies on the relation

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68 J. Konorski, Integrative Activity of the Brain, Chicago, University of Chicago Press, 1967, 531 p.

69 J. W. Gyr et al., "Computor Simulation and Psychological Theories of Perception," Psychological Bulletin, Vol. 65, 1966, p. 174-192.

70 L. Festinger et al., "Efference and the Conscious Experience of Perception," Journal of Experimental Psychology Monograph, Vol. 74, 1967, Whole No. 637.

71 J. W. Gyr, "Is a Theory of Direct Visual Perception Adequate?" Psychological Bulletin, Vol. 77, 1972, p. 246-261.

between perception and voluntary motion initiated by Held[72] and his associates.

Held and Freedman[73] suggest that human orientation depends upon the buildup of a complex yet isomorphic relationship between motor output and its contingent feedback (reafference). The central nervous system is both the source of movement and the receiver of feedback information. As do Werner and Wapner,[74] Held resists the supposition that:

> [...] the neurological processing of sensory input is independent of the organization of motor action, that is against the assumption that the analysis of sensory input preparatory to motor acts occurs solely in the course of a chain of neural events traversing the sensory projections but completed prior to the impingement of motor centers in the brain.[75]

Held's theoretical position is similar to the one proposed by von Holst except for the addition of the memory component referred to as the "correlation storage [...] which retains traces of previous combinations of concurrent efferent and reafferent signals."[76]

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73 R. Held and S. J. Freedman, "Plasticity in Human Sensorimotor Control," Science, Vol. 142, 1963, p. 455-462.

74 Werner and Wapner, op. cit., 1949, p. 88-107.

75 R. Held, "The Role of Movement in the Origin and Maintenance of Visual Perception," in Proceedings of the XVII International Congress of Psychology, Amsterdam, 1964, p. 141.

76 --------, "Exposure History as a Factor in Maintaining Stability of Perception and Coordination," Journal of Nervous and Mental Diseases, Vol. 132, 1961, p. 30.

Hein and Held[77] reared kittens with one eye open in an active condition and with the other open in a passive condition in an illuminated textured surrounding. The active condition allowed the kitten its own locomotion whereas in the passive situation the kitten was transported in a gondola. After several months of such exposure, stimulation resulted in normal sensory motor coordination when the active condition eye was visually stimulated, whereas the other was considered functionally blind. Held interpreted the findings to "clearly implicate the motor system in processes traditionally regarded as sensory."[78]

Held and Hein[79] also observed that only those cats allowed voluntary motion in development revealed behavioral evidence of depth perception and evidence of visually adaptive paw placement when confronted with the visual cliff experiment of Walk and Gibson.[80]

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77 A. Hein and R. Held, "A Neural Model for Labile Sensori-motor Coordinations," in E. E. Bernard and M. R. Kare (eds.), Biological Prototypes and Synthetic Systems, Vol.1, New York, Plenum Press, 1962.

78 Held, op. cit., 1964, p. 309.

79 R. Held and A.V. Hein, "Movement-produced Stimulation in the Development of Visually Guided Behavior," Journal of Comparative and Physiological Psychology, Vol. 56, 1963, p. 872-876.

80 R. D. Walk and E. A. Gibson, "A Comparative and Analytical Study of Visual Depth Perception," Psychological Monographs, Vol. 75, 1961, Whole No. 519.

Using prism lenses to induce optic disarray, Held and his colleagues have also compared the effectiveness of self produced movement with that of passive movement in the readaptation of visual motor coordination in human adult subjects. With an apparatus described by Held and Gottlieb,[81] Held and Hein[82] and Held and Freedman[83] had subjects mark on a piece of paper the apparent position of the corners of a square. The subject's hand was under a mirror and the subject saw an image of the target square but could not see his hand nor the marks on the paper. After ten trials, withdrawing the hand each time so as to have to re-position it on each successive trial, the mirror was withdrawn along with the square, and a prism was introduced. The subjects were allowed to view their hand for three minutes under one of three conditions: (1) the hand was motionless; (2) the hand was moved passively from side to side by the experimenter; or (3) the individual actively moved his own hand. The pre-testing procedure was then repeated. The results indicated that only the active

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81 R. Held and N. Gottlieb, "Technique for Studying Adaptation to Disarranged Hand-eye Coordination," Perceptual and Motor Skills, Vol. 8, 1958, p. 83-86.

82 R. Held and A. Hein, "Adaptation of Disarranged Hand-eye Coordination Contingent upon Re-afferent Stimulation," Perceptual and Motor Skills, Vol. 8, 1958, p. 87-90.

83 Held and Freedman, op. cit., p. 455-462.

movement condition produced a significant compensatory adaptation to the image displacement. The results were interpreted as indicating the important role of reafferent stimulation in visual-motor adaptation.

However, as Howard and Templeton[84] note from their research, although active training is better than passive training, knowledge of results in the passive and active conditions (that is, a target or reference point during observation of one's hand) decreases the discrepancy of readaptation between them.

Perhaps pertinent to these findings, as well, are the psychophysiological observations of Konorski[85] that electro-cortical stimulation of the primary motor region will not lead to operant or instrumentally conditioned learning. The voluntary activity of the nervous system rather than enforced movements appear to be a prerequisite condition. Stating it somewhat figuratively, this may indicate that a cortical issuance of command may precede voluntary activity in the production of spatially coordinated behavior.

Complementary to Konorski's observations are the recent experiments on the deafferentiated limb. Although

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84 Howard and Templeton, op. cit., p. 387.

85 Konorski, op. cit., p. 485.

Sherrington[86] reported no functional return after deafferentiation, it is now reported this only occurs when one limb is involved, the other remaining normal. Where both hind limbs of an animal are deprived surgically of afference, learning of conditioned responses utilizing these limbs does normalize after surgical recovery.[87,88,89] The effect of unilateral deafferentiation on learning in animals is of particular importance to this research as it, in part, parallels the peripheral (leg) status of the hemiplegic. In this experimentally induced condition, there is volition to respond but asymmetrical sensory feedback. It appears that the sensory loss interferes with the resumption of learning responses related to the limbs in question and may be said to have priority over cerebral intent as a sufficient condition for functional return of the limb.

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86 C. S. Sherrington, "Quantitative Management of the Contraction in Lowest Level Coordination," Brain, Vol. 54, 1931, p. 1-28.

87 A. J. Berman et al., "Conditioned Behavior Following Sensory Isolation in Primates," Transactions of the American Neurological Association, Vol. 89, 1964, p. 185-186.

88 T. Gorska and E. Jankowska, "The Effect of Deafferentiation on Instrumental (Type II) Conditioned Reflexes in Dogs," Acta Biologiae Experimentalis, Vol. 21, 1961, p. 219-234.

89 E. Taub, R. Bacon and A. J. Berman, "The Acquisition of a Trace-conditioned Avoidance Response after Deafferentiation of the Responding Limb," Journal of Comparative and Physiological Psychology, Vol. 56, 1963, p. 1012-1016.

The cumulative impact of the above studies in sensory-tonic and cybernetic relations is to suggest the following conclusions:

1. No particular modality is sufficient in itself to maintain spatial orientation although stimuli from without and within the body are necessary components in the over-all function.

2. Models of spatial orientation are in accord with a poly-integrational framework with emphasis on the integrative capacity of the organism.

3. Integrated and therefore accurate spatial orientation is closely allied functionally with bilaterally symmetrical afferent processing of information arising from the tonic state of the organism in its relations with the environment.

4. Feedback, both intra- and extra-organismic, especially when contingent upon movement, aids in shaping spatially oriented behavior.

5. The neurological correlate of cerebral intention (efferent command) and self-initiated movement play an important role in spatial perceptual learning and behavior.

6. The central nervous system would appear to monitor its own behavior in respect to the body and the environment and actively copies, compares, and judges rather than "resonating"[90] to the ambient optic array.

2. Spatial Disorientation in Left Hemiplegia.

Having discussed dynamics of human spatial orientation from an organismic perspective, it remains to relate

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90 J. J. Gibson, "What Gives Rise to the Perception of Motion?" Psychological Review, Vol. 75, 1968, p. 335-346.

these thoughts and findings to spatial dysfunction in left hemiplegia. The literature is presented under two major headings: (A) the clinical syndrome, and (B) cerebral asymmetry. The discussion endeavors to provide a rationale for directly treating the sensory input and feedback processing deficit which, it is maintained, exercises an important role in the spatial disturbance accompanying the illness.

A. The Clinical Syndrome

As noted by Diller[91] and Bogen,[92] the accumulation of literature on lateralized cerebral deficits would indicate a dominance of the right hemisphere for visual spatial skills. Bogen,[93] in a review of the minor hemisphere's role, notes that its actual function is only vaguely understood and thus loosely described. One can easily confirm Bogen's conclusion by asking the general psychological clinician what is really meant by perceptual motor

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91 Leonard Diller, "Perceptual and Intellectual Problems in Hemiplegia: Implications for Rehabilitation," Medical Clinics of North America, Vol. 53, 1969, p. 575-583.

92 J. E. Bogen, "The Other Side of the Brain II: An Appositional Mind," Bulletin of the Los Angeles Neurological Societies, Vol. 24, 1969, p. 135-162.

93 *Ibid.*, p. 149-150.

functioning. The vagueness of the response usually obtained no doubt reflects on our basic lack of knowledge with respect to the duty of the right hemisphere. Bogen settles arbitrarily for the word "appositional" as compared to the "propositional"[94] or symbolic functional dominance of the left hemisphere. By the term appositional, he implies a capacity for comparison of stimuli, percepts, schemas, etc. Bogen is inspired to add that this is a useful term in that it is ambiguous and implies little else than a comparative function.

The ambiguity of the acquired right hemisphere's specificity in the human adult is more than matched by the extensive literature identifying and describing the cluster of symptoms associated with right hemispheric impairment, especially those accompanying posterior parietal-temporal lesions.

Twenty years ago, Critchley[95] in a review of parietal lobe disease commented on the semantic difficulties arising from this host of descriptive clinical literature. He includes a sample of terminology of which the student of the field is confronted:

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94 Ibid., p. 150.

95 Macdonald Critchley, The Parietal Lobes, 4th ed., New York, Hafner Publishing Co., 1971, 480 p.

> Spatial agnosia, visuospatial agnosia; visual disorientation; agnosia for spatial orientation; agnosia for spatial relationships; apraxia for spatial articulation; apractagnosia for spatial articulation; disordered visual space perception; disturbance of spatial imagery; planotopoknesia; visual constructive derangement or disability; disturbances of geometrical vision; inaccurate spatial localization; spaceblindness; loss of abstract spatial relations; deformation of visual coordinate; disorganization of discriminative spatial judgment; impaired sense of spatial imagery.[96]

To add clarity, Table I presents some of the identified symptoms of right hemispheric impairment and clearly reflects that the symptomatology is in part a function of the test stimuli. The essential question that has been proposed by Benton[97] and Diller,[98] among others, is whether these are not reducible to one or a few fundamental defects in spatial organization with a host of possible manifestations. Although an intuitive organization is by no means objective, one may isolate at least five general areas of failure: (1) non-verbal spatial transformations including recognition, comparison and judgment; (2) general construction; (3) graphomotor construction; (4) pathfinding; and

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96 Ibid., p. 326.

97 A. L. Benton, "Construction Apraxia: Some Unanswered Questions," in A. L. Benton (ed.), Contributions to Clinical Neuropsychology, Chicago, Aldine Publishing Co., 1969, p. 129-141.

98 L. Diller et al., Studies in Cognition and Rehabilitation (final report), Project No. R. D. 2666-P, Department of Health, Education and Welfaire, Washington, 1971, 204 p.

Table I.-

Some Identified Neuropsychological
Symptoms in Left Hemiplegia.

Author[a]	Symptom
Friedlander	Spatial Dyscalculia
McFie and Zangwill	Construction Apraxia
Critchley	Dressing Apraxia
Heilbrun	Block Design
McFie	Memory for Design
Fitzhugh	Object Assembly
McFie	Picture Arrangement
McFie and Zangwill	Block Counting
McFie and Zangwill	Paper Cutting
Piercy	Progressive Matrices
Teuber	Rate of Necker Cube Reversals
Semmes	Route Following
Kimura	Recognition of Unfamiliar Objects
McFie	Time Estimation
Bruell	Verticality Perception
Diller	Short Term Visual Memory
Weinberg	Scanning

a References are given in Appendix 1.

(5) activities of daily living (ADL)--dressing and eating. Graphomotor are considered independent of general construction tasks in keeping with Benton's[99] findings that there may be differences in the quality of performance of these two types of tasks within individual left hemiplegics. In general, however, and evidenced clinically, these major areas of dysfunction are highly intercorrelated and, to preface the literature which follows, are predictable from the degree of somesthetic sensory loss of the patient. In fact, sensory integrity, excluding primary visual field deficit, is the one underlying variable providing a reliable scale of expected disorientation in spatial behavior. This correspondence of somatosensory and spatial parameters may well provide excellent common ground for a deeper analysis of the problem. It also may provide a logical bridge between organismic interaction in normal spatial orientation and the disability in spatial activity evidenced in left hemiplegia.

The interrelationship between sensory loss, perceptual dysfunction and functional loss in hemiplegia is central to the neuro-developmental relearning model of physical treatment espoused by Bobath.[100] Working within

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99 Benton, op. cit., p. 129-141.

100 B. Bobath, Adult Hemiplegia: Evaluation and Treatment, London, William Heinemann Medical Books Ltd., 1970, 159 p.

this perspective, Lerner[101] reports a common experience among physical therapists treating left hemiplegics:

> We found that with some patients we were not as successful in producing gait improvement as with others in whom the motor deficit may even have appeared more severe. Even with near normal motor return they were clumsy, gait was stiff and strained, and balance was poor.

She adds:

> The reason [...] that some patients did not utilize their motor ability to their maximum efficiency, was the superimposition of perceptual dysfunction on the motor deficiency.[102]

The left hemiplegic's dilemma, it would seem, is one in which the normal avenues by which spatial orientation is achieved and maintained are thereafter defective. As indicated in the discussion on normal spatial behavior, the harmonious functioning of the sensory modalities, its resultant body awareness, bilaterally coordinated input and output, feedback contingent upon movement, and cerebral intent and perceptual judgment are all necessary components. These are all deficient in hemiplegia and contribute to the behavioral difficulties observed.[103,104]

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101 S. Lerner, "Lack of Movement Efficiency in C.V.A. Patients with Perceptual Dysfunction," Journal of the Canadian Physiotherapy Association, Vol. 22, 1970, p. 59-62.

102 Ibid., p. 59.

103 Ibid.

104 Carol Leiper, "The Left Hemiplegic: Discrepancies Between Actual and Presumed Abilities," Journal of the Canadian Physiotherapy Association, Vol. 23, 1971, p. 159-162.

The reality of this permanent disability is reflected in the number of C.V.A. patients who remain in a dependent or semi-independent state following active rehabilitation. Averaging the estimated functional recovery statistics reported by Rankin,[105] Lowenthal _et al_.[106] and Ginsburg,[107] 65.2 percent of all hemiplegics are only partially rehabilitated or non-rehabilitated following treatment. From a vocational perspective, under ten percent of the hemiplegic patients in the United States return to a working life.[108]

To further explore the question of disorientation and its functional sequalae, literature is now presented bearing on the effects of right hemispheric impairment on the system of spatial coordinates upon which is built up the image of the external world. This particular area is

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105 J. Rankin, "Cerebral Vascular Accidents in Patients over the Age of 60," _Scottish Medical Journal_, Vol. 2, 1957, p. 127-136.

106 M. Lowenthal, J. S. Tobis and I.R. Howard, "Analysis of the Rehabilitation Needs and Prognosis of 232 Cases of Cerebral Vascular Accident," _Archives of Physical Medicine_, Vol. 40, 1959, p. 183-186.

107 L. Ginsburg, "Problems of Rehabilitation in Hemiplegics," _Harefuah_, Vol. 60, 1961, p. 351-356.

108 Diller _et al_., _op. cit_., p. iii.

chosen in that it is a well documented symptom and one explored in the literature cited on normal orientation.

Teuber and his associates[109,110,111] focused on a specific aspect of spatial orientation, that is, route following by means of maps, in order to decipher more accurately neuroanatomic concomitants and underlying defects in the more general syndrome. Their samples consisted of war veterans most of whom suffered from gun-shot wounds. In two earlier studies the experimental group consisted of sixty-two men with eighteen control subjects suffering from peripheral nerve injuries to the leg. In the first study, they showed that defective performance on a visual map test was apparent in subjects with parietal lobe lesions of either hemisphere.[112] The parietal lobe group performed significantly poorer than the control group as well as brain-injured subjects without a parietal lobe locus of injury.

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109 J. Semmes, S. Weinstein, L. Ghent and H. L. Teuber, "Performance on Complex Tasks after Brain Injury in Man: Analysis by Locus of Lesion," Journal of Psychology, Vol. 39, 1955, p. 227-244.

110 S. Weinstein et al., "Spatial Orientation in Man after Cerebral Injury: II. Analysis According to Concomitant Defects," Journal of Psychology, Vol. 42, 1956, p. 249-263.

111 J. Semmes et al., "Correlates of Impaired Orientation in Personal and Extrapersonal Space," Brain, Vol. 86, 1963, p. 747-772.

112 Semmes et al., op. cit., 1955, p. 227-244.

In a follow-up study, fifteen maps were administered sequentially to each subject, five visual and ten tactual. Of the latter ten maps, five were presented to each hand.[113] Prior to administering the maps procedure, general intelligence was assessed by the Army General Classification Test, along with a neuropsychological evaluation including aphasic symptomatology, evidence of epilepsy, visual fields, proprioception, Von Frey Tactile Thresholds, two point tactile thresholds, error of localizing a point on the center of the palm, and measures of decreased somatosensory functioning following serial testing of tactile and two point discrimination thresholds.

Z score transformations were made and a total sensory score was calculated for each individual. Three groups, reflecting no sensory loss (non-sensory), minimal, and severe sensory deficit, respectively, were then formed.

Controlling for intelligence, the group with severe sensory defect performed more poorly than the less affected group ($p < .02$), the non-sensory group ($p < .001$), and the control subjects ($p < .001$). The control group, non-sensory and minimal sensory defect group did not differ significantly from one another.

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113 Weinstein et al., op. cit., p. 249-263.

The lowest mean score was obtained by subjects with both sensory defect and parietal lobe lesions. The next lowest performance was by subjects with somesthetic deficit whose locus of lesion was not parietal. Thus, it was demonstrated that spatial disorientation on this task was not modality specific and that the chief concomitant was not locus of lesion but the presence of somesthetic defect. In a later article, two point tactile threshold was shown to be the most accurate independent predictor of visual or tactile map performance.[114] In this case, brain-damaged subjects with two point discrimination deficit performed significantly poorer than brain-damaged subjects without this defect ($p < .01$).

The authors conclude that disorientation is not a visual agnosia but a more general spatial one, and that route finding ability and somesthetic functions may share a common neuro substrate.[115] In 1963, arriving at the same result with respect to map following (extrapersonal orientation), they added:

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114 Semmes _et al_., _op. cit_., 1963, p. 747-772.

115 _Ibid_., 1955, p. 227-244.

> Somato-sensory defects (in two point discrimination) were associated with poor performance on the extrapersonal task. This relationship may merely reflect partial coincidence of the loci of lesion. Alternatively there may be a functional relationship; disorientation seems rarely to occur without an accompanying sensory defect, although the converse is common. Changes in cerebral somato-sensory processes may be a contributory factor in the impairment.[116]

Butlers and Barton[117] investigated the ability of right and left hemisphere impaired subjects to manipulate extracoporial space <u>in imagio</u>. Utilizing the tasks of Piaget and Inhelder,[118] constructed to assess development of reversible space operations, they observed that the patients with right parietal damage were significantly impaired in respect to a left parietal group on the 'village scene task.' The degree of rotation disturbance was significantly related to graphomotor construction defects.

In a second study, sixteen male subjects with right hemispheric damage (nine C.V.A. patients) and nine control subjects were administered intra- and cross-modal matching tasks and three tests of reversible operations.[119]

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116 Semmes <u>et al</u>., <u>op. cit</u>., 1963, p. 770.

117 N. Butlers and M. Barton, "Effect of Parietal Lobe Damage on the Performance of Reversible Operations in Space," <u>Neuropsychologica</u>, Vol. 8, 1970, p. 53-60.

118 Piaget and Inhelder, <u>op. cit</u>., 490 p.

119 N. Butlers, M. Barton and B. A. Brody, "Role of the Right Parietal Lobe in the Mediation of Cross-modal Associations and Reversible Operations in Space," <u>Cortex</u>, Vol. 6, 1970, p. 174-190.

When compared with the performance of left parietal lobe-damaged subjects obtained in earlier studies, it was observed that in intra-modal matching, the right- and left-damaged subjects were equally impaired, whereas in cross-modal matching the performance of left-damaged subjects was significantly poorer than the right impaired group. In contrast, the right-damaged subjects were more impaired than the left group on rotations, especially on the village scene test. It is suggested that the right hemisphere mediates spatial rotations to a greater degree than the left, whereas the left hemisphere is more involved in cross-modal associations. Yet, the results do not reflect clear differences in regard to mean levels of performance. The capacity to appreciate perspective from different viewpoints, which it appears is impaired in parietal lobe disease, may, however, add to the difficulties experienced by right hemisphere damaged subjects in the route following experiment of Teuber and his associates.[120]

Bender and Teuber[121] clinically scrutinized twelve patients with parietal-occipital involvement due to wounds incurred in war. After describing the maze of symptoms of

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120 Semmes et al., op. cit., 1963, p. 747-772.

121 M. B. Bender and H. L. Teuber, "Spatial Organization of Visual Perception Following Injury to the Brain," Archives of Neurology and Psychiatry, Vol. 59, 1948, p. 36-62.

spatial disorientation observed in their evaluations, they concluded: "Evidently, the patients behaved as though the subjective coordinates of their visual space had been permanently altered."[122]

A persistent and systematic change in the subjective axes of external space has subsequently become a major area of inquiry in hemiplegia.

Bruell et al.[123,124] considered the sensory-tonic theory in respect to unilateral brain damage resulting in hemiplegia. In their first report, they summarized the implications of this theory in respect to hemiplegia as follows:

> We hypothesize that, if short lived states of asymmetrical tonus lead to temporary disturbances of space perception, hemiplegic patients, who have a permanently asymmetrical distribution of tonus, should show permanent disturbance of space perception.[125]

Their findings in both studies confirmed this hypothesis in respect to the perceived vertical among left

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122 Ibid., p. 62.

123 J. H. Bruell, M. Peszczynski, and G. W. Albu, "Disturbance in Perception of Verticality in Patients with Hemiplegia: Preliminary Report," Archives of Physical Medicine, Vol. 37, 1956, p. 677-680.

124 J. H. Bruell and M. Peszczynski, "Perception of Verticality in Hemiplegics in Relation to Rehabilitation," Clinical Orthopedics, Vol. 12, 1958, p. 124-128.

125 Bruell et al., op. cit., 1956, p. 677.

and right hemiplegics.[126,127] However, no directional consistencies were noted in rotation and the greatest difference between hemiplegics and age-matched normal college students was in the variability of performance.

Birch _et al_.[128,129] investigated the perception of the vertical, horizontal and median planes in hemiplegic subjects. Twenty-two right and twenty-one left hemiplegics performed significantly poorer in their judgments of the horizontal and vertical axes as compared to a normal control group. Left hemiplegics tended to rotate the rod in a counterclockwise direction, whereas right hemiplegics tended to displace the rod in a clockwise direction. Hemiplegics also tended to perceive the median plane (midline) towards the affected side. The close agreement between the extent and direction of vertical and horizontal rotation in hemiplegics supported a strong intra-individual consistency. They state: "This suggests that the damage sustained has resulted in a given stable alteration of visual orientation in space."[130]

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126 _Ibid_.

127 Bruell _et al_., _op. cit_., 1958, p. 124-128.

128 H. G. Birch, F. Procter, M. Bortner, and M. Lowenthal, "Perception in Hemiplegia: I. Judgment of Vertical and Horizontal by Hemiplegic Patients," _Archives of Physical Medicine_, Vol. 41, 1960(a), p. 19-27.

129 --------, "Perception in Hemiplegia: II. Judgment of the Median Plane," _Archives of Physical Medicine_, Vol. 41, 1960(b), p. 71-75.

130 --------, _op. cit_., 1960(a), p. 26.

Diller and Weinberg,[131] Bender and Jung,[132] and DeCencio *et al*.[133] have all reported a tendency for left hemiplegics to perceptually rotate the vertical in the direction of their impaired side. Diller and Weinberg[134] also noted a mild clockwise tendency in right hemiplegia. However, they found that right hemiplegics are not as deviant in their judgments as left hemiplegics, or are their judgments as variable.

In a more recent study, Diller and Weinberg[135] found that sixteen left hemiplegic subjects showed a significant systematic tendency to rotate *Bender Gestalt* figures in a counterclockwise direction. Although some evidence supported a clockwise tendency in eleven right hemiplegics, there was inconsistency among this group. By combining those

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131 L. Diller and J. Weinberg, "Learning in Hemiplegia," *American Psychologist*, Vol. 18, 1962, p. 391 (Abstract).

132 M. Bender and R. Jung, "Abweichungen der Subjektiven Optischen Vertikalen und Horizontalem bei Gesunden und Hirnverletzten," *Archives of Psychiatry*, Vol. 181, 1948, p. 193-197.

133 D. V. DeCenzio, M. Leshner, and D. Voron, "Verticality Perception and Ambulation in Hemiplegia," *Archives of Physical Medicine*, Vol. 51, 1970, p. 105-110.

134 Diller and Weinberg, *op. cit.*, 1962, p. 391.

135 --------, "Bender Gestalt Distortions in Hemiplegia," *Perceptual and Motor Skills*, Vol. 20, 1965, p. 1313-1323.

hemiplegics who tended to rotate in a counterclockwise direction on the Bender Gestalt, deviations were significantly correlated with rotations on the rod test of horizontal and vertical perception.

DeCenzio et al.[136] found that, while hemiplegics perceive verticality less accurately than normal controls in the frontal plane, only left hemiplegics perform more poorly in the midsagital (fore-aft) plane. Again, a counterclockwise tendency occurred among the left hemiplegics in the midsagital as well as frontal planes. The results, therefore, are not explainable entirely in terms of sensory-tonic theory. The observed alterations in spatial axes are tridimensional as is the normal representation of space. The right hemisphere's particular role in that representation would appear to be demonstrated in the process of maintaining a stable and objective relationship between internal representation of space and objective axes in the spatial array. That is, it permits the retention of a stable and reliable organism-environment relationship.

Comalli, Wapner and Werner,[137] in this regard, reported developmental differences in verticality perception

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136 DeCenzio et al., op. cit., p. 105-110.

137 P.E. Comalli, S. Wapner, and H. Werner, "Perception of Verticality in Middle and Old Age," Journal of Psychology, Vol. 47, 1959, p. 259-266.

among normal subjects. Estimation of the vertical axis among boys, six to fifteen years, and older men from sixty-five to eighty years, was in the direction of the side of body tilt. However, the opposite tendency was observed in the intermediate years. This apparent egocentric orientation among the young and the old was interpreted in terms of a lack of differentiation between the self and the external world. Thus, the stimulus is interpreted in terms of one's own body position. As Diller and Weinberg[138] suggest, left hemiplegia may induce an organic egocentricity paralleling the normal developmental phenomenon. Wapner and Krus[139] reported that chemically induced cerebral dysfunction (LSD-25) resulted in an egocentric orientation as well, especially in terms of starting position effect.

The phenomenon of displacement in the objective vertical is paralleled in other localization judgments by hemiplegics and is not restricted to the visual sense modality.

Birch *et al*.[140] found that in hemiplegia the position of the apparent straight ahead was shifted towards the affected side.

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138 Diller and Weinberg, *op. cit*., 1965, p. 1313-1323.

139 S. Wapner and D. M. Krus, "Behavioral Effects of Lysergic Acid Diethylamide (LSD-25)," Progress Report, NIMH Grant No. MY-2262, 1960.

140 Birch *et al*., *op. cit*., 1960(b), p. 71-75.

Goldstein[141] reported a general tendency to mislocate sounds towards the affected side in patients with cerebellar or cortical lesions with resulting postural disturbance.

Similarly, Teuber and Diamond[142] found that patients with right hemispheric impairment required greater intensity in the left ear as compared to the right during dichotic listening in order to judge a sound to be in the median plane.

Diller _et al_.[143] reported that left hemiplegics, asked to copy a ten millimeter line and bisect it, displaced the midpoint to the left.

These consistent shifts in localization tasks would appear to implicate, to some extent, the gravitational disturbance contingent upon sensory-motor deficits. This is further substantiated in a study by Birch _et al_.[144] Recognizing the somatosensory imbalance in hemiplegia, they

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141 K. Goldstein, "Uber induzierte tonusveranderungen beim menschen," 1925, quoted in Howard and Templeton, _op. cit_., p. 160.

142 H. L. Teuber and S. Diamond, "Effects of Brain Injury on Binaural Localization of Sounds," Paper read before the Eastern Psychological Association, Atlantic City, 1956, reviewed in M. R. Rosensweig, "Development of Research on the Physiological Mechanisms of Auditory Localization," _Psychological Bulletin_, Vol. 58, 1961, p. 376-389.

143 Diller _et al_., _op. cit_., 1971, p. 117-119.

144 H. Birch, I. Belmont, T. Reilly, and L. Belmont, "Somesthetic Influences on Perception of Visual Verticality in Hemiplegia," _Archives of Physical Medicine and Rehabilitation_, Vol. 43, 1962, p. 556-560.

investigated the verticality perceptions of twenty left hemiplegic subjects and eighteen non-brain damaged but orthopedically handicapped patients. Judgments of verticality were initially assessed and at a later date the procedure was repeated after applying a ten-pound weight to the left and right shoulders of the subjects, sequentially. When the weight was applied to the intact (right) shoulder of the hemiplegics, the mean constant error tripled in size. In contrast, a weight applied to the affected shoulder improved judgments only slightly but decreased the error variance. That is, the mean constant error was not significantly less but the number of errorless judgments increased for the left hemiplegics.

As is evidenced clinically, variability in cortical functioning is a major obstacle in treatment of hemiplegia. Thus, reducing error variance by the method employed by Birth _et al_.[145] is an encouraging finding, especially as the sensory prosthetic used in the experiment was both arbitrary and intuitive. As reported above, normal subjects exposed to augmented tonic symmetry conditions, reveal an attenuation in performance variability.[146] These two studies would appear to be complementary and may indicate

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145 _Ibid_.

146 Freilicher, _op. cit_., 101 p.

a normal brain damaged commonality of effect; the degree of effect, however, being less apparent in individuals with cerebral impairment and permanent tonic asymmetry.

The extent of error in judgments of verticality has proven a valid indicator of rehabilitation prognosis in hemiplegia. Bruell and Peszczynski[147] reported that patients with error scores of less than ten degree in their verticality judgments are more likely to benefit from rehabilitation than those with error scores greater than ten degrees. DeCenzio *et al*.[148] obtained a significant correlation between verticality perception in the frontal and mid-sagital planes and ambulation ratings among a sample of left hemiplegics. The correlations were insignificant in the case of right hemiplegics.

Further, somatosensory deficits on the impaired side in hemiplegia and performance in rehabilitation have also been shown to covary significantly. Van Buskirk and Webster[149] observed that defects in pain, vibratory and two point discrimination were valid predictors of outcome in hemiplegic rehabilitation.

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147 Bruell and Peszczynski, *op. cit*., 1958, p. 124-128.

148 DeCenzio *et al*., *op. cit*., p. 105-110.

149 C. Van Buskirk and D. Webster, "Prognostic Value of Sensory Defect in Rehabilitation of Hemiplegics," *Neurology*, Vol. 5, 1955, p. 407-411.

Ben-Yishay *et al.*[150] reported that two point tactile discrimination and Purdue Peg Board performance contributed to the prediction of ambulation efficiency in a hemiplegic population.

Anderson[151] reported on 271 cases of stroke. Of these, thirty percent demonstrated significant sensory deficits and remained in dependent categories of rehabilitation at the time of discharge. Seventy-two percent of left hemiplegics with hemi-anesthesia and sixty-four percent with discriminatory sensory loss were also found to have concomitant severe spatial disorientation.

Thus, somesthetic or sensory impairment would seem to be related by cause or anatomic proximity to spatial disorientation and rehabilitation prognosis in left hemiplegia. In this regard, Hurwitz has noted: "There does seem to be an association as yet ill understood, between a lesion producing such a sensory impairment and poor recovery of motor impairment in hemiplegia."[152]

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150 Y. Ben-Yishay, L. Gerstman, L. Diller and A. Haas, "Prediction of Rehabilitation Outcomes from Psychometric Parameters in Left Hemiplegics," *Journal of Consulting and Clinical Psychology*, Vol. 34, 1970, p. 436-441.

151 Elizabeth K. Anderson, "Sensory Impairments in Hemiplegia," *Archives of Physical Medicine*, Vol. 52, 1971, p. 293-297.

152 L. J. Hurwitz, "Sensory Defects in Hemiplegia," *Physiotherapy*, Vol. 52, 1966, p. 338-342.

However, the literature does suggest that sensory-tonic input and feedback imbalance in interaction with the right hemisphere's functional specialization in spatial representation leads to the disturbance in spatial coordinates acutely observed in left hemiplegia. The literature would also suggest that the right hemisphere's 'food for spatial thought' is of a sensory nature arising from within and outside the body. The mechanism underlying the contribution of asymmetric input and processing to spatial dysfunction in left hemiplegia is the subject of the following section on cerebral asymmetry.

B. Cerebral Asymmetry

To ascertain the process whereby defects in sensory modalities are related to the integration of tasks labelled as spatial requires explanation of the nature of sensory processing following unilateral brain damage as distinguished from processing in the unimpaired brain. The following literature is directed at this question, and is considered under the subheadings of (a) cerebral inertia, and (b) inter-hemispheric relations.

(a) Cerebral Inertia

Blackburn and Benton,[153] Benton and Joynt,[154] Costa,[155] and DeRenzi and Faglioni[156] have all reported that prolongation and variability in simple reaction time to a stimulus are a sensitive measure of the degree of severity of brain damage.

DeRenzi and Faglioni[157] interpreted reaction time tasks as measures of psychological vigilance. According to their definition, they define a vigilance task as follows:

> A test which requires prolonged maintenance of high level of attention and the rapid activation of perceptive and motor structures which are represented bilaterally in a diffuse cortico-subcortical distribution.[158]

The authors administered the <u>Raven Progressive Matrices</u>, a visual reaction time test, and a continuous

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153 H. L. Blackburn and A. L. Benton, "Simple and Choice reaction Time in Cerebral Disease," <u>Neurology</u>, Vol. 15, 1955, p. 327-338.

154 A. L. Benton and R. Joynt, "Reaction Time in Unilateral Cerebral Disease," <u>Neurology</u>, Vol. 19, 1959, p. 247-256.

155 L. D. Costa, "Visual Reaction Time of Patients with Cerebral Disease as a Function of Length and Constancy of Preparatory Interval," <u>Perceptual and Motor Skills</u>, Vol. 14, 1962, p. 391-397.

156 E. DeRenzi and P. Faglioni, "The Comparative Efficiency of Intelligence and Vigilance Tests in Detecting Hemispheric Cerebral Damage," <u>Cortex</u>, Vol. 1, 1965, p. 410-433.

157 <u>Ibid</u>.

158 <u>Ibid</u>., p.412.

choice reaction procedure to 166 brain-damaged subjects and 139 controls. Of the experimental subjects, nine had sustained left-sided cortical damage and sixty-eight had unilateral impairment to the right hemisphere. The continuous choice reaction task was developed for the study and required subjects to press a button upon seeing a black circle and white square illuminated simultaneously within a matrix of eighty-one squares, all of which were possible stimuli.

On the basis of these three tasks, considered independently, it was reported that simple reaction time mean values correctly diagnosed 73 percent of the brain-damaged cases, continuous choice reaction correctly evaluated 76 percent, whereas the Raven Progressive Matrices obtained the lowest accuracy of 64 percent. The results suggest that vigilance tests may be more sensitive than global tests of intellectual ability in detecting cerebral lesions.

Of particular value in this discussion was the observation that right brain-damaged subjects performed significantly poorer on simple reaction time than left damaged patients ($p < .05$). This was not the case for Raven Progressive Matrices or continuous choice reaction performance. The authors were unable to explain this result although they do suggest that it may be due to a non-specific factor such as extent and severity of lesion. They hypothesize that on the average right-sided brain damage is more extensive and disorganizing than damage to the left hemisphere.

Vigilance has also been assessed in terms of the visual-temporal acuity measured by flicker fusion detection threshold. Battersby *et al.*,[159] among others, have observed that this threshold measure is highly sensitive to cerebral deficits. Shure and Halstead[160] considered the critical frequency for fusion as an estimate of Halstead's psychological vigilance factor. They note a relationship between fusion threshold and the size of lesion significant at the .05 level.

Belmont, Birch and Karp[161] further explored impeded sensory-motor integration in brain damage by studying the differential effects of intra-modal and hetero-modal condition on reaction time. The sample consisted of twenty-three

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159 W. S. Battersby, I. H. Wagner, E. Karp and M. B. Bender, "Neural Limitations of Visual Excitability: Alterations Produced by Cerebral Lesions," *Archives of Neurology*, Vol. 3, 1960, p. 24-42.

160 G. H. Shure and W. C. Halstead, "Cerebral Localization of Intellectual Processes," *Psychological Monographs*, Vol. 72, Whole No. 465, 1958, p. 1-40.

161 I. Belmont, H. G. Birch and E. Karp, "The Disordering of Intersensory and Intrasensory Integration by Brain Damage," *Journal of Nervous and Mental Diseases*, Vol. 141, 1965, p. 410-418.

left hemiplegics and twenty-one control subjects. The intra-sensory condition required the subject to respond to a sound stimulus paired with a metronome signal. The inter-sensory task utilized a light stimulus with the metronome signal as the response eliciting event. The results suggested that left hemiplegia is associated with a greater disturbance in inter-sensory than intra-sensory organization, significance between groups being obtained in the latter condition. The authors imply a regressive trend in unilateral brain damage in comparison to the normal differentiation towards heteromodal organization that has been demonstrated developmentally in normal children.[162]

Thus, these studies would appear to indicate that damage to the central nervous system results in an increase in time required by the impaired system to process sensory information. Additionally, temporally reduced sensory processing is more apparent when the evoking stimulus is complex or bimodal. Further, the right hemisphere may be more sensitive to impaired sensory processing than the left hemisphere. Lastly, reduced vigilance may be related to the extent of the lesion.

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162 H. G. Birch and I. Belmont, "Auditory-visual Integration, Intelligence and Reading Ability in Children," Perceptual and Motor Skills, Vol. 20, 1965, p. 295-305.

According to adjacent studies by Birch _et al_.,[163,164] unilateral cerebral damage is not only characterized by an increased latency of response but also by an inhibited recovery time following a processed stimulus.

Birch _et al_.[165] had left hemiplegic subjects and normal controls indicate which of two successively presented and objectively equivalent auditory stimuli were louder. Time intervals of one, three, and five seconds separated the stimuli and were randomly distributed in the experimental presentation. A clear and significant difference emerged between normals and brain-damaged subjects with the former tending to overestimate the loudness of the second as compared to the first and the hemiplegics underestimating the same stimulus. The longer the interval between the successive stimuli the less was the obtained difference in performance between normal and brain-damaged subjects. They concluded, on the basis of these results, that mechanisms of arousal and inhibition are only quantitatively

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163 H. G. Birch, I. Belmont and E. Karp, "Excitation-Inhibition Balance in Brain Damaged Patients," _Journal of Nervous and Mental Diseases_, Vol. 139, 1964(a), p. 537-544.

164 --------, "The Prolongation of Inhibition in Brain Damaged Patients," _Cortex_, Vol. 1, 1965, p. 397-409.

165 --------, _op. cit_., 1964(a), p. 537-544.

different in brain injured and normals and that this is reflected in the increased latency period for recovery of the cerebral excitory cycle following neurologic damage.

In a subsequent study by Birch _et al_.[166] this parameter was further investigated by increasing the temporal spread between successively presented tones according to the hypothesis that an extrapolated course of inhibitory recovery, based on the preceding experimental data, would indicate normal functioning at an eight-second time interval between stimuli. Four intervals were utilized, five, seven, eight and nine seconds, respectively. A nine-second time interval produced the anticipated result. This would seem to confirm the presence of a second parameter of impaired sensory processing; an increase in time required by the affected brain to recover from a prior stimulation.

(b) Inter-hemispheric Relations

It was suggested, on the strength of findings with respect to conditions for normal spatial behavior, that:

> Integrated and therefore accurate spatial orientation is closely allied functionally with bilaterally symmetrical afferent processing of information arising from the tonic state of the organism in its relations with the environment.[167]

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166 Birch _et al_., _op. cit_., 1965, p. 397-409.

167 Refer to page 32 of this text.

At the level of the cerebrum, this inherent unity of the functioning organism is maintained by the forebrain commissures, including the corpus callosum.[168] As Glees wrote, the corpus callosum "is the means whereby the two hemispheres can share and profit by each other's experience."[169]

Neurodynamic reactions following unilateral cerebral impairment suggest that inhibition of neuronal functioning may not only be restricted to the region of lesion but may result in a pattern of changes in the unaffected symmetrical areas of the cortex as well.

Thus, in a study of electroencephalographic disturbances in focal brain lesions, Bechtereva et al.[170] noted:

> After the intensification of changes at the pathological focus and appearance of changes in the adjacent parts of the affected hemisphere, the development of slow activity could be observed in the homologous area of the unaffected hemisphere.[171]

The authors conclude that the changes in the intact symmetrical areas cannot be understood independent of the

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168 S. R. Butler, "Organization of Cerebral Cortex for Perception," British Medical Journal, Vol. 4, 1971, p. 544-547.

169 P. Glees, Experimental Neurology, London, Oxford University Press, 1961, p. 498.

170 N. P. Bechtereva et al., "Localization of Focal Brain Lesions by Electroencephalography," Electroencephalography and Clinical Neurophysiology, Vol. 15, 1963, p. 177-196.

171 Ibid., p. 183-184.

involvement of the non-specific arousal system of the diencephalic formation. By this, they appear to be indicating diminuition in activation resulting from disruption in the diffuse thalamic projections of the cortex.

Parsons *et al*.[172] observed that flicker fusion detection thresholds in the intact hemisphere of patients with unilateral parietal and temporal lobe disease were significantly impaired when compared to threshold levels of non-brain damaged subjects ($p < .001$). They suggest that, with a unilateral lesion, cortical feedback to the homologous lobe would be interrupted with a consequent reduction in the arousal level of the opposing hemisphere. Visual-temporal acuity would then be decreased due to transcortical stimulation diminuition.

An additional source of cross-hemispheric interference, complementary to the interpretation by Bechtereva *et al*.,[173] would follow from the afferent connections between the sensory organ stimulated and the diencephalic arousal system as well as the primary projection area. This would correspond physiologically to Hebb's[174] division of a

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172 O. Parsons, R. K. Majunda, and P. K. Chandler, "Impaired Flicker Detection in Visual Fields Subserved by the Non-dominant Hemisphere," *Cortex*, Vol. 3, 1967, p. 307-316.

173 Bechtereva *et al*.,*op. cit*., p. 177-196.

174 D. O. Hebb, "Drive and the c.n.s. (Conceptual Nervous System)," *Psychological Review*, Vol. 62, 1955, p. 243-254.

sensory event into cue and vigilance vectors. Hence, an extensive lesion, as is often evidenced in C.V.A., would result in an over-all reduction in cortical afferent influx as well as non-specific corticofugal feedback. Consequently, a lower level of perceptual or adaptive activity contingent upon decreased vigilance would be expected. The trans-cortical component of arousal would then account for the bilateral elevation in perceptual threshold. In this regard, Lindsley[175] has demonstrated that reticular formation stimulation facilitates flicker-fusion performance and that lower levels of activation are accompanied by decreases in perceptual acuity. As well, Ben-Yishay and Haas[176] have demonstrated a therapeutic effect of isobaric and hyperbaric oxygen inhalation on psychological functioning in left hemiplegia. This effect has also been presently illustrated in right hemiplegics by Wyspianski _et al_.[177]

Cross hemispheric interference in unilateral brain damage has been further investigated with respect to

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175 D. B. Lindsley, "Attention, Consciousness, Sleep and Wakefulness," in J. Field (ed.), _Handbook of Physiology_, Vol. 3: Neurophysiology, Baltimore, Williams and Wilkins, 1960 , p. 155-1594.

176 Y. Ben-Yishay, A. Haas, and L. Diller, "The Effects of Oxygen Inhalation on Motor Impersistence in Brain Damaged Individuals," _Neurology_, Vol. 17, 1967, p. 1003-1010.

177 J. O. Wyspianski, A. Leonoff, M. Marois, and K. Finnegan, "Oxygen Therapy and Learning in Aphasia due to Cerebral Vascular Accident," unpublished paper, University of Ottawa, 1972.

extinction during double simultaneous stimulation[178] of bilaterally homologous sensory areas.

The phenomenon of extinction of the sensation on the impaired side during DSS has repeatedly been shown to exist in a number of sensory modalities including pain, touch, temperature, pressure, vision, proprioception, audition and vibration sense.[179,180]

Birch _et al._,[181] in a study of sixteen left hemiplegics and sixteen age- and sex-matched control subjects with orthopedic impairment, demonstrated that extinction was not a function of unawareness on the impaired side but one of neurodynamically modified awarenss in a bilateral condition. To test this, they equated subjects for threshold differences between the two body sides and administered the standard face-hand assessment of extinction. The stimulus was a mild electric shock augmented a constant degree bilaterally in order to render it supraliminal. To cross

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178 Hereafter also referred to as DSS.

179 M. Critchley, "The Phenomenon of Tactile Inattention with Special References to Parietal Lesions," _Brain_, Vol. 72, 1949, p. 538-561.

180 D. Denny-Brown, J. S. Meyer, and S. Horenstein, "The Significance of Perceptual Rivalry Resulting from Parietal Lesions," _Brain_, Vol. 75, 1952, p. 433-471.

181 H. G. Birch, I. Belmont, and E. Karp, "The Relation of Single Stimulus Threshold to Extinction in Double Simultaneous Stimulation," _Cortex_, Vol. 1, 1964(b), p. 19-39.

validate, they selected subjects in each group whose single stimulus thresholds did not differ and compared their responses under the condition of equal intensity testing. Hemiplegics were significantly different from the control group on both approaches ($p < .025$).

Thus, although left hemiplegics may perceive consciously single stimuli bilaterally in this procedure, awareness is extinguished on the affected side in the simultaneous condition. They demonstrated, therefore, that the only possible explanation for the phenomenon is an inter-cerebral one. In this regard, Birch et al.[182] hypothesized that the intact hemisphere processes information at a faster rate than the affected one and that consciousness of sensation, emerging in the unaffected hemisphere, is responded to while the slower processed signal in the impaired hemisphere is suppressed. Thus, neuro-integrative inhibitory interference across the hemispheres was an integral aspect of the model proposed.

In testing the model, nineteen left hemiplegic subjects, all showing extinction to DSS, comprised the sample. A tactile stimulus provided by a mild electric shock to the left and right forearms was presented at

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182 H. G. Birch, I. Belmont, and E. Karp, "Delayed Information Processing and Extinction Following Cerebral Damage," Brain, Vol. 90, 1967, p. 113-130.

threshold level, defined as 100 percent recognition. When the affected side was stimulated prior to the intact body side at an optimal time interval for each subject, extinction was fully eliminated in fourteen of the nineteen patients and reduced in the remaining five.

To demonstrate that improvement was not a function of successiveness but related to the order of presentation, retesting was done in which the intact side was stimulated prior to the affected one. In this condition, the mean accuracy of response was not different from that obtained under DSS and in five subjects performance deteriorated. The authors concluded:

> Thus, as predicted by the model, the availability of increased time for the organization of response on the damaged side resulted in effective bilateral awareness of stimulation. These findings provide support for the view that under conditions of simultaneous homologous stimulation, what is externally simultaneous is probably physiologically successive in patients with unilateral cerebral impairment.[183]

Given the concept of a highly related sensory-motor system, it is not surprising that independent research on motor patterns in hemiplegia has arrived at a similar conclusion regarding inter-hemispheric relations.

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183 Ibid., p. 124.

Cohn[184] examined the interaction of bilaterally simultaneous hand movements in patients with unilateral paralysis. He used as a test, alternating pronation and supination of the hand. Hemiplegic patients, when using their intact hand, performed equivalently, in terms of rhythm and amplitude, with normal controls. The paretic limb was reduced in both rhythm and amplitude. Simultaneous bilateral movements interfered with both the rhythm and amplitude of the healthy extremity, whereas improvement of the paretic limb was either slight or, more frequently, totally absent. Cohn failed to demonstrate, however, a similar phenomenon in cases of peripheral paresis.

Marks[185] also clinically observed that the affected hemisphere interferes with the functioning of the intact one. He stated:

> One is tempted to ascribe neurophysiological significance to the fact that bilateral patterns of motor abnormalities are obvious with unilateral brain damage.[186]

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184 R. Cohn, "Interaction in Bilaterally Simultaneous Voluntary Motor Functions," Archives of Neurology and Psychiatry, Vol. 65, 1951, p. 472-476.

185 Morton Marks, "Gait Analysis of the Hemiplegic Patient: Force Plate and Stroboscopic Studies," Quarterly Review of Pediatrics, Vol. 7, 1952, p. 15-24.

186 Ibid., p. 22.

Hausmanowa-Petrusewicz[187] studied simultaneous motor functions in twenty-one hemiplegics. Subjects were asked to squeeze a rubber ball at a frequency that was comfortable for them. A pen recorder responding to air pressure was used to evaluate frequency and amplitude of movements. As previously found, simultaneous movement of both the paretic and healthy hand resulted in deteriorated performance of the latter in all subjects. Beginning movements of the affected hand before or after movement of the healthy one resulted in the same interactional effect. That is, irrespective of the point at which the movements of the healthy limb were added to those of the paretic limb, both rate and amplitude of the healthy limb were depressed. Concomitantly, often the paretic limb would stop functioning. The author provides the following interpretation:

> We believe the phenomenon of interaction to correspond to the phenomenon of interference of two rival stimuli (e.g., visual, auditory, cutaneous, etc.) known in every field of perception and taking place in the central portion of the analyzer [...].[188]

Belmont _et al._[189] compared foot action pattern in eighteen hemiplegic subjects and compared their performance

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187 Irene Hausmanowa-Petrusewicz, "Interaction in Simultaneous Motor Functions," _Archives of Neurology and Psychiatry_, Vol. 81, 1959, p. 173-181.

188 _Ibid_., p. 180.

189 I. Belmont, H. G. Birch, and E. Karp, "Hemispheric Inco-ordination in Hemiplegia," _Brain_, Vol. 94, 1971, p. 337-348.

in twenty-one hospitalized patients who showed no evidence of central nervous system damage. Hemiplegic subjects were all chronic cases and, on neurological examination, revealed various left-sided sensory and motor defects. During bipedal action, the control group achieved bilateral equality in movements by a reduction in the rate of movement of the right foot with no change in rate of the left foot. In contrast, the hemiplegic group, during bipedal action, did not equalize their rates of movement in both legs. The intact side continued at a rate of nearly double the affected side. In addition, as previously found, the rates of action were reduced on both sides during bipedal activity, reduction being most severe on the intact side. Thus, whereas bipedal action was characterized by coordination and synchrony in the control group, bilateral incoordination characterized the hemiplegic group's performance along with depressed rates in functioning. Belmont _et al_. therefore state:

> Hemiplegia is accompanied not only by a reduction in functioning on one side but also by a more generalized disorganization of the coordinated relationship between the two sides of the body.[190]

This motoric phenomenon of cerebral interference and incoordination would seem to indicate a disruption in

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190 _Ibid_., p. 345.

inter-hemispheric integration in which the sensory-motor feedback patterns of the two hemispheres are desynchronized and reciprocally suppressing.

In summary, the literature on cerebral processing and hemispheric relations in unilateral brain damage and specifically left hemiplegia would suggest the following conclusions:

1. The impaired hemisphere processes information at a significantly slower rate than the unaffected side.

2. Processing by the impaired hemisphere is also characterized by sustained inhibition of prior cues affecting the perception of a sequential stimulus influx.

3. Unilateral cerebral impairment due to non-specific effects decreases the general vigilance of the psychological system mediated by the two hemispheres.

4. Inter-hemispheric relations, mediated by the cerebral commissures, are characterized by interference, desynchronization and incoordination.

5. Ameliorating the effect of cerebral inertia on the impaired side improves the conscious perception of simultaneously presented homologous stimuli.

3. Conclusions and Hypotheses.

The research findings relevant to normal spatial orientation, and the neurodynamics delineated with respect to right hemispheric impairment, suggest a mechanism that may contribute to the spatial dysfunction evidenced in left hemiplegia.

The marked increase in latency of response, latency of responsiveness to successive stimulation, the presence of inter-hemispheric interference and desynchrony, and a general decrease in vigilance may impair the normal elasticity and spatial awareness characteristic of the intact brain. Specifically, these neurodynamics may aid in explaining a number of phenomena associated with the symptomatology of left hemiplegia. For example:

1. Left hemiplegics make more errors on the left than right side while performing block designs.[191]
2. Left hemiplegics respond to isolated cues, impeding their ability to discriminate and recognize figures and other visually presented stimuli with normal alacrity or accuracy.[192]
3. Unilateral spatial neglect is more often than not associated with a hemisensory syndrome.[193]
4. Unilateral neglect is not necessarily associated with visual field deficits.[194]
5. Oxygen inhalation therapy increases the vigilance of the left hemiplegic and improves his performance in sensory-motor tasks without training.[195]

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191 Diller et al., op. cit., 1971, p. 18.

192 E. DeRenzi and H. Spinnler, "Facial Recognition in Brain Damaged Patients," Neurology, Vol. 16, 1966, p. 145-152.

193 W. S. Battersby, M. B. Bender, M. Pollack, and R. L. Kahn, "Unilateral Spatial Agnosia (Inattention) in Patients with Cerebral Lesions," Brain, Vol. 79, 1956, p. 68-93.

194 J. Leicester, M. Sidman, L. Stoddard and J. P. Mohr, "Some Determinants of Visual Neglect," Journal of Neurology, Neurosurgery and Psychiatry, Vol. 32, 1969, p. 580-587.

195 Ben-Yishay et al., op. cit., p. 436-441.

The above findings are suggestive of a general spatial extinction phenomenon due to the decreased processing efficiency of the right hemisphere and accompanying disorganization in neurosynchrony between the hemispheres. Thus, impaired spatial-perceptual vigilance on a behavioral level may be a psychological concomitant of the neurological defects described.

However, the literature is not only suggestive of a mechanism underlying spatial disorientation in left hemiplegia, but also infers a possible strategy of remediation in respect to this disorder. It is perhaps notable in the literature that increasing the afferent input bilaterally in the intact individual, and supplementing its loss in the left hemiplegic, resulted in more consistent perceptual (localization) performance. Equally as suggested is the finding that unilateral suppression, a perceptual distortion, can be treated by compensating for the time lag in processing efficiency. Further, when considered in total, sensory-motor involvement in spatial orientation would appear to be a strong possibility, and one that is difficult to ignore.

As Diller and Weinberg[196] have illustrated, retraining should be focused on residual defects rather than

196 L. Diller and J. Weinberg, "Attention in Brain Damaged People," Journal of Education, Vol. 150, 1968, p. 20-27.

assets. To this end, therefore, a sensory based treatment was proposed to assess the therapeutic benefit, in respect to spatially oriented behavior, in an attempt to offset asymmetrical sensory input and processing in left hemiplegia. The experimental hypotheses, expressed in the null form, are as follows:

1. Left hemiplegics, when exposed to asymmetrical programmed subfunctional electrical stimulation and auditory stimulation are not significantly improved on the following variables of spatial orientation when compared to subjects receiving symmetrical sham treatment, or subjects receiving no treatment:

   A. Block Design

   B. Object Assembly

   C. Block Design and Object Assembly

   D. Greek Cross

   E. Bender Gestalt.-
      (i) Design A Rotation
      (ii) Design 1 + 2 Rotation
      (iii) Horizontal Displacement of Diamond in Design 8
      (iv) Ratio of Longest to Shortest Line, Design A
      (v) Ratio of Longest to Shortest Line, Design 4
      (vi) Sum of Rotation, Omissions, Distortions, Collisions, Circles, Dots, and Dashes, and Perseverations.

   F. Rod and Frame - mean constant error

   G. Rod and Frame - variance

H. Line Dissection.-
(i) Total mean constant error
(ii) Left side mean constant error
(iii) Right side mean constant error
(iv) Variance

I. Tactile Localization.-
(i) Total mean constant error
(ii) Left side mean constant error
(iii) Right side mean constant error
(iv) Variance

2. Left hemiplegics, when exposed to asymmetrical programmed sub-functional electrical stimulation and auditory stimulation are not significantly improved on a total orientation score, cumulating independent measures, when compared to subjects receiving symmetrical sham treatment or subjects receiving no treatment.

The details of implementation are indicated in chapter two, which follows.

CHAPTER II

EXPERIMENTAL DESIGN

This chapter discusses the procedures involved in the investigation of the experimental hypotheses stated at the close of the first chapter.

First, the tools utilized for the experiment are presented. The sample is then elaborated. This is followed by a description of method used in conducting the experiment. Finally, the statistical procedures used in the analysis of data are reviewed.

1. The Tools of the Experiment.

In the assessment of subjects for the experiment, two categories of tasks were employed and comprised independent test batteries. The first, a sensory evaluation, was used in the establishment of groups for the study, and the second, measures of spatial orientation, comprised the dependent variable for the experiment. They are presented in the order enumerated.

A. Sensory Battery

Subjects were evaluated on eight tasks that considered four general areas of functioning: (a) primary sensory; (b) sensory discrimination; (c) scanning; and (d) suppression.

(a) Primary sensory tests included the following:

(i) Von Frey tactile thresholds;

(ii) position sense of the impaired arm;

(iii) visual confrontation.

Von Frey hairs[1] were used as a measure of tactile acuity. The subject was required to indicate whether he felt a sensation while blindfolded throughout the task. Stimulation was applied to the volar surface of the hand and forearm. Two ascending and two descending trials were administered in a method of limits procedure. Both the left and right extremity were assessed yielding a composite of four measures. The score for each surface tested was considered the sum of the four trials.

Position sense (proprioception) of the impaired arm was assessed by the clinical method of having the subject, while blindfolded, grasp the thumb of his affected arm with his intact hand.[2] The examiner held the left arm for the patient and positioned it below the level of the waist, at the waist, and at chest level, respectively. Three trials, one at each level, were administered. A subject received a score of one for normal performance, two for mild difficulty,

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1 Sensory Kit, Lafayette Instrument Co., Lafayette, Indiana.

2 L. J. Hurwitz, "Sensory Defects in Hemiplegia," Physiotherapy, Vol. 52, 1966, p. 338-342.

and three for a complete miss in the act of grasping. Again, the final score was the sum of three trials, giving a maximum of nine.

Visual confrontation[3] was administered as a test for visual field deficit. The subject was required to gaze directly at the examiner and indicate the laterality of movement in the peripheral fields of vision. The lower, middle and upper quadrants of the visual fields, bilaterally, were assessed. Recognition of movement in both fields permitted a score of one indicating normal functioning. A score of two was given for possible deficit, and three was indicative of unrecognized movement in a peripheral field.

(b) Sensory discrimination measures included the following:

(i) roughness discrimination;

(ii) two-point tactile discrimination;

(iii) form discrimination.

Roughness Discrimination[4] of the Halstead-Reitan battery was administered to the impaired hand. Due to the

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3 L. Diller et al., "Studies in Cognition and Rehabilitation in Hemiplegia," Final Report, Grant No. RD-2666-P, Department of Health, Education and Welfare, Washington, 1971, p. 38.

4 R. M. Reitan, "A Research Program on the Psychological Effects of Brain Lessions in Human Beings," in N. R. Ellis (ed.), International Review of Research in Mental Retardation, Vol. 1, New York, Academic Press, 1966, p. 153-214.

paretic state of the limb, a modified procedure was used in which the subject was presented with two successive stimuli and asked which of the two was the roughest. Six trials were given, three in which the first stimulus was the rougher and three in the converse condition. The score given was the number of errors committed while performing the task.

Two-point discrimination was administered as a test of sensory localization along the midline of the dorsal surface of the left and right hands. The subject was asked to indicate whether he was being touched by one or two points while blindfolded. A modified method of limits procedure was employed with two ascending and two descending trials for each hand. Thus, the score for the left and right sides, respectively, was the sum of the four trials. The calipers employed were divided in inches, thirty-two divisions to the inch.[5]

A final measure of sensory discrimination was provided by a modified administration of the Form Discrimination test of the Halstead-Reitan battery. The subject was blindfolded and asked to name the shape of each of four stimuli from the test, using his impaired hand. The cross, square,

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5 Sensory Kit, Lafayette Instrument Co., Lafayette, Indiana.

circle and semi-circle shapes were given. An error score of zero received a rank of one, an error of under two received a rank of two, and greater than two errors warranted a rank of three.

(c) Scanning was assessed by the Digits Cancellation Task[6] of Weinberg and Diller.. This has been demonstrated to be a sensitive measure of visual neglect in left hemiplegia. In this task the patient is asked to cancel out the digit "8" in a group of digits. On a page of 156 numbers, there were 54 digits to be cancelled out by a pencil stroke. Four estimates of performance were considered: total errors, errors on the left half of the page, errors on the right half, and time required in seconds to complete the task. A sample of the task is presented in Appendix 2.

(d) Suppression or extinction was assessed by the method described by Bender.[7] Tactile, auditory, and visual modalities were examined independently. Of twelve stimuli given in each modality four were simultaneous and bilateral. For each modality, a rank of one was given for no error, a rank of two for under three errors, and a rank of three for three or more errors.

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6 Diller et al., op. cit., p. 86-160.

7 M. B. Bender, Disorders in Perception, Springfield, Ill., Charles C. Thomas, 1952.

A final measure designated as the voltage level of electrical stimulation on the affected arm required to produce a sensation was intended as a psychophysiological index of tactile acuity. However, it was not possible to assess all subjects on this measure and it was therefore not included in the sensory battery. The measure was an average voltage over ten trials whereby on each occasion the subject was told: "Tell me when you feel a sensation, the moment you first feel it." Sham trials were interspersed to reflect any anticipatory response set and variations in the rate of voltage increase during trials were utilized to better ensure a valid measure. The apparatus used in the procedure is discussed with reference to the treatment procedure discussed below.[8] Although not incorporated into the sensory battery, this measure is considered in the discussion of results, and is therefore included at this time.

B. Spatial Orientation Battery

Spatial orientation was operationally considered with reference to four parameters of functioning: (a) general construction; (b) graphomotor construction, (c) verticality perception; (d) personal and extrapersonal

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8 Supra, p. 89-90.

localization. These accounted for a total of twenty measures of spatial functioning.

(a) General construction praxis was measured by the Block Design and Object Assembly subtests of the Wechsler Adult Intelligence Scale.[9,10] These tests were selected since the inspection of research results demonstrated them to be the most sensitive of the WAIS scales to right hemispheric impairment.[11] As IQ was not in question, raw scores were considered the relevant data, and a Block Design, Object Assembly and a cumulative score were derived.

(b) Graphomotor construction was assessed by the Bender Gestalt[12] and Greek Cross of the Halstead-Wepman Aphasia Examination.[13] The Bender Gestalt has been shown to be sensitive to spatial defect in right hemispheric impairment generally, and specifically in left hemiplegia.

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9 David Wechsler, Manual for the Wechsler Adult Intelligence Scale, New York, Psychological Corporation, 1955, 110 p.

10 Hereafter referred to as WAIS.

11 H. Klove and R. M. Reitan, "The Effect of Dysphasia and Spatial Distortion on Wechsler Bellevue Results," Archives of Neurology and Psychiatry, Vol. 80, 1958, p. 708-713.

12 L. Bender, "A Visual-motor Gestalt Test and its Clinical Use," American Orthopsychiatric Association, Research Monograph No. 3, 1938, 176 p.

13 W. C. Halstead and J. M. Wepman, "The Halstead-Wepman Aphasia Screening Test," Journal of Speech and Hearing Disorders, Vol. 14, 1947, p. 9-15.

The scoring method used was that suggested by Diller and Weinberg[14] and consisted of: vertical rotations of design A, designs 1 and 2, horizontal displacement of the internal diamond in design 8, and the ratio of longest to shortest line in the square of design A and the open square of design 4. A final estimate of Bender Gestalt performance was a cumulative summary of rotations exceeding thirty degrees, omissions, distortions, perseverations, and deviations in the production of dots and dashes.

The Greek Cross was included due to its sensitivity to right cerebral damage and its high correlation with the performance items of the WAIS.[15] A score of one to five, reflecting normal to severe impairment, respectively, was used following the scoring method of Russell et al.[16]

(c) Verticality perception was assessed by the portable Rod and Frame[17] apparatus with the frame in the

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14 L. Diller and J. Weinberg, "Bender Gestalt Distortions in Hemiplegia," Perceptual and Motor Skills, Vol. 20, 1965, p. 1313-1325.

15 Klove and Reitan, op. cit., p. 708-713.

16 E. W. Russell, C. Neuringer and G. Goldstein, Assessment of Brain Damage: A Neuropsychological Key Approach, New York, Wiley-Interscience, 1970, 166 p.

17 H. Werner and S. Wapner, "Sensori-tonic Field Theory of Perception: Basic Concepts and Experiments," Revue Psicologia, Vol. 50, 1956, p. 315-337.

non-rotated position. Twenty trials were given to each subject, ten begun with the rod 30 degrees left of center and ten with the rod 30 degrees right of the objective vertical. Starting position was randomized for each subject over the twenty trials. Mean constant error in judgment and variance were calculated and provided the measures of performance on the task.

(d) As a fourth parameter of spatial functioning, subjects were assessed on their ability to localize visual and tactile stimuli. On the visual measure, subjects were shown a 10 cm. horizontal line sectored at a particular point by a vertical stroke. The stimulus lines were drawn on cards 10 x 20 cm. in size. The subject was shown the card for ten seconds and requested to indicate, on an identical response card, the point of dissection. The stimulus and response cards were positioned immediately in front of the subject in a specified area to ensure equality of presentation across patients. Bender and Teuber[18] and Diller _et al_.[19] used a line bissection approach and noted impairment on this task in right hemispheric impaired subjects.

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18 M. B. Bender and H. L. Teuber, "Spatial Organization of Visual Perception Following Injury to the Brain," _Archives of Neurology and Psychiatry_, Vol. 59, 1948, p. 36-62.

19 Diller _et al_., _op. cit_., p. 114.

Tactile localization was employed as a measure of orientation for corporeal or personal space. Diller *et al*.[20] had reported that C.V.A. patients tend to displace the midline of their body and that a relationship exists between degree of visual neglect and the subjective estimate of the body center. In the present study, each subject indicated on a dimensionally equal model of the back and head, the point on his back stimulated by punctate pressure. The stimulus was applied for five seconds and the subject was asked to position the stimulus with a small pointer within this time period. A tape measure secured to the subject's back provided the objective position of the stimulus.

In assessing visual and tactile localization, ten trials left and ten trials right of center were administered in a random order. The following criteria comprised the assessment of performance:

1. mean constant error
2. mean constant error left
3. mean constant error right
4. variance

In summary, therefore, the tools used to assess spatial orientation were intended as a general survey

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20 *Ibid*., p. 117.

battery of symptoms associated with right hemispheric lesions.

The experimental treatment consisted of auditory amplification and sub-functional electrical stimulation. The intensity of the compensatory stimuli applied to the impaired body side provided the independent variable of the study. Hartline,[21] Rose and Mountcastle,[22] and Katsuki,[23] among others, have demonstrated through electrophysiological investigation that increasing the intensity, in this case amplitude and voltage, of the stimulus decreases the latency of arousal in the nervous system. This has been referred to as the "intensity-latency law."[24]

Auditory stimulation of the ear was provided by two Beltone Audiometers (Model 10D) attached to a single earphone set to provide independent aural control. The

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21 H. K. Hartline, "The Response of Single Optic Nerve Fibres of the Verbebrate Eye to Illumination of the Retina," American Journal of Physiology, Vol. 121, 1941, p. 400-415.

22 J. E. Rose and V. B. Mountcastle, "Touch and Kinesthesias," in J. Field (ed.), Handbook of Physiology, Section 1, Neurophysiology, Vol. 1, American Physiological Society, Washington, 1960, p. 387-429.

23 Y. Katsuki, "Electric Responses of Auditory Neurons in Cat to Sound Stimulation," Journal of Neurophysiology, Vol. 21, 1958, p. 569-588.

24 H. G. Birch, I. Belmont, and E. Karp, "Delayed Information Processing and Extinction Following Cerebral Damage," Brain, Vol. 90, 1967, p. 113-130.

procedure employed in the experimental group to provide remedial stimulation was as follows:

1. Absolute thresholds of audition were assessed to ascertain and therefore adjust, if necessary, for differential auditory acuity in both ears; frequency was held constant at 1000 cps, and a method of limits procedure with two ascending and two descending trials for each ear provided a mean threshold level.

2. Following corrections for differential auditory acuity, subjects were assessed on the extent of auditory suppression during double simultaneous stimulation.

3. Assessement by the psychophysical method of constant stimuli was then used to determine the amplification required on the affected side to eliminate suppression completely on any series of ten DSS trials; stimuli were presented at 2.5 decibel intervals beginning at a baseline supraliminal value of 40 decibels; ten single stimulation trials were interspersed among the simultaneous trials to avoid the development of a possible response set to DSS.

This procedure, then, evaluated the degree of auditory amplification on the affected side required to induce bilateral awareness of stimulation. The treatment paradigm, described below in the section on method of the experiment, utilized a comparable "white noise" stimulation at the previously ascertained remedial values described above. White noise was utilized in the treatment procedure in that it provides a controlled auditory environment, employs the widest range of frequency and thus stimulates the largest possible area of cortex, and amplifies each frequency to the same specified degree.

Sub-functional electrical stimulation was provided by two Neurotron Minidyne Mark III faradic stimulation units (electro-medical supplies). This stimulator gives an output of surged faradism, the rate of surge being variable. Intensity was described in terms of degree of arc from the zero voltage position. The stimuli used were low intensity electrical shocks and prolonged stimulation, administered to the right and left forearms.

Zinc electrodes measuring 8.5 x 10 cms. covered in gauze (ten layers) were used to provide a dispersive stimulation. The electrodes were moistened with water and then strapped in place. They were positioned with the anode distal to the elbow and the cathode over the wrist. Both electrodes were placed on the extensor surface of the forearm approximately three inches apart.

The objectives of the large electrodes was to provide a non-selective diffuse sensation that would permit afferent conduction via the radial, ulnar, and median peripheral nerves. Stimulation was at all times prior to cathode closing threshold to guard against overt contraction and increases in spasticity.

A procedure paralleling that for ascertaining remedial auditory amplification was followed for the treatment group with the surge rate during prolonged stimulation being held constant at twenty per minute. Surge was employed during the experimental procedure due to its curvilinear intensity course, thus preventing a recruitment effect and the onset of contraction. During assessment of compensatory voltage required to eliminate extinction, two degree elevations between intensity levels were used with an approximately one-second stimulus duration on each trial.

In both the auditory and electrical stimulation procedures, the subject was positioned with the apparatus out of view to prevent contamination from visual cues.

2. The Sample.

The subjects for the study were obtained from St. Vincent Hospital and Laurier Manor, Ottawa. The sample consisted of twenty-seven subjects, all of whom had suffered cerebral thrombosis and consequent left hemiplegia. The subjects were selected from a total population of approximately fifty left hemiplegic patients according to the following criteria: (a) chronic cases in whom the disease process had stabilized; (b) no evidence of aphasia; (c) capable of comprehending the tasks and indicating basic mental control; (d) no evidence of previous psychiatric history or a present disease involving the central nervous system; and (e) the presence of some residual sensation on the impaired side.

Demographic data including age, education and time since onset of stroke are presented in Table II. Age ranged from 58 to 88 years with a mean age of 66.83, and a standard deviation of 8.01 years. The mean education, coded to indicate primary, secondary, post-secondary schooling, was 1.95 with a standard deviation of .52, indicating an average education within the grade 7 to 12 level. Patients were seen an average of 24.65 months following the C.V.A. although the variability as indicated by a standard deviation of 21.84 was extensive.

3. The Method of the Experiment.

Initially all subjects were assessed on the sensory and spatial orientation batteries. Following this, three groups were formed and matched for age, sex and sensory integrity. The order of test administration was randomized and subjects were evaluated during an average of two sessions to control for fatigue effects.

The three groups designated as Experimental (asymmetrical), Sham (symmetrical) and Control group contained eleven, nine and seven subjects, respectively. The deviation in size of groups was due to unforeseen problems in subject availability during the course of the study.

The experimental or treatment group received fifteen consecutive days of compensatory asymmetric auditory and

Table II.-

Age, Education, and Time Since Onset of Stroke.

Subject	Age	Education[a]	Time since Onset of C.V.A. and Pre-testing (months)
1	75	2	12
2	72	2	59
3	61	2	20
4	68	2	10
5	71	2	16
6	67	2	21
7	68	3	18
8	73	2	4
9	60	1	67
10	63	2	8
11	73	2	1
12	62	2	29
13	75	2	32
14	71	2	17
15	71	2	50
16	66	1	54
17	70	2	25
18	88	2	15
19	59	3	12
20	43	2	4
21	60	1	1
22	71	1	1
23	58	2	36
24	70	2	80
25	64	3	10
26	64	2	40
27	68	2	1

a 1 = primary; 2 = secondary; 3 = post-secondary.

electrical stimulation. Auditory stimulation was administered with a constant intensity of 40 decibels white noise to the right ear (k) and the derived incremented remedial value to the left ear (k + x). Electrical stimulation was given at threshold value plus five degrees arc increase in intensity to the right forearm (k) and the ascertained compensatory value to the left or impaired forearm (k + y). Thus, for both auditory and electrical stimulation, stimuli were retained at supraliminal levels but within a non-aversive range and in the case of electrical stimulation at sub-contraction values.

The symmetrical or sham group received bilateral stimulation equated for threshold differences (k) but not amplified on the impaired side. That is, stimulation was not sufficient to eliminate the phenomenon of extinction for either tactile or auditory modalities although it was supraliminal.

For both the experimental and sham treatment groups, treatment sessions, that is, actual treatment time, were thirty minutes per day. Subjects were not asked to perform any tasks during the sessions in order to minimize influences on the subjects beyond the experimental procedure. The two groups received the same explanation at the outset of the treatment procedure which was as follows:

> We are trying a new treatment for patients who have your problem. When I connect all this you will hear and feel something but don't be concerned. This is part of the treatment. After we finish the treatments, I will see how you do once again.

The third group, a second control group, received the pre-testing but did not receive any treatment or placebo of it.

Following the fifteen sessions, the administration of the spatial orientation battery was repeated, thus completing the experimental procedure. For the experimental and sham treatment groups, the equipment was left on during post-testing as the literature did not suggest that any permanent treatment effect could be expected.

4. Statistical Operations.

In order to compute a composite score, reflecting the general status of subjects' performance relative to the sample, raw scores of the sensory and pre- and post-experimental orientation evaluations were transformed into standard scores with an arbitrary mean of 50 and a standard deviation of 10.

The subjects' total sensory scores were used to equate groups on sensory functioning which was a criterion of division along with age and sex. The deployment of subjects into groups was accomplished by ranking subjects on sensory integrity and equalizing and, near as possible, the mean group ranks. To replicate the validity of this parameter of division, a Spearman[25] rank-order correlation was calculated between composite sensory and mean pre-test spatial orientation scores for the total sample.

As the pre-experimental level of competence on spatial orientation measures more or less predetermines the general level of the criteria or post-experimental measures, change was evaluated from the statistical perspective of covariance analysis. According to Campbell and Stanley,[26] this approach is most applicable to these data. Ferguson[27] notes, in this regard, that both difference and ratio scores do not render the dependent variable independent of initial values. Analysis of covariance was therefore employed to (1) remove the potential source of bias contingent upon inter-subject differences on initial values, and (2) increase the precision of the experiment.

In evaluating the effectiveness of covariance analysis, analyses of variance on pre-treatment measures of

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25 G. A. Ferguson, Statistical Analysis in Psychology and Education, New York, McGraw-Hill, 1966, p. 216-220.

26 D. T. Campbell and J. C. Stanley, Experimental and Quasi-experimental Designs for Research, Chicago, Rand McNally, 1971, 84 p.

27 Ferguson, op. cit., p. 266.

spatial orientation as well as the pre-test composite orientation score were calculated. However, it was considered, *a priori*, that since groups were equated on sensory integrity, initial group differences on measures of spatial orientation should not be extensive and the main contribution of covariance would be in respect to increased precision of results.

The analysis of covariance was then applied to each post-test of criterion variable as well as to the summated score of spatial functioning.

In the presence of significant F ratios, Scheffé's[28] procedure for a posteriori comparison of means to determine the source of significance was computed.

In testing the hypotheses, the five percent level of significance was used. An exception was in *post hoc* comparisons of means in which the twenty-five percent level of significance was used due to the extreme conservatism of Scheffé's test.[29]

The results and ensuing discussion are the topics of chapter three.

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28 B. J. Winer, *Statistical Principles in Experimental Design*, New York, McGraw-Hill, 1962, p. 97.

29 Ferguson, *op. cit.*, p. 297.

CHAPTER III

EXPERIMENTAL RESULTS

This chapter presents the results of the study and a discussion of the findings. The material is organized under the following headings:

1. Presentation of Data
2. Presentation of Results
    - A. Relationship between sensory and spatial orientation measures
    - B. Analysis of variance between groups on spatial orientation pre-test means
    - C. Analysis of covariance between groups on orientation post-test means
    - D. Replicative analyses of covariance between groups of equal size
    - E. Analysis of group differences on total orientation change scores
    - F. Conclusions
3. Interpretation of Results

The outline of statistical procedures, presented in chapter two, is less extensive than those indicated above. The reasons necessitating further analysis are described during the course of presentation.

1. Presentation of Data.

The data describing the sample studied, and utilized in the analyses of results discussed below, are presented in the appendix section.

Raw score data, prior to transformation, are presented in appendices 3, 4 and 5. These include, respectively, the results of sensory examination, the pre-test on spatial orientation skills, and the post-testing on these same orientation variables. A summary of these data, in terms of group values, is provided in appendices 6, 7 and 8 in the same respective order. These same data, following linear Z-score transformations, are given in appendices 9, 10 and 11, with an arbitrary mean of 50 and standard deviation of 10. Appendix 12 presents the group means and standard deviations on the total sensory score, derived from a summation of Z-score values, reflecting the experimenter's intention of equating groups on this criterion. Appendix 13 indicates the relative performance of groups on the summated or total spatial orientation variable prior to and after the experimental procedure.

The demographic status of each group, including mean age, education, and time since onset of C.V.A. with corresponding standard deviations, is presented in Appendix 14.

The above, then, comprises the data obtained from the assessment procedures in raw score, transformed score, and group score terms.

2. Presentation of Results.

A. Relationship between Sensory and Spatial Orientation Measures

Sensory integrity was one subject variable used in the matching of groups. To demonstrate the validity of this factor, a Spearman rank-order correlation was calculated between the total sensory and spatial orientation pre-test ranks. The value obtained was .738 reflecting significance beyond the .01 level (rho .99 = .457). The strength of this correlation indicates a strong positional relationship between these two behavioral dimensions and would appear to warrant division of groups on the sensory factor with spatial orientation as a criterion measure.

B. Analysis of Variance between Groups on Spatial Orientation Pre-test Means

To investigate the significance of group differences in initial functioning on spatial orientation measures, a one-way analysis of variance was used. The resultant F ratios for each variable, and the collated or mean pre-experimental orientation score, are presented in Table III. For the .05 level of significance, the critical value is F .95 (k = 3; df = 2,24) = 3.40. Inspection of these results indicates that of twenty-one independent measures, only one, the mean constant error on Tactile Localization

Table III.-

Mean Square Values, F Ratios, and Probabilities in Analysis of Variance of Pre-test Scores on Twenty-one Subtest Variables.

Subtest	Between Groups Mean Square	Within Groups Mean Square	F Ratio	Probability
Block Design	34.55	184.15	.187	.83
Object Assembly	2.74	3.96	.692	.51
Block Design + Object Assembly	191.35	623.59	.307	.73
Greek Cross	388.18	258.25	1.503	.24
Bender Gestalt:				
Design A	55.71	61.55	.905	.42
Design 1 + 2	95.11	60.02	1.584	.23
Design 8	2.79	.99	2.790	.08
A Ratio	.78	.39	1.980	.16
4 Ratio	94.48	169.56	.557	.58
Error Sum	6.50	11.63	.559	.58
Rod and Frame:				
Error	267.51	170.90	1.565	.23
Variance	96.79	54.66	1.771	.19
Line Dissection:				
Error Total	20.06	13.50	1.486	.25
Error Left	205.60	130.33	1.578	.23
Error Right	.30	1.89	.156	.86
Variance	4.08	6.22	.657	.53
Tactile Localization:				
Error Total	.80	1.26	.636	.54
Error Left	59.34	97.17	.611	.55
Error Right	3.18	.85	3.74	.04*
Variance	5.61	3.07	1.826	.18
Sum Orientation	774.00	3174.72	.244	.78

* Significant beyond .05 level ($F_{.95} = 3.40$; $k = 3$, $df = 2,24$).

right, was significant. The general equivalence of the sample is evidenced by the low F ratio ($F = .244$; $p = .78$) derived from a comparison of composite group means on spatial orientation. Thus, considering that initial differences between groups are small, the primary advantage of analysis of covariance is in terms of increased precision rather than the removal of a significant bias in the estimation of treatment effects.

C. Analysis of Covariance between Groups on Post-test Orientation Means

A one-way analysis of covariance was used in the analysis of the data presented in Appendices 4 and 5 in respect to the group mean differences on each measure of spatial orientation following the experimental procedure. To assess the over-all effect on spatial orientation, the data from Appendices 10 and 11 were utilized in the computation of a summated score for each subject which was then subjected to covariance analysis. The F ratios, resulting from these analyses, are presented in Table IV.

For the .05 level of significance, the critical value is $F_{.95}$ ($k = 3$, $df = 2,23$) $= 3.42$. As indicated in Table IV, mean differences between groups were significant on the total orientation score. Significance on Block Design, rotation on Design A of the Bender Gestalt, mean

Table IV.-

Mean Square Values, F Ratios, and Probabilities in Analysis of Variance of Post-test Scores on Twenty-one Subtest Variables.

Subtest	Between Groups Mean Square	Within Groups Mean Square	F Ratio	Probability
Block Design	116.93	20.44	5.720	.01*
Object Assembly	2.90	28.94	.100	.91
Block Design + Object Assembly	120.63	54.71	2.205	.13
Greek Cross	.71	.55	1.287	.30
Bender Gestalt:				
Design A	363.00	63.63	5.705	.01*
Design 1 + 2	532.99	270.27	1.972	.16
Design 8	19.78	10.07	1.965	.16
A Ratio	51.63	27.73	1.862	.18
4 Ratio	40.44	53.71	.753	.48
Error Score	230.50	458.22	.503	.61
Rod and Frame:				
Error	8.44	57.78	.146	.86
Variance	105.94	251.25	.421	.66
Line Dissection:				
Error Total	1.20	4.68	.257	.77
Error Left	.51	11.50	.044	.96
Error Right	3.18	2.41	1.317	.29
Variance	14.16	48.65	.291	.75
Tactile Localization:				
Error Total	239.44	155.44	1.540	.24
Error Left	677.49	170.52	3.973	.03*
Error Right	998.55	707.56	1.411	.26
Variance	927.19	259.97	3.566	.04*
Sum Orientation	3488.35	993.54	3.511	.05

* Significant beyond .05 level ($F_{.95} = 3.42$; k = 3, df = 2,23).

constant error left and variance on tactile localization would indicate that these contributed most to the significance of the F ratio computed for the total orientation measure.

Table V presents the adjusted mean scores for each group on those variables in which significant F ratios were obtained. With the exception of Block Design, a lower score reflects relatively superior performance. As indicated, the relative group performance level remains constant for each of the five subtests. That is, the experimental group's performance exceeds the control group which, in turn, exceeds the sham treatment group.

A posteriori comparisons (Scheffé's procedure) between the means are given in Table VI. For Block Design and Design A of the *Bender Gestalt*, this *post hoc* procedure indicates the relative superiority of the experimental group and relative inferior functioning of the symmetrical stimulation of sham treatment group. However, due to an exceedingly high intra-group variance on the tactile localization and total orientation measures, the mean differences were undermined and the applicability of analysis of covariance was questioned on these variables. Inspection of the group variances indicated that the source of heterogeneity was primarily in the third or control group which had the smallest number of subjects and which was also most

Table V.-

Adjusted Group Means in the Presence of Significant F Ratios Obtained by Analysis of Covariance on Six Subtests in the Experimental, Sham and Control Groups.

Subtest	Group		
	Experimental	Sham	Control
Block Design	10.21 (1)*	3.40 (3)	8.14 (2)
Design A	13.26 (1)	25.30 (3)	19.80 (2)
Tactile Localization: Error Left	2.39 (1)	3.95 (3)	3.72 (2)
Variances	5.00 (1)	11.22 (3)	8.12 (2)
Total Orientation	48.37 (1)	52.13 (3)	49.82 (2)

* Number in brackets indicates relative rank.

Table VI.-

A Posteriori Comparisons of Means in Analysis of Covariance on Five Subtest Variables.[a]

Subtest	Comparison $M_1 - M_2$	$M_2 - M_3$	$M_1 - M_3$
Block Design	6.81* (2.66)**	4.74* (2.98)	2.07 (2.86)
Design A	-12.04* (4.69)	5.50* (5.26)	-6.54 (5.05
Tactile Localization: Error Left	-1.56 (7.68)	.23 (8.62)	-1.33 (8.27)
Variance	-6.22 (30.00)	3.10 (33.64)	-3.12 (32.27)
Total Orientation	-3.76 (18.55)	2.31 (20.80)	-1.45 (19.95)

a Scheffé's procedure.
* Indicates significance at .25 level (df = 2,24; F = 1.714).
** Indicates critical mean difference value.

heterogeneous on sensory functioning (Appendix 12) and duration since onset of C.V.A. (Appendix 13).

Heterogeneity was confirmed by F tests on the variance measure of Tactile Localization ($F = 3.08$, $p < .05$) and the total orientation score ($F = 5.86$, $p < .05$).[1] It was not substantiated on the mean constant error left of tactile localization ($F = 1.68$, $p < .05$).

D. Replicative Analyses of Covariance between Groups of Equal Size

To further explore the obtained results, a subsequent analysis was performed equalizing group size to seven. It was proposed that a repetition of findings would add to the probability that the results were not obtained by chance. Groups one and two were equated in size with group three by randomly removing four subjects and two subjects, respectively, for each independent covariance analysis. The resultant F ratios are presented in Table VII and compared with those obtained on the first analysis of results. Inspection of Table VII indicates that the F ratio with respect to the total orientation measure remains robust when group size is equated and the general trend of significance

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1 G. A. Ferguson, *Statistical Analysis in Psychology and Education*, New York, McGraw-Hill, 1966, p. 181-182.

Table VII.-

Comparison of Replicative and Initial F Ratios and Probabilities on Analysis of Covariance on Twenty-one Subtest Variables.

Subtest	F_1^a	F_2^b	$Prob_1^c$	$Prob_2^d$
Block Design	5.720*	3.83*	.01	.04
Object Assembly	.10	.24	.91	.79
Block Design + Object Assembly	2.215	2.57	.13	.11
Greek Cross	1.29	3.26	.30	.06
Bender Gestalt:				
Design A	5.711*	3.77*	.01	.04
Design 1 + 2	1.97	2.17	.16	.14
Design 8	1.97	1.62	.16	.23
A Ratio	1.86	.87	.18	.44
4 Ratio	.75	1.88	.48	.18
Error Score	.50	.31	.61	.74
Rod and Frame:				
Error	.15	.12	.86	.89
Variance	.42	.65	.66	.53
Line Dissection:				
Error Total	.26	.20	.77	.82
Error Left	.04	.13	.96	.88
Error Right	1.32	.42	.29	.67
Variance	.29	.44	.75	.65
Tactile Localization:				
Error Total	1.54	.96	.24	.40
Error Left	3.97*	3.30	.03	.06
Error Right	1.41	1.12	.26	.35
Variance	3.57*	2.48	.04	.11
Sum Orientation	3.51*	3.55*	.05	.05

* Indicates significance.
a Initial F Ratios.
b Replicative F Ratios.
c Initial probabilities.
d Replicative probabilities.

is maintained. However, significance was not replicated on the tactile localization measures, although the mean constant error left variable approached significance ($F = 3.30$, $p = .06$).

Subsequent _post hoc_ comparisons of the second covariance analysis results by several methods did not permit a localizing of the source of significance on the total orientation score.[2,3] The Kurtz _et al._[4] range test of multiple comparisons is indicative of the results obtained and is presented in Table VIII. As indicated, none of the comparisons for this measure reaches the level of ninety-five percent confidence although the difference between groups one and two is most closely approximating.

Returning to the initial covariance analysis, it would seem that none of the group means, on the sum orientation measure, are statistically distinguishable due to the extent of within group variability. Although a logical contradiction may be argued, it would appear that the differences between groups one and two, which most

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2 B. Winer, _Statistical Principles in Experimental Design_, New York, McGraw-Hill, 1962, p. 77-104.

3 G. W. Snedecor and W. G. Cochran, _Statistical Methods_ (6th ed.), Aimes, Iowa, Iowa State University Press, 1967, p. 260-277.

4 _Ibid._, p. 275.

Table VIII.-

A Posteriori Comparison by Kurtz Range Test of Differences of Means on Total Orientation Scores.

Comparison	Difference	Critical Difference[a]	P
$M_1 - M_2$	-4.49	7.41	$>.05$
$M_2 - M_3$	2.18	7.41	$>.05$
$M_1 - M_3$	-2.32	7.41	$>.05$

a D = (Factor) (Sum of Ranges) /n = 7.41 at .05 level.

closely approximate the critical difference, contribute most to the over-all significance of the F value. With the conservative boundary of selection not exceeded, in this case, it remains reasonable that the absence of an exact solution to the posterior analysis does not exclude the meaningfulness of the data. It does, however, substract from the level of confidence in terms of contributory strengths, although not from the level of significance.

E. Analysis of Group Differences on Total Orientation Change Scores

As individual variation across measures of spatial orientation remained large, another method of analysis was used on the total orientation score to clarify the source of significance between means of the three groups. Thus, individual percentage of change scores were calculated by means of the following formula:

$$\left[\frac{M_1 - M_2}{80 - M_1} \times 100\right] + 50$$

M_1 is the mean total orientation scores of a subject on pre-testing, and M_2 is the mean total orientation score at post-experimental testing. To control for point of entry into the scale, a value of 80, three standard deviations above the mean, was used as a maximum score[5] A constant value of 50 was added to render all scores positive. The data are presented in Table IX.

These scores were then subjected to t tests for independent samples repeating the hypothesis that the experimental group performs significantly better on spatial orientation than the two comparison groups. The results are presented in Table X. As indicated, only the difference between the experimental and sham treatment group reached significance ($t = 1.83$, $p < .05$). This, then, verified the significant F ratios obtained on the two analyses of covariance and provided an indication of the source of significance.

F. Conclusions

At the conclusion of chapter one, the hypotheses of the experiment were expressed as follows:

1. Left hemiplegics, when exposed to asymmetrical programmed subfunctional electrical stimulation and auditory stimulation are not significantly improved on the following variables of spatial orientation than subjects receiving symmetrical sham treatment, or subjects receiving no treatment:

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5 C. I. Hovland, A. A. Lumsdaine, and F. D. Sheffield, "A Baseline for Measurement of Percentage Change," in Experiments on Mass Communication, Princeton, Princeton University Press, 1949.

Table IX.-

Percentage Change Scores on Total Orientation

	Groups		
	Experimental	Sham	Control
	82.97	43.24	47.42
	42.06	41.07	105.73
	57.65	54.66	51.56
	40.71	25.40	24.76
	60.37	50.69	49.32
	40.04	47.52	53.79
	59.73	48.42	53.44
	66.81	41.65	
	50.65	32.15	
	55.40		
	66.97		
Mean	56.67	42.76	55.15

Table X.-

Mean Differences, Standard Errors of Differences, and t Values for Total Spatial Orientation Change Scores in Experimental-Sham, Sham-Control and Experimental-Control Comparisons.

Group	Mean Difference	Standard Error of Difference	t
Experimental-Sham	13.91	7.62	1.83*
Sham-Control	12.38	9.86	1.26
Experimental-Control	1.52	9.97	.15

* Significant at .05 level (1 tail), df 18, = 1.734.

A. Block Design

B. Object Assembly

C. Block Design and Object Assembly

D. Greek Cross

E. Bender Gestalt.-
   (i) Design A Rotation
   (ii) Design 1 - 2 Rotation
   (iii) Horizontal Displacement of Diamond in Design 8
   (iv) Ratio of Longest to Shortest Line, Design A
   (v) Ratio of Longest to Shortest Line, Design 4
   (vi) Sum of Rotation, Omissions, Distortions, Collisions, Circles, Dots, and Dashes, and Perseverations.

F. Rod and Frame - mean constant error

G. Rod and Frame - variance

H. Line Dissection.-
   (i) Total mean constant error
   (ii) Left side mean constant error
   (iii) Right side mean constant error
   (iv) Variance

I. Tactile Localization.-
   (i) Total mean constant error
   (ii) Left side mean constant error
   (iii) Right side mean constant error
   (iv) Variance

2. Left hemiplegics, when exposed to asymmetrical programmed sub-functional electrical stimulation and auditory stimulation are not significantly improved on a total orientation score, cumulating independent measures, than subjects receiving symmetrical sham treatment or subjects receiving no treatment.

Thus, considering the hypotheses, the following is a summary of results:

1. In terms of independent measures of spatial orientation, the null hypothesis was rejected in the case of (a) block design, (b) design A of the Bender Gestalt, (c) tactile localization, mean constant error left, and (d) tactile localization subject variance. The null hypothesis was accepted on the other measures.

2. A difference significant at the .05 level was obtained between groups on the total orientation score. Thus, it was possible to reject the null hypothesis on this cumulative measure of spatial functioning.

3. Significance was on the whole attributable to the difference between the experimental (asymmetrical) and sham (symmetrical) groups, whereas the experimental and control (no treatment) groups did not differ in level of performance to any appreciable extent. An exception was on block design of the WAIS in which the experimental group's performance was distinguishable from the sham and control groups and superior to both.

3. Interpretation of Results.

Any applicable hypothesis to explain the results of the stimulation procedure must account for (1) the adverse effects of symmetrical stimulation, and (2) the sustainable power of asymmetrical stimulation on spatially oriented behaviors. Considering that the differential factor was in compensating for the temporal lag in processing of sensory input, the most viable explanation would appear to be one which relates functional reciprocity and synchrony of the hemispheres with spatial-perceptual processes.

This view bears directly upon the findings of Birch _et al_.[6,7,8,9] that in unilateral brain damage, the damaged hemisphere is characterized in functioning by increased latency in the processing of stimuli and a suppressing action of the intact hemisphere on the impaired one. Thus, on a sensory level,[10] they observed that bilateral but temporally simultaneous tactile stimulation did not reduce extinction on the impaired side. On a motor level, they reported that bilateral foot movements in left hemiplegia were accompanied generally by a cessation of movement on the impaired side and a reduction of rate of movement on the intact body side.[11] In both situations, a symmetrical pattern or bilaterally equivalent input result in disorganization of functioning or the maintenance of a pathological phenomenon.

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6 H. G. Birch, I. Belmont, and E. Karp, "The Relation of Single Stimulus Threshold to Extinction in Double Simultaneous Stimulation," _Cortex_, Vol. 1, 1964(a), p. 19-39.

7 --------, "Excitation-Inhibition Balance in Brain Damaged Patients," _Journal of Nervous and Mental Diseases_, Vol. 139, 1964(b), p. 537-544.

8 --------, "The Prolongation of Inhibition in Brain Damaged Patients," _Cortex_, Vol. 1, 1965, p. 397-409.

9 --------, "Delayed Information Processing and Extinction Following Cerebral Damage," _Brain_, Vol. 90, 1967, p. 113-130.

10 --------, _op. cit_., 1964(a), p. 19-39.

11 I. Belmont, E. Karp and H. G. Birch, "Hemispheric Inco-ordination in Hemiplegia," _Brain_, Vol. 94, 1971, p. 337-348.

The present study appears to have observed a variant of the finding that bilateral stimulation in left hemiplegia offers no therapeutic gain and, in this procedure, resulted in further deterioration in performance. It would appear most reasonable to explain this deterioration in terms of the paradigm of dysfunction formulated by Birch, since it also provides a rationale for the lack of behavioral interference in the asymmetrical or compensated condition of stimulation. The increased intensity of input on the impaired side offsets the regression through being processed at a clinically significant higher rate. This, then, prevented the hemispheric interference resulting from bilaterally equivalent stimulation amplitudes. Whereas Birch[12] illustrated this mechanism utilizing the tactile modality as a criterion measure, this study has observed the same mechanism on a spatial-perceptual level. This finding provides support for the hypothesis that spatial deficit in right hemispheric impairment may be a function of a more general extinction phenomenon resulting in poor identification of cues and consequential disruptions in scanning or spatial vigilance. This may also offer a neurodynamic model to explain the relationship between

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12 Birch _et al_., _op. cit_., 1967, p. 113-130.

sensory deficit and the integration of stimuli underlying perceptual behavior.

Diller and Weinberg[13] noted that left hemiplegics who demonstrated extinction during double simultaneous stimulation were also those who committed most errors on the Digits Cancellation test, a measure of visual scanning, and had greatest difficulty in objectively localizing their body center when stimulated on the back. In the present study, the mean correlation between degree of extinction and the mean constant error on tactile localization was significant at the .05 level (mean r = .421). Consistently, the total score on Digits Cancellation correlated with the mean constant error on tactile localization (r = .553) and variance (r = .581) at the .01 level of significance. These results are replicative of the observations by Diller and Weinberg[14] and appear to reflect a syndrome characterized by dysfunction in localizing points in personal and extra-personal space. In combination, these findings may implicate the role of defective information processing in corporeal and extra-corporeal spatial vigilance.

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13 L. Diller, "Cognitive and Motor Aspects of Handicapint Conditions," in W. S. Neff (ed.), Rehabilitation Psychology, Washington, American Psychological Association, 1971(a), p. 1-32.

14 Ibid.

Within this explanatory framework or neurodynamic model, symmetrical stimulation bilaterally would be ineffective in compensating for the temporal lag. Deterioration in performance, as observed in this study, could be understandable in terms of a geometric progression of interference, the differential temporal processing factor increasing between the hemispheres as a function of the intensity (rate of conduction in the nervous system) and duration (quantity) of stimulation. As has been demonstrated, left hemiplegics recover slowly from the inhibitory effects of prior stimulation.[15] Thus, with recurring stimulation, inhibition would be compounded in the affected hemisphere while the intact hemisphere processed the incoming sensory information at an approximately normal rate. Discrepancy between the hemispheres would, therefore, increase and concurrently inter-hemispheric interference would be progressively augmented. This would be comparable to the procedure of Birch *et al*.[16] where the intact side was stimulated electrically prior to the affected body side. In this case, thirty-eight percent of subjects performed more poorly when compared to the condition of simultaneous

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15 Birch *et al*., *op. cit*., 1964(b), p. 537-544.

16 --------, *op. cit*., 1967, p. 113-130.

stimulation. Comparatively, as well, Birch et al.[17] reported that applying a ten-pound weight to the intact shoulder of left hemiplegics tripled their mean constant error in verticality perception.

Thus far, it has been postulated that the temporal differential in cerebral processing and resultant interference may account for the observed deterioration in spatial functioning of the symmetrical treatment group in this study. It has been suggested, as well, that the behavioral concomitant of this neuropathology is defective scanning or vigilance in respect to identifying cues arising from the body and environmental space.

After observing that scanning as measured by the Digits Cancellation test was associated with problems in spatial behavior such as visual imagery, body localization, and perception of external space, Diller and Weinberg hypothesized:

> [...] that a problem in scanning underlies all of these tasks. Failures on these tasks are therefore not due to correlation abilities; rather they are due to a single and underlying mechanism, which is identifiable and treatable.[18]

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17 H. G. Birch, I. Belmont, T. Teilly, and L. Belmont, "Somesthetic Influences in Perception of Visual Verticality in Hemiplegia," Archives of Physical Medicine and Rehabilitation, Vol. 43, 1962, p. 556-560.

18 L. Diller et al., "Studies in Cognition and Rehabilitation in Hemiplegia," Final Report, Research Grant No. RD-2666-P, Department of Health, Education and Welfare, Washington, 1971(b), p. 132.

The relationship between impeded information processing on the affected side and scanning was further validated in this experiment without the direct intention to do so. As described in chapter two, the mean voltage over ten consecutive trials, required to elicit a sensation on the impaired arm, was assessed on twenty-two of the subjects. This index was intended as a psychophysiological measure of tactile acuity to be utilized in the multiple task sensory battery. Pearson product-moment correlations between this voltage measure and the sensory battery are presented in Table XI.

As indicated in Table XI, the expected correlation with measures of primary sensory integrity were not forthcoming. The mean level of stimulation correlated instead with errors in scanning at the .001 level and with two-point tactile threshold on the left side at the .01 level of significance. This latter measure shares a common property with <u>Digits Cancellation</u> in that both require sustained attention and awareness. The discriminant nature of the correlations would appear to indicate that the voltage measure was assessing the point when the subject did attend to the sensation rather than when he could attend to it in terms of the extent and locus of damage. The less aware the subjects were of the stimulation, the more errors they made on <u>Digits Cancellation</u> generally. That is, it was not

Table XI.-

Pearson Product-moment Correlations and Probability Values Between Mean Voltage and Fifteen Measures of Sensory Integrity.

Subtest	r	Probability*
Roughness Discrimination	.243	
Von Frey - left side	.265	
Von Frey - right side	.180	
2-point tactile - left	.507	.01
2-point tactile - right	.225	
Digits Cancellation - total error	.711	.001
Digits Cancellation - errors left	.708	.001
Digits Cancellation - errors right	.670	.001
Digits Cancellation - time	.129	
Proprioception	.094	
Tactile Suppression	.093	
Visual Suppression	.034	
Auditory Suppression	.056	
Hemianopia	.119	
Form Discrimination	-.217	

* $r_{.95} = .423$

predictive of a specific visual agnosia or neglect of left-sided space but of the total visual field required for the task. There is the possibility, therefore, that the predictive power of measures such as two-point tactile threshold on the impaired side is not only sensitive to direct organic impairment but to the retention of sensory and spatial vigilance.[19] This is consistent with the findings of DeRenzi and Faglioni[20] that measures such as reaction time which require prolonged attention and high levels of awareness are more sensitive to organicity than standard psychometric tests.

If cerebral asymmetry in information processing, augmented in the bilaterally equivalent stimulation condition, can account for the deterioration in performance on spatial skills, the absence of pervasive improvement in the compensated or asymmetric condition remains an issue. Although <u>post hoc</u> comparisons did not reveal significant differences in functioning between the experimental and control (no treatment) groups, there was a consistent tendency for the experimental group to perform at a somewhat

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19 C. Van Buskirk and D. Webster, "Prognostic Value of Sensory Defect in Rehabilitation of Hemiplegics," <u>Neurology</u>, Vol. 5, 1955, p. 407-411.

20 E. DeRenzi and P. Faglioni, "The Compaeative Efficiency of Intelligence and Vigilance Tests in Detecting Hemispheric Cerebral Damage," <u>Cortex</u>, Vol. 1, 1965, p. 410-433.

higher level on post-testing. This may be suggestive of a treatment effect that was not fully realized in this study. In this regard, it would be difficult to ignore the finding that symmetrical stimulation significantly disorganized spatial behavior and that asymmetrical stimulation did not. The only plausible explanation would be that of a treatment effect at least in terms of a lack of regressive influence on spatial orientation. However, the rejection of the null hypothesis must remain qualified and mainly interpretable in terms of the obtained differences between the experimental and sham treatment groups.

It would seem that two factors may have influenced the results and rendered the evaluation of the positive aspects of the treatment difficult.

As noted in the presentation of results, the control group was small and the within-subject variance large. This did not permit a clear comparison of the control and experimental groups. A larger control group may have aided the analysis with regards to the effect of the treatment procedure.

A second factor concerns the bilaterality of stimulation. This may be less effective than an unilateral treatment condition where attention would be less divided and therefore more compensatory on a behavioral level. However, in this investigation, the level of stimulation would have had to have been arbitrary and the interpretation of results in terms of the model of perceptual or spatial extinction would have been restricted. This difficulty is considered below in a proposal for further research.

Besides a significant difference between groups on the total spatial orientation score, specific differences were obtained on block design of the _WAIS_, Design A of the _Bender Gestalt_, and errors left and variance on tactile localization. In particular, the experimental group performed significantly better on block design at post-testing than either comparison group, the only measure in which this occurred.

In respect to block design, the results do not indicate why improvement should be clearly obtained on this measure and not on others. However, it is known that left hemiplegics commit more errors on the left side as compared to the right while performing block designs.[21] The concomitant improvement in tactile localization in the experimental group may indicate that vigilance or awareness of stimuli on the impaired side was heightened due to the stimulation procedure or more constant rather than

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21 Diller _et al_., _op. cit_., 1971(a), p. 16.

fluctuating. It may be hypothesized that this improved the general scanning process and decreased errors on the left side while subjects did block designs. This, however, must remain speculative until a greater understanding of the relationship between stimulation and extrapersonal scanning can be experimentally ascertained.

For two of the patients involved in the study, the stimulation procedure resulted in some functional return of movement in the impaired arm. Both cases were part of the experimental group. According to physiotherapy reports, these individuals were considered capable of further progress in this area but did not respond to regular physiotherapy treatments. It may be postulated that the asymmetrical procedure, which was sub-functional in intensity for electrical stimulation, increased awareness of the impaired body side and offset the clinical tendency to ignore its existence with increasing chronicity. Indirectly, this may add support to the hypothesis that attentional processes or spatial vigilance is a primary factor in perceptual deficit in left hemiplegia and a critical issue in rehabilitation.

Attention implies an apprehension of specific objects, events or stimuli out of a series of possible mental possessions at any moment in time. By definition, it denotes the formulation of figure and ground by an absence of focalization on some things in order to effectively concentrate on others. As discussed by James, the immediate effects of attention are to allow us to:

> [...] perceive, conceive, distinguish, remember better than otherwise we could--both successive things and each thing more clearly. It also shortens "reaction time."[22]

Of interest is James' positioning of attention as a prerequisite of organized, adaptive mental functioning. One may well ask, on the basis of this research endeavor and others, as has Diller,[23] whether or not the disordering in left hemiplegia of these capacities outlined by James is not originated at the antecedant level of attention or pre-attention (vigilance). Perhaps, as Diller[24] suggests, what one treats in the hemiplegic is his ability to attend, his pre-perception or apperception, and the higher cognitive adjustment follows, given the central and peripheral apparatus to do so.

Exploring this avenue of explanation, one may, as suggested previously, consider that psychophysical assessments of residual sensory integrity on the impaired body

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22 William James, The Principles of Psychology, Vol. 1, New York, Dover Publications, 1950, p. 424-425.

23 Leonard Diller, "Psychomotor and Vocational Rehabilitation," Presentation 11, in Arthur L. Benton (ed.), Behavioral Change in Cerebrovascular Disease, New York, Harper and Row, 1970, p. 81-105.

24 Ibid., p. 101-102.

side are, in essence, measuring the individual's apperceptive loss and his residual attentional capacities needed for spatial orientation. It would appear plausible that the link between the predictive power of sensory discrimination measures, spatial orientation, and success in physical rehabilitation therapy, lie in their common requirement of sustained vigilant focalization or attention.

As an example, the mean voltage level at which subjects perceived the electrical stimulation may be operationally defined, in view of its discriminant relationship with visual scanning, as a measure of attentional capacity. Notably, this voltage value correlated significantly with eight measures of spatial orientation. The subtests, correlations, and levels of significance are presented in Table XII. Generally, construction apraxia as measured by block design, object assembly, the <u>Bender Gestalt</u>, and the <u>Greek Cross</u> is particularly implicated by virtue of these relationships. The significant correlation with tactile localization would be expected due to the somesthetic nature of the measure. Perhaps, construction apraxia is a function of distractability, inattention being the primary locus of difficulty. The efforts of Diller <u>et al</u>.[25] on saturation cueing in block designs, and training in scanning would support this

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25 Diller <u>et al</u>., <u>op. cit</u>., 1971(a), p. 1-85; 86-160.

Table XII.-

Pearson Product-moment Correlations between Mean Voltage and Eight Measures of Spatial Orientation.

Subtest	Correlation	Probability*
Block Design	-.728	.001
Object Assembly	-.423	.05
Block Design - Object Assembly	-.646	.01
Greek Cross	.537	.01
Bender Gestalt: Sum of errors	.576	.01
4 Ratio	.551	.01
Tactile Localization: Error total	.447	.05
Error right	.647	.01

*Significant correlation at .05 level for N of 22 = .423.

conclusion. It may then be postulated that given the condition in which the left hemiplegic can learn to attend to what is essential for appropriate spatial behavior, he will respond accordingly with generally improved functioning, consistent with rehabilitation goals.

As is often evidenced in organicity, what is beneficial for the intact individual is disruptive for the brain damaged. Thus, as Freilicher[26] reported, symmetrical stimulation decreased the variability in perception of the objective median plane in normal subjects. In this present investigation, symmetrical stimulation resulted in increased perceptual disorganization. The converse would appear to hold true, as well. For example, Shapiro[27] has shown that brain damaged patients improve their performance on block designs when viewing the stimulus pattern through a pinhole of light. This is in contrast to normal subjects who show deterioration in performance under this condition. This example is opportune in that it highlights the difficulty of brain injured subjects in identifying perceptual cues through what may be termed an inundation effect in the

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26 J. Freilicher, Effect of Symmetrical Extraneous Stimulation on the Position of the Apparent Median Plane, unpublished Master's thesis, Clark University, 1963, 101 p.

27 M. B. Shapiro, "Experimental Studies of Perceptual Anomaly: I. Initial Experiments," Journal of Mental Science, Vol. 97, 1951, p. 90-160.

normal stimulus condition. The pinhole may be said to reduce the availability of cues and therefore improve attentional processes and the identification of appropriate cues in the stimulus dimension.

The present study has attempted to relate the dynamics and requirements of normal spatial orientation and spatial dysfunction in left hemiplegia to a neurodynamic model based on the reciprocal functioning of the hemispheres. The argument has been made that in not compensating for the temporal processing differential between the hemispheres in left hemiplegia, attentional or vigilance functions and the scanning ability they subserve are further impaired, resulting in augmented spatial disorientation of the body and environment. Although the attempt to apply this information processing model systematically did not result in obvious benefits for the treatment group, the lack of regression and trend towards improvement are considered favorable indications which warrant further investigation of the remedial paradigm.

Specifically, a study utilizing unilateral stimulation on the impaired side, as a treatment technique, rather than bilateral but compensated stimulation may prove more beneficial in this regard. Although unilateral stimulation may be preferable to bilateral treatment, a possible consideration is the amount of input of which the affected hemisphere is capable of processing at any point in time. Given the finding of Birch et al.[28] that a nine-second interval between successive tones was required to produce normal functioning in loudness judgments, this may be a pertinent variable in a further investigation of this therapeutic paradigm. An adjunctive approach would be to vary the intensity of stimulation and observe if a graded therapeutic effect occurs. However, a problem which was central to this study concerns the intensity of stimulation needed to induce a beneficial effect for an individual. This problem would remain and leads to a specific proposal for research that may answer this question.

Basic to this proposal is an analysis of the electroencephalographic correlates of suppression during double simultaneous stimulation (DSS) as measured by the evoked potential technique. Of importance is the extent to which the intact hemisphere suppresses neurophysiological registration of a stimulus on the impaired side during DSS. The question in neuropsychological terms is, does lack of awareness correspond to an absence of cortical response? This may be answered through comparisons of the latency and amplitude parameters of the

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28 Birch *et al.*, *op. cit.*, 1965, p. 397-409.

auditory or visual evoked potential during single and bilateral stimulation while recording from the appropriate homologous cerebral regions.

To further test the model of perceptual extinction discussed in this study, a relationship may be postulated between the degree of disruption in the evoked potential during DSS and the extent of spatial dysfunction in left hemiplegic subjects.

Returning to the question of remediation, this technique could also provide a measure of the degree of amplification on the impaired side required to equalize the parameters of the evoked potential between the two hemispheres. The resultant stimulus levels could then be used in a unilateral treatment paradigm. The increased accuracy provided by a neurophysiological index may prove highly beneficial in a physiologically based treatment.

It is hoped that with further effort and investigation this technique may be integrated with others such as saturation cueing procedures and oxygen inhalation therapy in a combined treatment approach for spatial disorientation in hemiplegia. In keeping with the frame of reference and endeavors of Diller _et al._,[29] the aim is for a developed psychotechnology of remediation bringing psychology from

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29 Diller _et al._, _op. cit._, 1971(a).

the level of diagnosis and description to that of therapeutics in physical rehabilitation.

SUMMARY AND CONCLUSIONS

This study dealt with the issue of spatial disorientation in left hemiplegia. It attempted to explore the significance of interplay between the organism and spatial-perceptual behavior in health, and extrapolate these observations to the illness in question.

At the outset of the discussion, priority was given to the view that human spatial orientation is a psychological product of sensory-motor processing and integration. The inseparability of afferent and efferent processing and the functional unity of the bilaterally symmetrical organism were stressed in this regard. In particular, the central nervous system was postulated as being the focal point in the physiology of spatial behavior as a comparing, judging and remembering control system which resolves the anatomic duplication so plainly evident.

To preface the importance of unilateral paralysis, often symptomatic of vascular occlusion of the right hemisphere, research was presented on the experimental inducement of asymmetric body tonus. It was noted that this procedure resulted in altered perceptual experience of the subjective coordinates of external space, and identified a somesthetic component or influence in spatial orientation. It reinforced the postulate that bilateral symmetry of input is a characteristic of effective spatial functioning.

To further the analysis, literature centering on the concept of feedback was presented. Research in this area was shown to stress the self-organizational properties of the organism in respect to spatial behavior and the definitive role of the cerebrum in the organizational process. For perceptual harmony with the object world and efficient spatial coordination, an ongoing monitoring of executive intention with peripheral input was deemed necessary. The intent to act, and the self-initiation of action, with its contingent feedback, were noted as playing an important role in spatial-perceptual learning and behavior.

From this review of necessary processes for maintaining adequate spatial contact with the object world, a discussion of the spatial disorientation syndrome in left hemiplegia followed. It was noted that sensory defects were prominent and shown to be highly correlated with perceptual dysfunction and success in rehabilitation programs. Basically, it was noted that, what is considered germane to the integrity of spatial functioning, is affected in this illness. The functional dominance of the right hemisphere in non-verbal skills was noted as being a further confounding factor, interacting with the reduction in sensory input.

A departure was then made into the neurodynamics of the evidenced disorientation as an extension of the preceding discussion. It was noted that in left hemiplegia, cerebral vigilance was impaired, the affected hemisphere processed stimuli at an impoverished rate, and recovered from a prior stimulation with only one-third efficiency. It was also observed that cross-hemispheric interference and desynchrony were evident on a sensory and motor level, with the residual powers of the affected hemisphere being further reduced. It was also reported that bilateral stimuli, when given simultaneously and of equal intensity, result in extinction of awareness on the affected side. However, in compensating for the temporal lag in processing of the affected hemisphere, bilateral awareness was achieved.

Thus, the supposition was made that the observed difficulties of hemiplegic patients in identifying stimuli may be a variant of this phenomenon or, in essence, a general perceptual extinction effect. This led to the hypothesis that electrical and auditory stimulation, utilized in a treatment procedure which compensated for the temporal processing discrepancy between the hemispheres, would improve inter-hemispheric harmony and the ability of the affected hemisphere to function in its spatial capacity.

Three groups were formed to assess this hypothesis. An experimental group received asymmetrical or compensated stimulation, a sham group received symmetrical or uncompensated stimulation, and a control group received no treatment.

The results were indicative of a further deterioration in spatial functioning with uncompensated stimulation, and a tendency, although not clearly demonstrated, of asymmetrical stimulation to improve performance on spatial orientation when twenty-one measures were considered in a cumulative index of spatial behavior. Of these measures, block design of the WAIS, design A rotation of the Bender Gestalt, and the mean constant error left and variance on tactile localization revealed independent significant differences in group functioning, with the primary difference in performance being between the experimental and sham treatment groups. On block design, however, the experimental group's superiority in functioning over the two comparison groups was demonstrated.

The results were interpreted in support of the model proposed, and specific significance was given to the dependence of spatial vigilance and attentional processes on cerebral processing symmetry and synchrony. It was, however, noted that although a trend towards amelioration was evident, essential support of this model rests on replication and clarification of the degree of improvement. Suggestions for further research were, then, orientated in this direction.

The conclusion to this study is one that invites further investigation of what appears to be a promising area of inquiry. Increasingly, the role of spatial vigilance evidenced in attention and scanning is assuming importance in the rehabilitation and neuropsychological literature, and the applicability of this model, which awaits further investigation, may prove a contribution in this regard.

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This investigation revealed, on the level of motor behavior, the cross-hemispheric sensorimotor dissociation phenomenon characteristic of hemiplegic functioning. It was a core finding in respect to the model of perceptual extinction presented in this study.

Benton, Arthur L., "Constructional Apraxia: Some Unanswered Questions," in Arthur L. Benton (ed.), Contributions to Clinical Neuropsychology, Chicago, Aldine Publishing Co., 1969, p. 129-141.

Benton indicates in this discussion or review of construction apraxia that a particular syndrome may or may not be demonstrated depending on the measure used. This influenced the utilization of a large battery of spatial orientation measures in this study. Benton also underlines the importance of understanding defects leading to behavioral difficulties.

Birch, Herbert G., Ira Belmont and Eric Karp, "The Relation of Single Stimulus Threshold to Extinction in Double Simultaneous Stimulation," Cortex, Vol. 1, 1964, p. 19-39.

The initial study of the Birch group on double simultaneous stimulation, the focal point of the model developed in this thesis. The results indicated that sensory extinction was not a function of threshold differences between the affected and intact body side.

--------, "Excitation-Inhibition Balance in Brain Damaged Patients," Journal of Nervous and Mental Diseases, Vol. 139, 1964, p. 537-544.

Utilizing the successive presentation of tones and different inter-stimulus intervals, the authors demonstrated that the affected hemisphere shows a marked inhibition of a prior stimulus opposite to that which occurs in normal functioning. The degree of inhibition was inversely related to the inter-stimulus interval indicating that recovery would occur to normal levels of responsiveness given an optimum time period between stimuli.

Birch, Herbert G., Ira Belmont and Eric Karp, "The Prolongation of Inhibition in Brain Damaged Patients," Cortex, Vol. 1, 1965, p. 397-409.

On the basis of prior studies, the authors extrapolated a curve of inhibitory recovery following a prior stimulus and the presentation of the succeeding one. A nine-second time interval produced the hypothesized result. The study was interpreted as indicating a degree of cerebral processing inertia in left hemiplegia. This also provided a basis for considering repercussions such as attentional loss and difficulties in scanning.

--------, "Delayed Information Processing and Extinction Following Cerebral Damage," Brain, Vol. 90, 1967, p. 113-130.

The major contribution of this study was indicating that extinction during double simultaneous stimulation was a result of the impeded processing of stimuli by the intact hemisphere, and interference with conscious awareness of stimuli on the affected body side due to suppression, cross-hemispherically, from the intact hemisphere. The explication of the neurodynamics of tactile perception in this study provided the major support for the theory of general perceptual extinction expounded in this present thesis.

Birch, H. G., I. Belmont, T. Reilly and L. Belmont, "Somesthetic Influences on Perception of Visual Verticality in Hemiplegia," Archives of Physical Medicine and Rehabilitation, Vol. 43, 1962, p. 556-560.

Important to this thesis in that the authors demonstrated that a sensory prosthesis applied to the intact side severely disorganized verticality perception, whereas when applied to the intact side it resulted in minor improvement in functioning. This provided encouragement for considering sensory stimulation as a viable prosthetic tool in spatial disorientation.

Bogen, Joseph E., "The Other Side of the Brain: II. An Appositional Mind," Bulletin of the Los Angeles Neurological Societies, Vol. 34, 1969, p. 135-162.

An informative and well organized discussion of the functional differentiation between the right and left hemispheres. Bogen underlines the duality of the cerebrum and hypothesizes two modes of thought corresponding to hemispheric functional independence.

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Bruell, J. H. and M. Peszczynski, "Perception of Verticality in Hemiplegia in Relation to Rehabilitation," Clinical Orthopedics, Vol. 12, 1958, p. 124-128.

The first investigators to apply the sensory-tonic theory of Werner and Wapner to hemiplegia. They demonstrated a consistent distortion in perception of the vertical coordinatesof external space and indicated a relationship between degree of displacement and rehabilitation prognosis.

Critchley, Macdonald, The Parietal Lobes, New York, Hafner Publishing Co., 1971 (6th ed.), 480 p.

First published in 1953, this volume is classic in its description and discussion of symptomatology evidenced in right and left hemispheric impairment. It remains a primary source of knowledge in the field. The author describes explicitly the diverse symptomatology possible in lesions of this cortical area and adjacent parts.

Diller, Leonard, Yehuda Ben-Yishay, Joseph Weinberg, and Robert Goodkin et al., Studies in Cognition and Rehabilitation in Hemiplegia, Grant No. RD 2666-P, Division of Research and Demonstration Grants, Social and Rehabilitation Service, Department of Health, Education and Welfare, Washington, 1971, 205 p.

This group of investigators have been the major influence in rehabilitation psychology towards remediation of neuropsychological deficits. This report summarizes their work, in this regard, on re-training techniques in spatial orientation and aphasia. They demonstrate that re-training in the area of perceptual deficit is feasible contingent upon a clear delineation of the reasons for failure on any particular task sensitive to the deficit in question. Development of a systematic cueing procedure based on the original block design task of the WAIS, and the construction of a training program in visual scanning are prototypes of what can be accomplished in the area of psychotechnology in physical rehabilitation.

Diller, Leonard, and Joseph Weinberg, "Bender Gestalt Distortions in Hemiplegia," Perceptual and Motor Skills, Vol. 20, 1965, p. 1313-1323.

The authors developed a quantitative scoring system for Bender - Gestalt performance and found a relationship between certain parameters of Bender - Gestalt functioning and judgments in the rod test of vertical and horizontal perception. They note a consistent tendency among left hemiplegics to rotate the rod and specific

Bender - Gestalt stimuli in a counterclockwise direction. The authors interpret the results in terms of a de-differentiation of the self and external world in left hemiplegia.

Diller, Leonard, and Joseph Weinberg, "Attention in Brain Damaged People," Journal of Education, Vol. 150, 1968, p. 20-27.

The article underlines the differential deficits in right and left hemiplegia. Left hemiplegics were demonstrated to have primary difficulty in short term visual memory storage. The authors stress the importance of considering what conditions will induce the left hemiplegic to pay attention to the tasks given in rehabilitation. It is suggested that allowing the left hemiplegic more time than normally needed to register a stimulus will improve his performance. The authors introduce the construct of attention as being essential to the deficits involved in right hemispheric impairment.

DeCenzio, Domino V., Martin Leshner, and David Voron, "Verticality Perception and Ambulation in Left Hemiplegia," Archives of Physical Medicine, Vol. 51, 1970, p. 105-110.

The contribution of this study was in demonstration that in right hemispheric impairment, perception of the vertical was not only disturbed in the frontal plane but as well in the midsagittal plane. The authors interpret these results in terms of a combination of effect involving asymmetric proprioceptive cues and the spatial dysfunction accompanying right hemispheric impairment. A high and significant correlation was found between errors in verticality perception and ambulation ratings among the left, although not the right, hemiplegics.

de Renzi, Ennio, and Piero Faglioni, "The Comparative Efficiency of Intelligence and Vigilance Tests in Detecting Hemispheric Cerebral Damage," Cortex, Vol. 1, 1965, p. 411-433.

This paper reports the superior sensitivity of reaction time procedures to brain damage than a standard test of fluid intelligence. It is noted that reaction time is more impaired in right hemispheric than left hemispheric damage. The authors interpret reaction time as a measure of psychological vigilance based on cortical integrity and hypothesize a relationship between size of lesion and impaired reaction time functioning.

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Freilicher, J., Effect of Symmetrical Extraneous Stimulation on the Position of the Apparent Median Plane, unpublished Master's thesis, Clark University, 1963, 101 p.

Of importance in this study is the observation that increasing bilaterally symmetrical intensity in normal subjects results in improved perception of the median plane. It reinforces the conception, presented in this thesis, that human spatial orientation depends upon a bilateral integration of stimuli in a condition of cerebral synchrony.

Friedlander, Walter J., "Anosognosia and Perception," American Journal of Physical Medicine, Vol. 46, 1967, p. 1394-1408.

The author introduces the concept that what was considered an independent syndrome may be an extreme form of perceptual-conceptual inattention or denial that is present in degrees among most left hemiplegics. The more frequent occurrence of visual neglect and anosognosia among left hemiplegics is interpreted in terms of the greater importance among normals of right-sided space rendering left-sided space even less important when sensory input is significantly reduced on that body side. Attention and denial are considered in the context of non-integration of multiple cues arising from the body and environment.

Gooddy, William, and Margaret Reinhold, "Some Aspects of Human Orientation in Space," Brain, Vol. 75, 1952, p. 472-509.

A thoughtful formulation of the role of sensation and movement in human spatial orientation. The concept of body symmetry and the inseparable nature of sensation and motion are stressed. Clinical material is presented and discussed within the context of their theoretical exposition.

Gyr, J. W., "Is a Theory of Direct Visual Perception Adequate?" Psychological Bulletin, Vol. 77, 1972, p. 246-261.

A comprehensive discussion of the role of central nervous system participation in the perceptual process. The author stresses the importance of cerebral intention, feedback on its own activity, and the ongoing comparison of the organism of its intention with the behavior being produced. The author draws on both behavioral and physiological evidence to support his thesis.

Held, Richard, and Sanford J. Freedman, "Plasticity in Human Sensorimotor Control," Science, Vol. 142, 1963, p. 455-462.

A basic summary of theory and research findings on the role of movement in the development of spatial orientation and its maintenance. The authors stress the importance of self-produced movement in visual-motor adaptation and the ontogenetic development of spatial abilities.

Holst, E. von, "Relations Between the Central Nervous System and the Peripheral Organs," British Journal of Animal Behavior, Vol. 2, 1954, p. 89-94.

A theoretical discussion of the author's experiments on the common house fly with respect to its contribution to an understanding of spatial orientation. The paper develops the concept of re-afference and stresses the copying, storing, comparing and decision-making processes of the central nervous system and its relation to perception. Perception is conceived as an interaction between central and peripheral inputs and feedback. The experimental procedures of the author are clearly described and remarkable for their precision and clarity.

Howard, I,P., and W. B. Templeton, Human Spatial Orientation, New York, John Wiley and Sons, 1966, 533 p.

A highly comprehensive review of experimentation on spatial orientation in its many aspects. It represents the only published work to date that has synthesized the many studies done in this area. Although pathology is mentioned, it is given only brief consideration. Although the authors do not present a summary leading to a theoretical position, they provide a critical assessment of what is understood in specific areas and what remains to be investigated.

Lerner, Shirley, "Lack of Movement Efficiency in C.V.A. Patients with Perceptual Dysfunction," Journal of the Canadian Physiotherapy Association, Vol. 22, 1970, p. 59-62.

An outline of the reasons for perceptual deficit in left hemiplegia from a physiotherapeutic context. The author indicates the importance of sensation, balance, bilateral input and feedback in perceptual disorders. The significant observation is that perceptual dysfunction may impede functional return irrespective of motor facility.

Rose, Jerzy E., and Vernon B. Mountcastle, "Touch and Kinesthesias," in Handbook of Physiology, Section 1, Neurophysiology, Vol. 1, American Physiological Society, Washington, 1960, p. 387-429.

A systematic and comprehensive review of the physiological properties of the somesthetic system. The authors note a common topographical pattern for position sense and tactile sensation within the cerebral cortex. A second pertinent finding concerns the relationship between intensity of stimulation and latency of arousal in the nervous system. The authors report that a more intense stimulus is processed more quickly than one of lesser intensity. In general, the theories of sensation are reviewed in light of neurophysiological evidence and the authors conclude that a highly interconnected system exists at a peripheral as well as central level.

Semmes, Josephine, Sidney Weinstein, Lila Ghent, and Hans-Lukas Teuber, "Correlates of Impaired Orientation in Personal and Extrapersonal Space," Brain, Vol. 86, 1963, p. 747-772.

In this study extrapersonal orientation was assessed by route-following guided by visual maps. The left and right posterior regions of the cerebral cortex were implicated in disorientation of this ability. The major finding was that degree of somatosensory defect was predictive of map performance. The authors conclude that this may represent a functional relationship although geographical proximity of lesion site must also be considered. In the present study, this observation was considered in the postulated relationship between sensory input and spatial dysfunction.

Van Buskirk, C., and D. Webster, "Prognostic Value of Sensory Defect in Rehabilitation of Hemiplegics," Neurology, Vol. 5, 1955, p. 407-411.

This study clearly demonstrated the relationship between somatosensory deficits and rehabilitation parameters. Defects in pain, vibration sense and two-point tactile discrimination were valid predictors of treatment outcome. This study aided in clarifying the question of the relationship between sensation and perception although it did not indicate an answer.

APPENDIX 1

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K. B. Fitzhugh and L. Fitzhugh, "WAIS Results for Subjects with Long-standing, Chronic Lateralized and Diffuse Cerebral Dysfunction," Perceptual and Motor Skills, Vol. 19, 1964, p. 735-739.

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L. Diller and J. Weinberg, "Attention in Brain Damaged People," Journal of Education, Vol. 150, 1968, p. 20-27.

J. Weinberg and L. Diller, "On Reading Newspapers by Hemiplegics--Denial of Visual Ability," Proceedings of the American Psychological Association, 1968, p. 655-656.

APPENDIX 2

DIGITS CANCELLATION TEST: SAMPLE

APPENDIX 2

DIGITS CANCELLATION TEST: SAMPLE

1 8 5 6 3 8 3 4 8 7 8 9 4 8 2 4 8 5 1 8 3 6 2 8 7 4 8 9 6 4 8 9 8 3 4 8 2 1 8 6 4 8 6 8 3 9 2 8 6 2

8 5 7 8 6 8 5 4 8 3 4 8 2 6 8 1 4 8 3 5 8 9 8 7 4 8 7 5 4 8 5 4 8 9 8 3 8 5 4 8 3 9 8 5 4 8 7 6 2 8

8 2 8 5 4 8 2 8 3 6 8 1 4 8 7 4 8 7 1 8 3 2 1 8 7 5 4 8 3 8 2 4 8 2 7 8 5 2 4 8 2 9 6 8 5 8 2 4 8 5

APPENDIX 3

SENSORY BATTERY: RAW SCORES OF TWENTY-SEVEN SUBJECTS ON SEVENTEEN SUBTEST VARIABLES

APPENDIX 3

Key to Subtest Variables:

1. Roughness Discrimination
2. Von Frey - left hand
3. Von Frey - right hand
4. Von Frey - left forearm
5. Von Frey - right forearm
6. 2-point Tactile - left hand
7. 2-point Tactile - right hand
8. Digits Cancellation - total error
9. Digits Cancellation - left side error
10. Digits Cancellation - right side error
11. Digits Cancellation - time (seconds)
12. Proprioception
13. Tactile Suppression
14. Hemianopia
15. Visual Suppression
16. Auditory Suppression
17. Form Discrimination

APPENDIX 3

SENSORY BATTERY: RAW SCORES OF TWENTY SEVEN SUBJECTS ON SEVENTEEN SUBTEST VARIABLES

Subjects		Variables											
		1	2	3	4	5	6	7	8	9	10	11	12
E	1	3	27	5	27	7	208	18	53	27	26	70	7
E	2	2	17	6	23	11	66	21	35	18	17	313	9
E	3	3	27	8	27	5	208	15	16	6	10	250	6
E	4	3	19	5	7	3	208	48	21	15	6	140	6
E	5	0	5	13	4	3	18	40	17	10	7	68	7
E	6	3	27	4	27	4	208	16	10	6	4	90	6
E	7	2	4	3	4	3	72	20	0	0	0	0	90
E	8	2	9	4	7	5	148	22	35	19	16	147	6
E	9	4	7	3	3	3	40	14	5	3	2	120	6
E	10	0	9	8	3	3	68	22	31	18	13	60	3
E	11	0	8	0	7	4	20	22	27	15	12	167	7
S	12	4	24	19	22	16	208	196	40	24	16	240	6
S	13	4	27	6	27	9	208	208	44	25	19	260	6
S	14	6	7	5	7	7	16	20	20	8	12	148	6
S	15	0	22	8	27	27	28	10	32	18	14	105	6
S	16	3	13	11	19	4	208	26	33	19	14	80	7
S	17	1	4	3	5	4	24	18	18	10	8	130	4
S	18	1	3	3	7	4	9	18	3	1	2	180	6
S	19	3	23	6	25	15	208	20	15	6	9	83	6
S	20	3	4	5	3	5	82	15	3	1	2	95	3
C	21	5	19	11	26	4	208	44	32	18	14	298	4
C	22	0	27	10	27	6	208	19	35	23	12	60	6
C	23	1	5	3	3	4	38	20	2	2	0	285	3
C	24	4	27	8	27	9	208	50	17	7	10	186	9
C	25	5	27	11	27	6	45	22	28	13	15	70	4
C	26	4	3	3	3	3	19	27	17	8	9	70	4
C	27	1	7	3	4	3	56	20	0	0	0	75	7

E - Experimental Group
S - Sham Group
C - Control Group

SENSORY BATTERY: RAW SCORES (Cont'd.)

Subjects		Variables 13	14	15	16	17
E	1	3	1	3	3	3
E	2	1	2	2	2	3
E	3	3	3	3	3	3
E	4	3	1	3	3	3
E	5	1	1	1	2	1
E	6	2	2	2	3	3
E	7	3	1	1	1	2
E	8	3	1	1	3	2
E	9	3	2	3	2	3
E	10	1	2	1	1	3
E	11	3	2	2	3	3
S	12	1	2	3	3	3
S	13	2	1	1	1	2
S	14	1	1	1	3	3
S	15	3	2	2	3	2
S	16	3	2	3	3	1
S	17	3	1	3	3	2
S	18	1	1	1	1	3
S	19	2	1	1	2	3
S	20	3	1	1	3	3
C	21	3	2	1	1	3
C	22	3	1	3	2	2
C	23	2	1	1	3	2
C	24	3	2	3	3	3
C	25	3	2	2	2	2
C	26	1	1	1	1	1
C	27	1	1	1	1	2

E - Experimental Group
S - Sham Group
C - Control Group

APPENDIX 4

SPATIAL ORIENTATION BATTERY: PRE-TEST RAW SCORES OF TWENTY-SEVEN SUBJECTS ON TWENTY-ONE SUBTEST VARIABLES

APPENDIX 4

Key to Subtest Variables:

1. Block Design
2. Object Assembly
3. Block Design + Object Assembly
4. Greek Cross
5. Bender Gestalt - Design A
6. " - Design 1
7. " - Design 2
8. " - Design 8
9. " - A Ratio
10. " - 4 Ratio
11. Total Errors
12. Rod and Frame - mean constant error
13. " - variance
14. Line Dissection - total mean constant error
15. " - left side mean constant error
16. " - right side mean constant error
17. " - variance
18. Tactile Localization - total mean constant error
19. " - left side mean constant error
20. " - right side mean constant error
21. " - variance

APPENDIX 4

SPATIAL ORIENTATION BATTERY: PRE-TEST RAW SCORES OF TWENTY-SEVEN SUBJECTS ON TWENTY-ONE SUBTEST VARIABLES

Subjects	Variables 1	2	3	4	5	6	7	8	9	10	11
E 1	0	3	3	5.0	70	2.0	5.2	.7	1.50	1.74	11
E 2	0	8	4	5.0	90	3.0	6.0	.8	3.70	1.66	9
E 3	6	21	27	1.0	5	2.0	2.5	.5	1.60	1.45	7
E 4	0	5	5	5.0	20	1.6	2.2	.8	2.25	1.25	10
E 5	12	6	18	4.5	13	2.0	1.6	.3	1.46	1.46	10
E 6	8	18	26	1.0	14	1.5	1.7	.1	1.60	1.44	3
E 7	10	15	25	1.0	10	.6	.3	.3	1.15	1.39	2
E 8	2	12	14	3.0	8	3.5	3.1	.1	2.30	2.00	8
E 9	20	15	35	2.0	15	1.0	1.3	.7	1.25	1.21	3
E 10	8	18	26	4.0	25	1.6	1.7	.5	1.31	1.87	5
E 11	0	4	4	4.0	20	1.6	.6	.9	1.16	1.66	9
S 12	0	9	9	2.0	43	2.5	6.5	.5	4.80	2.50	8
S 13	8	3	11	3.5	12	.5	.4	.1	3.00	2.30	10
S 14	0	4	4	4.5	30	.9	.7	.5	.70	.60	8
S 15	6	11	17	3.0	12	.2	.1	.3	1.40	1.10	4
S 16	0	7	7	4.0	15	2.0	2.5	.2	6.50	5.50	10
S 17	16	18	34	2.0	12	2.6	5.2	.1	1.60	1.10	7
S 18	14	21	35	1.0	16	.5	3.0	.1	1.90	1.70	5
S 19	10	10	26	2.0	26	.1	2.0	.6	2.00	1.40	7
S 20	12	9	21	3.5	14	.9	6.3	.3	2.90	1.80	8
C 21	0	13	13	3.5	35	.7	3.2	.8	1.60	.80	12
C 22	0	1	1	3.5	39	1.9	1.5	1.8	2.10	1.20	14
C 23	8	12	20	3.5	2	.4	.2	.3	1.60	1.10	7
C 24	0	2	2	5.0	95	1.6	.5	.2	.40	.10	13
C 25	19	9	25	3.0	18	.3	.8	.5	2.40	1.30	3
C 26	28	31	59	2.0	3	1.1	1.3	.4	.80	.50	6
C 27	9	9	18	1.0	10	.2	1.5	.3	1.90	1.30	4

E - Experimental Group
S - Sham Group
C - Control Group

APPENDIX 4

SPATIAL ORIENTATION BATTERY: PRE-TEST RAW SCORES (Cont'd.)

Subjects	Variables 12	13	14	15	16	17	18	19	20	21
E 1	14.20	17.25	1.19	1.43	.94	1.36	7.10	12.00	2.20	50.45
E 2	2.35	1.75	.86	1.01	.71	1.57	2.83	3.35	2.35	4.14
E 3	1.60	1.10	.42	.56	.27	.32	3.35	4.65	2.05	5.77
E 4	1.30	1.12	.95	.83	1.06	.56	4.10	1.90	2.20	2.70
E 5	.45	.19	.77	.98	.56	.36	2.45	2.70	2.20	3.82
E 6	.70	.46	.35	.29	.40	.43	3.30	.28	.38	6.55
E 7	.60	.38	.32	.22	.41	.12	1.65	2.20	1.10	2.77
E 8	1.60	1.43	.52	.47	.55	.23	5.90	9.40	2.40	19.53
E 9	.45	.14	.31	.40	.22	.14	2.50	3.70	1.30	3.84
E 10	.75	.24	.32	.24	.40	.36	2.95	2.70	3.20	5.42
E 11	2.65	2.68	1.04	1.11	.97	1.07	4.00	4.00	3.60	20.30
S 12	1.60	1.21	1.14	.94	1.33	1.66	3.60	5.10	2.10	15.32
S 13	1.70	1.96	.63	.54	.71	.06	2.20	1.80	2.60	4.80
S 14	1.90	1.10	.42	.42	.41	.06	4.20	5.10	3.20	7.50
S 15	1.70	.54	1.04	1.49	.59	1.16	2.95	1.10	1.85	10.05
S 16	3.35	6.18	.54	.59	.49	.16	3.65	2.40	4.90	7.20
S 17	.50	.14	1.18	1.14	1.22	1.17	2.40	2.60	2.20	4.78
S 18	.80	1.14	.25	.18	.32	.04	3.10	4.40	1.8	6.54
S 19	1.05	.62	1.51	.58	.44	.16	3.80	4.30	3.30	4.44
S 20	1.30	.96	.92	.49	1.34	.38	2.80	3.00	2.60	6.27
C 21	1.10	.89	.64	.58	.69	.22	3.80	3.20	4.40	6.69
C 22	1.30	.57	.94	1.42	.46	.77	5.65	.61	.52	13.92
C 23	.45	.14	.52	.64	.40	.29	2.35	2.80	1.90	2.87
C 24	1.55	1.70	2.78	4.44	1.11	3.39	4.00	4.00	3.60	11.90
C 25	1.10	.56	.64	.67	.61	.34	4.15	5.10	3.20	4.87
C 26	.75	.18	.25	.19	.31	.94	1.35	1.80	.90	2.56
C 27	1.00	.70	.97	.98	.95	1.12	2.15	2.90	1.40	2.66

E - Experimental Group
S - Sham Group
C - Control Group

APPENDIX 5

SPATIAL ORIENTATION BATTERY: POST-TEST RAW SCORES OF TWENTY-SEVEN SUBJECTS ON TWENTY-ONE SUBTEST VARIABLES

APPENDIX 5

Key to Subtest Variables:

1. Block Design
2. Object Assembly
3. Block Design - Object Assembly
4. Greek Cross
5. Bender Gestalt - Design A
6. " - Design 1
7. " - Design 2
8. " - Design 8
9. " - A Ratio
10. " - 4 Ratio
11. Total Errors
12. Rod and Frame - mean constant error
13. " - variance
14. Line Dissection - total mean constant error
15. " - left side mean constant error
16. " - right side mean constant error
17. " - variance
18. Tactile Localization - total mean constant error
19. " - left side mean constant error
20. " - right side mean constant error
21. " - variance

APPENDIX 5

SPATIAL ORIENTATION BATTERY: POST-TEST RAW SCORES OF TWENTY-SEVEN SUBJECTS ON TWENTY-ONE SUBTEST VARIABLES

Subjects	Variables 1	2	3	4	5	6	7	8	9	10	11
E 1	2	1	3	5.0	33	.5	1.8	.2	1.55	1.63	6
E 2	0	4	4	5.0	30	1.0	3.5	.7	1.17	2.12	8
E 3	12	15	27	1.0	5	.5	1.7	.4	1.46	1.11	7
E 4	4	2	6	5.0	10	2.0	2.2	.8	1.50	2.50	9
E 5	12	19	31	4.0	5	1.0	2.3	.3	1.41	1.12	5
E 6	10	10	20	2.0	10	2.2	5.8	.1	1.58	1.40	6
E 7	24	17	41	1.0	15	.8	.6	.0	1.20	1.17	1
E 8	2	22	24	2.0	30	3.5	.5	.2	1.31	1.64	7
E 9	24	24	47	2.0	21	1.6	1.5	.3	1.84	1.17	1
E 10	8	8	24	1.5	10	2.1	4.0	.2	1.29	1.54	3
E 11	4	4	6	3.0	7	1.3	.6	.6	1.60	1.56	9
S 12	0	9	9	3.0	16	1.7	1.2	.8	6.00	2.40	11
S 13	0	8	8	3.0	25	2.0	1.0	.1	1.90	1.30	6
S 14	2	12	14	5.0	24	.5	.8	.5	.80	.70	7
S 15	4	8	12	4.0	20	1.8	1.3	.6	2.10	1.70	4
S 16	0	10	10	3.0	28	2.6	2.0	.3	9.00	4.50	8
S 17	8	7	25	2.0	20	3.6	2.3	.9	1.20	.90	5
S 18	0	21	21	1.0	28	1.8	4.4	.3	.20	1.90	8
S 19	10	7	17	3.5	27	.1	2.5	.4	1.90	.70	4
S 20	8	15	23	3.5	32	1.1	5.5	.3	3.00	1.90	6
C 21	0	8	8	3.5	25	.3	1.2	1.5	1.70	.90	10
C 22	0	2	2	3.0	41	2.0	1.1	1.2	2.00	1.00	16
C 23	8	-20	32	4.0	25	.5	.4	.6	2.30	1.50	5
C 24	0	4	4	5.0	20	.5	1.1	1.0	1.20	.30	13
C 25	12	8	20	3.0	15	.4	.9	.4	2.20	1.20	3
C 26	24	32	56	2.0	6	2.0	1.6	.1	.70	.60	4
C 27	18	14	32	1.5	12	.2	1.4	.4	1.80	1.70	4

E - Experimental Group
S - Sham Group
C - Control Group

SPATIAL ORIENTATION BATTERY: POST-TEST RAW SCORES (Cont'd.)

	Variables									
Subjects	12	13	14	15	16	17	18	19	20	21
E 1	10.00	11.38	.62	.52	.72	.26	2.88	3.35	3.40	14.81
E 2	2.80	1.23	1.14	1.45	.87	1.30	2.78	3.20	4.35	6.86
E 3	.75	.35	.53	.63	.43	.13	3.05	3.60	2.50	5.21
E 4	2.20	1.71	.83	.73	.93	.93	3.30	2.50	1.00	1.55
E 5	.70	.94	.38	.30	.40	.09	2.65	1.40	2.20	3.45
E 6	1.45	.87	.67	.82	.52	.76	3.15	.26	.40	7.22
E 7	.75	.24	.34	.31	.36	.05	1.05	1.60	.50	1.16
E 8	2.45	5.05	.56	.56	.55	.16	3.95	3.10	3.80	10.16
E 9	.95	.25	.37	.36	.37	.14	3.25	2.50	3.50	7.67
E10	.40	.23	.58	.57	.58	.22	1.90	2.30	1.50	2.62
E11	.85	.56	.48	.64	.32	.38	2.25	1.50	2.80	3.26
S12	2.85	2.65	.50	.45	.55	.18	4.35	5.10	3.60	14.98
S13	2.45	2.69	.70	.91	.49	.50	3.20	3.10	3.30	8.17
S14	1.75	1.13	.47	.50	.44	.13	3.40	5.30	1.50	6.46
S15	1.50	3.61	.58	.84	.32	.77	6.80	6.50	7.10	27.43
S16	1.00	1.85	.55	.51	.59	.22	3.40	3.40	3.40	14.30
S17	.55	.82	.47	.59	.35	.13	2.20	1.30	1.80	5.96
S18	.65	.27	.30	.26	.33	.06	2.20	2.30	2.10	4.59
S19	1.30	.91	.63	.76	.50	.25	3.30	4.20	2.40	6.96
S20	2.75	5.63	.90	1.14	.66	3.08	3.63	3.75	3.50	8.30
C21	.80	.47	.75	.87	.63	.79	2.76	3.55	1.97	4.01
C22	1.20	1.79	1.06	1.63	.49	.68	7.55	4.60	15.10	20.48
C23	.60	.24	.42	.21	.62	.88	1.60	1.50	1.70	2.16
C24	2.15	2.84	1.55	2.40	.70	2.62	4.50	5.90	3.10	10.71
C25	1.05	.66	.61	.77	.44	.37	3.70	3.90	3.50	5.25
C26	.90	.38	2.85	.26	.31	.09	1.98	1.90	2.05	3.33
C27	1.05	.91	.36	.34	.37	.08	3.30	3.50	3.10	5.80

E - Experimental Group
S - Sham Group
C - Control Group

APPENDIX 6

SENSORY BATTERY: RAW SCORES, MEANS, AND STANDARD DEVIATIONS FOR THE EXPERIMENTAL, SHAM, AND CONTROL GROUPS ON SEVENTEEN SUBTEST VARIABLES

APPENDIX 6

SENSORY BATTERY: RAW SCORES, MEANS, AND STANDARD DEVIATIONS FOR THE EXPERIMENTAL, SHAM, AND CONTROL GROUPS ON SEVENTEEN SUBTEST VARIABLES

Subtest	Experimental Mean	Experimental S.D.	Sham Mean	Sham S.D.	Control Mean	Control S.D.
Roughness Discrimination	2.00	1.41	2.77	1.85	2.86	2.12
Von Frey: Left Hand	14.45	9.25	14.11	9.91	16.42	11.11
: Right Hand	5.73	2.97	7.33	5.02	7.00	3.87
: Left Forearm	12.63	10.75	15.78	10.12	16.71	12.52
: Right Forearm	4.64	2.46	10.11	7.85	5.00	2.16
Digits Cancellation : Total Error	22.73	15.42	23.11	15.03	18.71	13.92
: Left Error	12.45	8.14	12.44	9.32	10.14	8.36
: Right Error	10.27	7.60	10.66	5.94	8.57	6.21
: Time	135.72	81.95	146.78	66.94	270.00	297.37
Proprioception	6.09	1.57	5.56	1.23	5.29	2.14
Tactile Suppression	2.36	.92	2.11	.93	2.28	.95
Visual Suppression	2.00	.89	1.78	.97	1.71	.95
Auditory Suppression	2.36	.81	2.44	.88	1.86	.90
Hemianopia	1.64	.67	1.33	.50	1.43	.53
Form Discrimination	2.64	.67	2.44	.73	1.85	1.06
2-point Tactile - Left	97.63	79.77	110.11	95.10	113.43	92.94
2-point Tactile - Right	25.63	11.46	59.00	81.24	40.67	29.14

APPENDIX 7

PRE-TEST RAW SCORE MEANS AND STANDARD DEVIATIONS FOR THE EXPERIMENTAL, SHAM, AND CONTROL GROUPS ON TWENTY-ONE SPATIAL ORIENTATION SUBTESTS

APPENDIX 7

PRE-TEST RAW SCORE MEANS AND STANDARD DEVIATIONS FOR THE EXPERIMENTAL, SHAM, AND CONTROL GROUPS ON TWENTY-ONE SPATIAL ORIENTATION SUBTESTS

	Experimental		Sham		Control	
Subtest	Mean	S.D.	Mean	S.D.	Mean	S.D.
Block Design	6.00	6.45	7.33	6.24	8.71	10.44
Object Assembly	11.36	6.42	10.22	5.93	10.86	10.12
Block Design + Object Assembly	17.00	11.57	18.22	11.54	21.00	18.33
Greek Cross	3.27	1.73	3.00	1.32	4.14	2.91
Bender Gestalt:						
Design A	26.36	27.49	20.00	10.81	29.43	32.85
Design 1	1.96	1.02	1.13	.97	.83	.61
Design 2	2.11	1.35	2.97	2.49	1.29	.98
Design 8	.99	1.68	3.00	.19	1.13	1.38
A Ratio	1.52	.45	1.38	.25	2.01	.90
4 Ratio	1.46	.38	1.63	.80	1.42	.22
Error sum	7.00	3.22	7.44	2.01	19.42	31.78
Rod and Frame:						
Error	2.42	3.98	1.54	.82	6.58	14.79
Variance	2.34	5.01	1.54	1.81	.60	.58
Line Dissection:						
Total error	.64	.33	.73	.34	10.84	26.14
Error left	.68	.41	.70	.41	6.81	14.76
Error right	.59	.29	.76	.42	3.44	7.32
Variance	.45	.41	.54	.62	9.48	22.33
Tactile Localization						
Total error	3.53	1.70	3.19	.67	3.35	1.47
Error left	4.21	3.45	3.31	1.46	2.91	1.45
Error right	2.18	.98	2.73	.95	2.27	1.47
Variance	11.23	14.52	7.43	3.43	6.50	4.66

APPENDIX 8

POST-TEST RAW SCORE MEANS AND STANDARD DEVIATIONS FOR THE EXPERIMENTAL, SHAM, AND CONTROL GROUPS ON TWENTY-ONE SPATIAL ORIENTATION SUBTESTS

APPENDIX 8

POST-TEST RAW SCORE MEANS AND STANDARD DEVIATIONS FOR THE EXPERIMENTAL, SHAM, AND CONTROL GROUPS ON TWENTY-ONE SPATIAL ORIENTATION SUBTESTS

	Experimental		Sham		Control	
Subtest	Mean	S.D.	Mean	S.D.	Mean	S.D.
Block Design	9.36	8.25	3.56	4.09	9.43	9.71
Object Assembly	11.45	17.95	10.77	4.81	12.57	10.50
Block Design - Object Assembly	21.18	15.64	15.44	6.34	22.00	19.49
Greek Cross	2.86	1.47	3.11	1.20	3.29	1.11
Bender Gestalt:						
Design A	13.54	8.96	24.44	5.00	20.57	11.36
Design 1	1.82	1.23	1.69	1.65	.84	.80
Design 2	2.40	2.20	2.33	1.62	1.10	.38
Design 8	.55	.76	.77	.87	.74	.50
A Ratio	1.57	.36	1.67	.60	1.92	.99
4 Ratio	1.13	.58	1.84	.86	1.85	.86
Error sum	5.63	2.77	6.56	2.24	7.86	5.15
Rod and Frame:						
Error	2.12	8.88	1.64	.87	1.11	.50
Variance	2.07	3.38	2.17	1.69	1.04	.95
Line Dissection:						
Total error	.59	.25	.57	.17	.72	.45
Error left	.63	.25	.66	.27	.93	.82
Error right	.55	.32	.47	.12	.51	.14
Variance	.40	.94	.59	.96	.79	.87
Tactile Localization:						
Total error	2.70	1.09	3.61	1.37	3.63	1.99
Error left	2.26	1.33	3.65	1.96	3.55	1.51
Error right	2.40	1.24	3.12	1.87	4.36	4.79
Variance	5.83	4.12	10.79	7.20	7.39	6.39

APPENDIX 9

SENSORY BATTERY: TRANSFORMED SCORES OF SEVENTEEN SUBTEST VARIABLES AND MEAN TOTAL SENSORY SCORE ON TWENTY-SEVEN SUBJECTS

APPENDIX 9

Key to Subtest Variables:

1. Roughness Discrimination
2. Von Frey - left hand
3. Von Frey - right hand
4. Von Frey - left forearm
5. Von Frey - right forearm
6. 2-point Tactile - left hand
7. 2-point Tactile - right hand
8. Digits Cancellation - total error
9. Digits Cancellation - left side error
10. Digits Cancellation - right side error
11. Digits Cancellation - time (seconds)
12. Proprioception
13. Tactile Suppression
14. Hemianopia
15. Visual Suppression
16. Auditory Suppression
17. Form Discrimination

18. Mean Total Sensory Score

SENSORY BATTERY: TRANSFORMED SCORES OF SEVENTEEN SUBTEST VARIABLES AND MEAN TOTAL SENSORY SCORE ON TWENTY-SEVEN SUBJECTS

Subjects	Variables 1	2	3	4	5	6	7	8	9	10
E 1	53.0	62.6	45.9	61.4	50.8	72.0	69.0	74.5	58.0	58.2
E 2	47.2	52.2	49.0	58.0	58.2	59.1	58.0	61.0	70.4	37.0
E 3	53.0	62.6	53.6	61.4	47.1	46.0	43.0	51.0	51.8	58.2
E 4	53.0	54.3	45.9	43.0	44.0	49.4	54.0	43.9	51.8	58.2
E 5	35.7	40.0	66.4	40.0	44.0	47.0	48.0	46.0	58.0	37.0
E 6	53.0	62.6	43.3	61.4	46.0	41.8	43.0	41.0	51.8	47.1
E 7	47.2	38.7	41.0	40.0	44.0	34.9	36.0	35.0	39.4	58.2
E 8	47.2	43.9	43.3	43.0	47.1	59.1	59.0	59.2	51.8	58.2
E 9	58.7	41.8	41.0	39.1	44.0	39.0	40.0	37.8	51.8	58.2
E 10	35.7	43.9	53.6	39.1	44.0	56.3	57.4	54.6	33.2	37.0
E 11	35.7	43.0	43.3	43.0	46.0	54.0	54.0	53.1	58.0	58.2
S 12	58.7	59.5	82.0	57.0	68.0	63.0	65.0	59.2	51.8	37.0
S 13	58.7	62.6	49.0	61.4	54.5	65.3	66.0	63.8	51.8	47.1
S 14	70.2	41.8	45.9	42.8	50.8	48.7	45.4	53.1	51.8	36.0
S 15	35.7	57.4	53.6	61.4	88.0	57.0	57.4	56.2	51.8	58.2
S 16	53.0	48.1	61.3	54.0	45.2	57.7	58.6	56.2	58.0	58.2
S 17	41.5	38.7	40.8	40.9	45.3	47.4	47.8	47.0	39.4	58.2
S 18	41.5	37.7	40.8	42.8	45.3	37.0	37.0	37.8	51.8	36.1
S 19	53.0	58.5	48.5	59.5	65.7	45.3	43.0	48.5	51.8	47.1
S 20	53.0	38.7	45.9	39.1	47.1	37.0	37.0	37.8	33.2	58.2
C 21	64.5	54.3	61.3	60.5	45.3	57.0	57.4	56.2	39.4	58.2
C 22	35.7	62.6	58.7	61.4	49.0	59.1	63.4	53.1	51.8	58.2
C 23	41.5	39.8	40.8	39.1	45.3	36.3	38.2	34.8	33.2	47.1
C 24	58.7	62.6	53.6	61.4	54.5	46.7	44.2	50.1	70.4	58.2
C 25	64.5	62.6	61.3	61.4	49.0	54.3	51.4	57.7	39.4	58.2
C 26	58.7	37.7	40.8	39.1	43.4	46.7	45.4	48.5	39.4	36.1
C 27	41.5	41.8	40.8	40.0	43.4	34.9	35.8	34.8	58.0	36.1

E - Experimental Group
S - Sham Group
C - Control Group

SENSORY BATTERY: TRANSFORMED SCORES
(Cont'd.)

Subjects	Variables 11	12	13	14	15	16	17	18
E 1	42.0	63.0	58.6	57.5	62.0	47.0	43.7	57.60
E 2	58.9	51.6	47.0	57.5	45.3	48.0	58.3	53.92
E 3	77.0	63.0	58.6	57.5	62.0	47.0	55.0	55.75
E 4	42.0	63.0	58.6	57.5	62.0	49.0	47.9	51.62
E 5	42.0	40.6	47.0	34.0	40.0	49.0	43.6	44.60
E 6	58.9	51.6	58.6	57.5	40.0	49.0	43.6	50.01
E 7	42.0	40.6	35.3	46.0	46.0	47.0	44.9	42.13
E 8	42.0	40.6	58.6	46.0	54.9	47.1	49.0	50.00
E 9	58.9	63.0	47.0	57.5	43.0	47.0	46.7	47.91
E 10	58.9	40.6	35.3	57.5	46.0	47.1	43.1	46.08
E 11	58.9	51.6	58.6	57.5	39.9	47.1	50.0	50.11
S 12	58.9	63.0	58.6	57.5	62.0	59.0	54.0	59.66
S 13	42.0	40.6	35.3	46.0	62.0	60.0	56.0	54.24
S 14	41.7	40.6	58.6	57.5	39.5	47.0	48.4	48.22
S 15	59.0	51.6	58.6	45.6	40.9	46.3	45.8	54.78
S 16	59.0	62.7	58.6	33.7	62.0	47.4	44.3	54.00
S 17	41.7	62.7	58.6	45.6	40.4	46.9	47.3	46.48
S 18	41.7	40.6	35.3	57.5	38.6	46.9	50.3	42.27
S 19	41.7	40.6	47.0	57.5	62.0	46.9	44.5	50.65
S 20	41.7	40.6	58.6	57.5	47.2	46.7	45.2	44.97
C 21	58.9	40.6	35.3	57.5	62.0	48.5	57.4	53.80
C 22	41.7	62.7	47.0	21.7	63.4	97.5	93.9	57.70
C 23	41.7	40.6	58.6	45.6	42.0	46.9	56.7	42.84
C 24	58.9	62.7	58.7	57.5	62.0	49.0	50.7	56.46
C 25	58.9	51.6	46.9	45.6	42.9	47.1	43.7	52.74
C 26	41.7	40.6	35.3	33.7	39.8	47.4	43.7	42.24
C 27	41.7	40.6	35.3	45.6	44.2	47.0	44.0	41.50

E - Experimental Group
S - Sham Group
C - Control Group

APPENDIX 10

SPATIAL ORIENTATION BATTERY: TRANSFORMED PRE-TEST SCORES ON TWENTY-ONE SUBTEST VARIABLES AND MEAN TOTAL ORIENTATION SCORE FOR TWENTY-SEVEN SUBJECTS

APPENDIX 10

Key to Subtest Variables:

1. Block Design
2. Object Assembly
3. Block Design + Object Assembly
4. Greek Cross
5. Bender Gestalt - Design A
6. " - Design 1
7. " - Design 2
8. " - Design 8
9. " - A Ratio
10. " - 4 Ratio
11. Total Errors
12. Rod and Frame - mean constant error
13. " - variance
14. Line Dissection - total mean constant error
15. " - left side mean constant error
16. " - right side mean constant error
17. " - variance
18. Tactile Localization - total mean constant error
19. " - left side mean constant error
20. " - right side mean constant error
21. " - variance
22. Sum Orientation Score

SPATIAL ORIENTATION BATTERY: TRANSFORMED PRE-TEST SCORES ON TWENTY-ONE SUBTEST VARIABLES AND MEAN TOTAL ORIENTATION SCORE FOR TWENTY-SEVEN SUBJECTS

Subjects		Variables 1	2	3	4	5	6	7	8	9	10	11
E	1	59.7	61.0	61.8	58.1	68.5	56.0	66.7	49.3	48.3	54.5	50.4
E	2	59.7	54.0	61.0	58.1	76.7	77.1	54.5	90.2	34.8	32.5	49.2
E	3	51.6	35.7	43.5	37.8	41.8	56.0	51.8	47.7	49.9	48.9	47.9
E	4	59.7	58.2	60.2	58.1	47.9	52.1	50.1	50.0	60.9	45.1	49.8
E	5	43.4	56.8	50.3	58.1	45.0	56.0	46.8	46.2	47.6	49.1	49.8
E	6	48.8	40.0	44.2	37.8	45.5	51.1	47.3	44.6	49.9	48.7	45.5
E	7	46.1	44.2	45.0	37.8	43.8	42.2	39.6	46.2	42.4	47.8	44.9
E	8	57.0	48.4	53.4	47.9	43.0	70.8	55.1	44.6	61.7	59.5	48.6
E	9	32.6	44.2	37.4	42.8	45.9	46.1	45.1	49.3	44.0	44.3	45.5
E	10	48.8	39.9	44.2	53.0	50.0	52.1	47.3	47.7	45.1	57.0	46.7
S	11	59.7	59.6	61.0	53.0	47.9	52.1	41.3	50.8	50.9	53.0	49.2
S	12	59.7	52.6	57.2	42.8	57.4	60.9	73.9	47.7	55.3	48.3	48.6
S	13	48.8	61.0	55.7	53.0	44.6	41.2	40.1	44.6	44.9	56.0	49.8
S	14	59.7	59.6	61.0	58.1	52.0	45.2	41.8	47.7	42.5	46.6	48.6
S	15	51.6	49.8	51.1	47.9	44.6	38.3	38.5	46.2	44.4	43.7	46.1
S	16	59.7	55.4	58.7	53.0	45.9	56.0	51.8	45.4	42.9	91.5	49.8
S	17	38.0	39.9	38.2	42.8	44.6	61.9	66.7	44.6	47.4	43.7	47.9
S	18	40.7	35.7	37.4	37.8	46.3	41.2	54.5	44.6	41.9	47.8	46.7
S	19	46.1	51.2	44.2	42.8	50.4	37.3	49.0	48.5	47.1	41.8	47.9
S	20	43.4	52.6	48.1	53.0	45.5	45.2	72.8	46.2	50.1	51.4	48.6
C	21	59.7	47.0	54.1	53.0	54.1	43.2	55.6	50.0	56.7	41.4	51.0
C	22	59.7	65.3	56.4	83.5	57.4	55.0	46.2	57.8	52.5	55.5	99.2
C	23	48.8	48.4	48.8	53.0	40.5	40.2	39.0	46.2	47.4	48.7	47.9
C	24	59.7	62.4	62.5	58.1	78.8	48.1	40.7	45.4	90.4	49.9	51.6
C	25	38.0	52.6	45.0	47.9	47.1	39.2	42.4	47.7	54.0	45.1	45.5
C	26	21.7	21.7	19.1	42.8	40.9	47.1	45.1	74.8	49.9	47.9	47.3
C	27	47.5	52.6	50.3	37.8	43.8	38.3	46.2	46.2	47.2	50.5	46.1

E - Experimental Group
S - Sham Group
C - Control Group

SPATIAL ORIENTATION BATTERY: TRANSFORMED PRE-TEST SCORES (Cont'd.)

Subjects	Variables 12	13	14	15	16	17	18	19	20	21	22
E 1	64.1	96.6	48.4	48.9	48.8	48.7	78.0	84.2	48.3	93.0	61.6
E 2	48.9	50.4	48.2	48.3	48.2	47.5	36.5	47.0	58.7	43.4	53.6
E 3	47.9	48.4	47.8	47.7	47.0	47.8	49.8	54.4	47.0	46.9	47.5
E 4	47.6	48.5	48.2	48.1	49.1	48.0	55.5	43.2	48.3	43.8	51.1
E 5	46.5	45.7	48.0	48.3	47.8	47.9	43.1	46.4	48.3	44.9	48.4
E 6	46.8	46.5	47.8	47.4	47.4	47.9	49.5	36.6	31.9	47.7	45.4
E 7	46.7	46.3	47.8	47.3	47.4	47.6	37.1	44.4	38.4	43.9	44.1
E 8	47.9	46.4	47.9	47.6	47.8	47.7	69.0	73.7	50.1	61.1	53.8
E 9	46.5	45.6	47.7	47.5	46.9	47.7	43.5	50.5	40.2	45.0	44.7
E10	46.9	45.9	47.8	47.3	47.4	47.9	46.8	46.4	57.3	46.6	48.2
E11	49.3	53.2	48.3	48.5	48.9	48.5	54.7	51.7	61.0	61.9	52.6
S12	47.9	48.8	48.4	48.2	49.8	49.0	51.7	56.2	47.4	56.8	52.8
S13	48.1	51.0	48.0	47.7	48.2	47.6	41.2	42.8	51.9	45.9	48.2
S14	48.3	48.4	47.8	47.6	47.4	47.6	56.2	56.2	57.3	48.7	50.9
S15	48.1	46.8	48.3	49.0	47.9	48.6	46.8	39.9	45.2	51.4	46.4
S16	50.2	63.6	47.9	47.8	47.6	47.7	52.1	45.2	72.7	48.4	54.0
S17	46.5	45.6	48.4	48.5	49.6	48.6	42.7	46.0	48.3	45.9	46.9
S18	46.9	48.6	47.7	47.2	47.1	47.6	48.0	53.3	44.7	47.7	45.4
S19	47.2	47.0	47.9	47.8	47.5	47.7	53.2	52.9	58.2	45.6	47.7
S20	47.6	48.0	48.2	47.6	49.9	47.9	45.7	47.7	51.9	47.5	41.5
C21	47.3	47.8	48.0	47.8	48.1	47.7	53.2	48.5	68.2	47.9	60.0
C22	97.2	45.3	100.0	99.9	99.8	99.9	67.1	37.9	33.1	55.3	67.8
C23	46.5	45.6	47.9	47.8	47.4	47.8	42.3	46.8	45.6	44.0	46.2
C24	47.9	50.2	49.6	52.8	49.3	50.5	54.7	51.7	61.0	53.2	55.6
C25	47.3	46.8	48.0	47.9	47.9	47.8	55.8	56.2	57.3	46.0	47.9
C26	46.9	45.7	47.7	47.3	47.1	48.4	34.8	42.8	36.6	43.6	42.8
C27	47.2	47.2	48.2	48.3	48.8	48.5	40.8	47.2	41.1	43.7	46.1

E - Experimental Group
S - Sham Group
C - Control Group

APPENDIX 11

SPATIAL ORIENTATION BATTERY: TRANSFORMED POST-TEST SCORES ON TWENTY-ONE SUBTEST VARIABLES AND MEAN TOTAL ORIENTATION SCORE FOR TWENTY-SEVEN SUBJECTS

APPENDIX 11

Key to Subtest Variables:

1. Block Design
2. Object Assembly
3. Block Design - Object Assembly
4. Greek Cross
5. Bender Gestalt - Design A
6. " - Design 1
7. " - Design 2
8. " - Design 8
9. " - A Ratio
10. " - 4 Ratio
11. Total Errors
12. Rod and Frame - mean constant error
13. " - variance
14. Line Dissection - total mean constant error
15. " - left side mean constant error
16. " - right side mean constant error
17. " - variance
18. Tactile Localization - total mean constant error
19. " - left side mean constant error
20. " - right side mean constant error
21. " - variance
22. Sum Orientation Score

SPATIAL ORIENTATION BATTERY: TRANSFORMED POST-TEST SCORES ON TWENTY-ONE SUBTEST VARIABLES AND MEAN TOTAL ORIENTATION SCORE FOR TWENTY-SEVEN SUBJECTS

Subjects	Variables 1	2	3	4	5	6	7	8	9	10	11
E 1	57.0	60.4	61.5	65.2	64.7	40.8	48.6	43.5	47.8	51.0	48.8
E 2	58.2	9.7	63.6	57.3	36.2	75.4	77.7	54.5	47.0	51.8	45.9
E 3	44.2	49.5	44.6	33.7	37.2	40.8	48.0	46.3	46.4	32.1	51.7
E 4	54.4	59.7	59.4	65.2	42.1	56.1	42.8	77.9	62.7	30.8	57.6
E 5	44.2	46.4	41.8	57.3	37.2	45.3	51.5	44.9	45.6	44.7	45.9
E 6	46.7	53.4	49.5	41.5	42.1	56.1	71.6	42.2	48.2	48.1	48.8
E 7	28.8	47.9	34.8	33.7	47.0	43.5	41.7	40.8	42.3	45.3	34.1
E 8	57.0	44.0	46.7	41.5	35.3	67.7	41.1	43.5	44.0	43.7	51.7
E 9	28.8	43.3	30.5	41.5	52.9	50.7	46.9	44.9	52.3	45.3	34.1
E 10	49.3	48.7	46.7	41.5	42.1	55.2	61.3	43.5	43.7	49.9	40.0
E 11	54.4	59.7	59.4	49.4	39.2	48.0	41.7	49.0	48.6	50.1	57.6
S 12	59.5	54.2	57.3	49.4	48.0	51.6	45.2	51.8	62.7	81.5	63.5
S 13	59.5	55.0	58.0	49.4	56.8	54.3	44.0	42.2	46.4	49.4	48.8
S 14	57.0	51.9	43.7	65.2	55.8	40.8	42.8	47.7	41.3	49.4	51.7
S 15	54.4	55.0	55.2	57.3	51.9	52.5	45.7	49.0	42.7	51.3	42.9
S 16	59.5	53.4	56.6	49.4	59.8	59.7	49.8	82.0	54.8	47.0	54.7
S 17	49.3	47.9	46.0	41.5	51.9	68.6	51.5	53.2	44.3	52.7	45.9
S 18	59.5	44.8	48.8	33.7	59.8	52.5	63.6	44.9	39.9	48.5	54.7
S 19	46.7	55.8	51.6	57.3	58.8	37.2	52.6	46.3	66.0	50.2	42.9
S 20	49.3	49.5	47.4	57.3	63.7	46.2	69.9	44.9	48.1	52.0	48.8
C 21	59.5	55.0	58.0	57.3	56.8	39.0	45.2	61.4	53.1	46.6	60.5
C 22	59.5	59.7	62.2	49.4	72.5	54.3	44.6	57.3	54.8	55.5	78.1
C 23	44.2	45.6	41.1	57.3	56.8	40.8	40.5	49.0	47.5	47.2	45.9
C 24	59.5	58.1	60.8	65.2	51.9	40.8	44.6	54.5	86.2	76.1	69.3
C 25	44.2	55.0	49.5	49.4	47.0	39.9	43.4	46.3	52.2	51.8	40.0
C 26	28.8	36.2	24.2	41.5	38.2	54.3	47.5	42.2	41.6	44.9	42.9
C 27	36.5	50.3	41.1	41.5	44.1	38.1	46.3	46.3	39.9	53.2	42.9

E - Experimental Group
S - Sham Group
C - Control Group

APPENDIX 11

SPATIAL ORIENTATION BATTERY: TRANSFORMED POST-TEST SCORES (Cont'd.)

Subjects	Variables 12	13	14	15	16	17	18	19	20	21	22
E 1	62.7	89.6	50.0	46.1	58.1	45.8	54.3	57.7	50.9	61.5	55.5
E 2	97.5	53.8	71.0	59.3	88.1	52.6	35.1	39.6	52.3	42.5	55.7
E 3	46.6	43.5	46.9	48.4	45.5	44.4	48.7	53.2	47.6	45.8	45.0
E 4	49.1	49.2	57.2	50.5	67.3	79.6	44.9	37.8	44.2	40.5	53.8
E 5	46.5	46.0	41.8	41.3	44.2	43.9	46.0	41.4	48.4	42.9	45.1
E 6	47.8	45.7	51.7	52.5	49.5	51.4	56.2	33.5	40.0	49.1	48.8
E 7	46.6	43.1	40.4	41.6	42.5	43.5	35.1	41.4	40.4	39.2	40.7
E 8	49.6	63.2	47.9	46.9	50.8	44.7	54.8	56.2	52.4	53.9	49.4
E 9	46.9	43.2	41.4	42.6	42.9	44.5	50.1	49.7	51.3	49.8	44.5
E 10	46.0	43.0	48.6	47.1	52.1	45.3	40.9	45.5	44.0	41.6	46.5
E 11	46.8	44.4	45.2	48.6	40.8	47.1	43.3	42.0	48.7	42.8	48.0
S 12	50.2	53.1	45.9	44.6	50.8	44.9	57.5	62.1	51.6	61.8	54.6
S 13	49.6	53.3	52.8	54.4	48.2	48.5	99.7	50.3	50.5	50.7	51.0
S 14	48.3	46.8	44.9	45.6	46.0	44.4	51.1	63.3	44.0	47.9	49.5
S 15	47.9	57.2	48.6	52.9	40.8	51.5	74.2	70.4	64.3	82.2	54.6
S 16	47.0	49.8	47.6	45.8	52.5	45.4	51.1	52.0	50.9	60.7	53.8
S 17	46.3	45.5	44.9	47.6	42.1	44.4	42.9	39.6	49.8	47.0	47.7
S 18	46.4	43.2	39.0	40.5	41.2	43.6	42.9	33.3	39.3	44.8	50.0
S 19	47.6	45.9	50.4	51.2	48.6	45.7	50.4	56.8	47.3	48.7	50.4
S 20	50.1	65.6	59.6	59.3	55.5	77.2	52.6	54.1	51.3	50.9	54.9
C 21	46.7	44.0	54.5	53.5	54.2	51.7	46.7	52.9	45.7	43.8	51.7
C 22	47.4	49.6	65.2	69.8	48.1	50.5	79.3	59.1	93.4	70.8	61.0
C 23	46.3	43.1	43.1	39.4	53.8	52.7	38.8	40.8	44.7	40.8	45.7
C 24	49.0	53.9	82.0	86.3	57.3	72.1	58.6	66.8	49.8	54.8	61.8
C 25	47.1	44.8	49.7	51.4	46.0	47.0	53.1	55.0	51.3	45.9	48.1
C 26	46.9	43.7	38.7	40.5	40.3	43.9	41.4	43.2	46.0	42.7	41.4
C 27	47.1	45.9	41.1	42.2	42.9	43.8	50.4	52.6	49.8	46.8	44.9

E - Experimental Group
S - Sham Group
C - Control Group

APPENDIX 12

GROUP MEANS AND STANDARD DEVIATIONS FOR THE EXPERIMENTAL, SHAM, AND CONTROL GROUPS ON TOTAL SENSORY SCORES

APPENDIX 12

GROUP MEANS AND STANDARD DEVIATIONS FOR THE EXPERIMENTAL, SHAM, AND CONTROL GROUPS ON TOTAL SENSORY SCORES

Group	Mean	S.D.
Experimental	49.98	4.64
Sham	50.54	5.48
Control	49.61	7.14

APPENDIX 13

GROUP MEANS AND STANDARD DEVIATIONS FOR THE EXPERIMENTAL, SHAM, AND CONTROL GROUPS ON TOTAL SPATIAL ORIENTATION SCORES

APPENDIX 13

GROUP MEANS AND STANDARD DEVIATIONS FOR THE EXPERIMENTAL, SHAM, AND CONTROL GROUPS ON TOTAL SPATIAL ORIENTATION SCORES

Test	Experimental		Sham		Control	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Orientation:						
pre-test	50.08	5.15	49.08	2.94	51.06	8.44
post-test	48.43	4.85	51.40	3.30	50.66	7.98

APPENDIX 14

GROUP MEANS AND STANDARD DEVIATIONS FOR THE EXPERIMENTAL, SHAM, AND CONTROL GROUPS ON THE DEMOGRAPHIC VARIABLES OF AGE, EDUCATION, AND TIME SINCE ONSET OF ILLNESS

APPENDIX 14

GROUP MEANS AND STANDARD DEVISIONS FOR THE EXPERIMENTAL, SHAM, AND CONTROL GROUPS ON THE DEMOGRAPHIC VARIABLES OF AGE, EDUCATION, AND TIME SINCE ONSET OF ILLNESS

Group	Age		Education		Time since Onset[a]	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Experimental	68.27	5.12	2.00	.45	23.36	20.48
Sham	67.22	12.30	2.00	.50	26.44	16.90
Control	65.00	4.93	1.86	.71	24.14	29.77

a Time dimension corresponds to months.

APPENDIX 15

ABSTRACT OF

The Effects of Asymmetrical Sub-functional Electrical Stimulation and Auditory Amplification on Spatial Disorientation in Left Hemiplegia

APPENDIX 15

ABSTRACT OF

<u>The Effects of Asymmetrical Sub-functional Electrical Stimulation and Auditory Amplification on Spatial Disorientation in Left Hemiplegia</u>[1]

This study endeavored to investigate the application of a neurodynamic model of cerebral dysfunction in left hemiplegia.

Based on the findings that in right hemispheric impairment, cerebral functioning was characterized by a degree of inertia in processing sensory stimuli, increased inhibition, and hemispheric incoordination, and that amelioration could be induced by compensating for the temporal processing lag, it was postulated that extended compensated asymmetrical stimulation may facilitate general spatial functioning.

To assess this hypothesis, twenty-seven subjects were exposed to one of the three conditions, asymmetrical adjusted electrical and auditory stimulation, bilaterally symmetrical stimulation, and no treatment, respectively.

An analysis of mean differences between each of the groups, by the method of covariance, was utilized to

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1 Arthur S. Leonoff, doctoral thesis presented to the School of Graduate Studies of the University of Ottawa, Ontario, February 1973, ix-188 p.

investigate the therapeutic effectiveness of the experimental or asymmetric treatment on twenty-one independent measures of spatial orientation and a cumulative or total orientation score.

The results of the analyses of covariance indicated a significant difference between groups on the total orientation score, and performance on five independent measures, block design of the WAIS, Rotation of Design A of the Bender Gestalt, and the mean constant error left and variance on tactile localization. Generally, the performance differences between the asymmetrical and symmetrical stimulation groups contributed to the significance of the analyses.

Suggestions for further research may include an analysis of the extent of inter-hemispheric interference in left hemiplegia, under bilateral simultaneous conditions, utilizing the evoked potential. Not only may this clarify the extent of suppression, but could also be adapted to assess the degree of amplification required to equalize electroencephalographic parameters between the hemispheres. This may then lead to a unilateral treatment paradigm of ascertained compensatory values for the individual left hemiplegic patient.