THE EFFECTS OF UNILATERAL SUB-FUNCTIONAL ELECTRO-CUTANEOUS STIMULATION ON SPATIAL DISORIENTATION IN LEFT HEMIPLEGIA

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CURRICULUM STUDIORUM

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INTRODUCTION

Stroke has come to be recognized as a major syndrome affecting the aged. Its incidence grows each year with increases in life expectancy.

In 1974 among a random group of one million American citizens, there are expected to be 12,500 stroke victims. A little under half of these will die within thirty days of onset. Of the remaining group 5,000 are expected to require specialized rehabilitation services, and 1,250 will need long-term institutional care.[1]

The majority of stroke survivors will exhibit a condition known as hemiplegia. This is one of the primary sequelae of cerebral vascular accidents.[2]

In left hemiplegia most symptoms appear in relation to the left body side, contralateral to the damaged hemisphere. Left hemiplegia has been operationally defined to include loss of function of the left body side, paresis or paralysis of that side, increases in sensory thresholds, position sense loss, displacements, astereognosis, pathological reflexes, and reduced muscle strength all limited to the affected side.[3]

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1 Report of the Joint Committee for Stroke Facilities, "Epidemidogy for Stroke Facilities Planning," Stroke, Vol. 3, May-June 1972, p. 359-371.

2 Hereafter referred to as C.V.A.

3 I. Belmont, E. Karp, and G. Birch, "Hemispheric Incoordination in Hemiplegia," Brain, Vol. 94, 1971, p. 337-344.

INTRODUCTION

The major psychological deficit in left hemiplegia involves dysfunction in spatial skills requiring the synthesizing of multiple percepts.[4,5] This is but one description of a complex deficiency within the appositional mode of thought.[6] In accord with this complexity, most symptoms are described in terms of the tasks used to assess impaired behavior.[7]

The purpose of this present investigation is to provide an evaluation of a remedial technique for the visuo-spatial deficits found among left hemiplegics.

The first chapter initially discusses the context of spatial orientation in left hemiplegics. This is followed by a review of the syndrome as found in such patients and a description of the mechanisms of perceptual disturbance. The final subsection contains a review of remedial techniques and the hypotheses attached to this investigation.

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4 L. Diller, "Brain Damage: Spatial Disorientation and Rehabilitation," in S. J. Freeman (Ed.), The Neuropsychology of Spatially Oriented Behavior, Homewood, N.J., Dorsey Press, 1968, p. 265-279.

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

6 J. Bogen, "The Other Side of the Brain: An Appositional Mind," in R. Ornstein (Ed.), The Nature of Human Consciousness, San Francisco, Freeman & Co., 1973, p. 101-125.

7 M. W. VanAllea, "Objective Behavioral Assessment in Diagnosis and Prediction," in A. L. Benton (Ed.), Behavioral Change in Cerebrovascular Disease, New York, Harper & Row, 1970, p. 166-168.

Chapter two presents the method of the experiment. It includes the tools, the sample, the treatment procedure, and the statistical methods used in the analysis of the data.

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

CHAPTER I

REVIEW OF THE LITERATURE

The literature leading to the experimental hypotheses is presented under the following headings: (1) Perceptual Deficits; (2) Mechanisms of Disruption; (3) Remedial Strategies; (4) Summary and Conclusions; and (5) Hypotheses.

1. Perceptual Deficits.

The first subsection of perceptual deficits describes the complex nature of the deficits and their effect on the rehabilitation prognosis in left hemiplegia. This subsection provides a context in which disturbed perceptual processes are discussed and shows the necessity of remedial research.

A. The Context

Hemiplegics in general have a poor record in rehabilitation. Rankin,[1] Lowenthal,[2] and Ginsburg,[3] in separate surveys, reported that an average 65.2 per cent of hemiplegics failed to

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1 J. Rankin, "Cerebral Vascular Accidents in Patients over the Age of 60," Scottish Medical Journal, Vol. 2, 1957, p. 127-136.

2 M. Lowenthal, J. Tobis, and I. 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.

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

regain independence in daily living skills after rehabilitation. This is not surprising in view of the average age (sixty-eight) of left hemiplegics[4] and the correlation between age and severity of lesion.[5]

Hemiplegics present a more negative occupational prognosis. In the United States, Diller _et al_.[6] reported that only ten per cent of hemiplegics ever regain occupational status.

When left hemiplegics are considered alone, the prognosis is poorer still.[7] There are numerous interdependent factors underlying this reality. First, DeRenzi[8] and Semmes[9] have suggested that lesions of the minor hemisphere appear to be more diffuse than those of the major hemisphere, disrupting

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4 Report of the Joint Committee for Stroke Facilities, "Epidemiology for Stroke Facilities Planning," _Stroke_, Vol. 3, May-June, 1972, p. 359-371.

5 Lowenthal _et al_., _op. cit_., p. 183-186.

6 L. Diller _et al_., _Studies in Cognition and Rehabilitation_, Grant No. RD 2666-P, _Division of Research and Education Grants_, Social and Rehabilitation Service, Department of Health, Education and Welfare, Washington, D.C., 1971, p. 204.

7 V. Carroll, "Implications of Measured Visuo-spatial Impairment in a Group of Left Hemiplegic Patients," _Archives of Physical Medicine and Rehabilitation_, January 1958, p. 11-14.

8 E. DeRenzi and P. Faglioni, "The Comparative Efficiency of Intelligence and Vigilance Tests in Detecting Hemispheric Damage," _Cortex_, Vol. 1, 1965, p. 410-433.

9 J. Semmes _et al_., _Somatosensory Changes after Penetrating Brain Wounds in Man_, Cambridge, Mass., Harvard University Press, 1960, p. 159.

both perceptual and motor behaviors.[10] In combination with these observations, Luria[11] reported that damage to the right hemisphere tends to be accompanied by lack of awareness of personal disability. The consequences of this unawareness are grave in terms of motivation for the patient and the rehabilitation staff. As Leiper[12] observed, brain damage is overtly observable only in the form of paretic symptoms and forgetfulness toward the left side.

Bogen[13] has noted that the right hemisphere functions in the metaphoric spatial mode of language expression which disguises, due to its covert nature, the extent of cortical impairment in right hemispheric patients. This impairment is extensive for, as Benton[14] notes, neoplasms of the right hemisphere are on the average larger when discovered than lesions of the left hemisphere.

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10 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

11 A. Luria, Higher Cortical Functions in Man, New York, Basic Books, 1960, p. 490.

12 C. Leiper, "The Left Hemiplegic, Discrepancies between Actual and Presumed Disabilities," Journal of the Canadian Physiotherapy Association, Vol. 23, 1971, p. 159-162.

13 J. Bogen, "The Other Side of the Brain: An Appositional Mind," in R. Ornstein (Ed.), The Nature of Human Consciousness, San Francisco, Freeman & Co., 1973, p. 101-125.

14 A. L. Benton, Post Doctoral Institute, American Psychological Association, Montreal, 1973.

In summary, the prognosis of left hemiplegics reflects a relatively stable disability that contains within itself elements that impede retraining. These elements include the greater size of lesions affecting the minor hemisphere, lack of awareness of personal disability, and the more diffuse nature of sensory and motor deficits found in minor hemisphere C.V.A.'s. This underscores the need for research into remedial techniques which will ameliorate perceptual disturbances or their preconditions and thereby increase the left hemiplegics' rehabilitation potential.

B. Specific Perceptual Deficits

It has been suggested that the basic deficit in lesions of the posterior right hemisphere is one of visual spatial perception.[15] Specifically, such patients are unable to organize the visual and temporal aspects of a situation for the purpose of deriving meaning and understanding of the external world.[16]

From a cybernetic perspective, Weiner[17] has suggested that perceptual functioning is a product of intact sensory

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15 Diller *et al*., *op. cit*., p. 22.

16 E. Lorenze and R. Cancro, "Dysfunction in Visual Perception with Hemiplegia: Its Relation to Activities of Daily Living," *Archives of Physical Medicine and Rehabilitation*, October 1962, p. 514-517.

17 N. Weiner, *Cybernetics*, New York, Wiley & Sons, 1948, p. 212.

and motor systems. The individual constructs an interior model of the external world based on feedback from voluntary motor acts conducted in reference to perceived spatial and temporal coordinates. Following Weiner's notion, a description of the sensory and motor systems as evident in left hemiplegia would alter the basis of sensory feedback from motor behaviors and thereby result in altered perceptual experiences.

Significantly Levin's[18] study of feedback intensity showed a decrement in performance among left hemiplegics under increased feedback intensities. Using sixteen left hemiplegics, sixteen right hemiplegics, and thirty-two healthy controls, Levin required that his subjects push a spring-loaded button into the close proximity of a solid state proximity detector. As the button approached the detector a milliammeter showed the increasing strength of the impulse generated by the detector.

All subjects were given two trials of thirty seconds each at spring loadings of 10, 100, and 300 gms. Time, measured in milliseconds, outside of the target proximity was used as the dependent variable. The results indicated that while the control group and the right hemiplegic subjects performed better with increasing feedback intensity (greater spring loadings), left

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18 H. Levin, "Motor Impersistence and Proprioceptive Feedback in Patients with Unilateral Cerebral Disease," Neurology, Vol. 23, August 1973, p. 833-841.

hemiplegics showed an opposite trend toward impaired performance significant at the .01 level. The author concluded that:

> The impaired utilization of proprioceptive cues has lateralizing significance and may be another manifestation of defective appreciation of spatial relations after damage to the minor hemisphere.[19]

While this study does not overtly support Weiner's theory, it does point the way to a more complex perceptual disturbance originating from a deficit in the proprioceptive analysis and organization of increased feedback.

A disruption of proprioception from the optic muscles was suggested by Chèdru et al.[20] to result in modified conscious awareness of eye movement. It appeared that the occulomotor feedback systems were falsely informing the cerebrum about the movements being performed. By means of electromechanical relays attached to the eye muscles, he observed that left hemiplegics' scanning of the left side of space is weakened by permanent reduction of occulomotor tonicity. Decreased tonicity was hypothesized to be caused by inactivity in relation to increased sensory and motor thresholds on the impaired side.[21] While the observed shift toward the right

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19 Ibid.

20 F. Chèdru, M. Leblanc, and F. Hermitte, "Visual Searching in Normal and Brain Damaged Subjects," Neuropsychologia, Vol. 11, 1973, p. 94-111.

21 Ibid.

side of visual space could be momentarily compensated for by voluntary effort to gaze toward the left, it could not be maintained due to motor impersistence and disturbed awareness of occular position sense.

Further difficulties arise when training for left visual field searching is attempted. Carroll[22] observed that left hemiplegics are unable to generalize across situations involving scanning skills. Clinically, she observed that the interaction of this faulty learning pattern and the subjects' inability to discriminate incorrect from correct responses resulted in "very slight momentary gains which they [left hemiplegics] are unable to maintain from day to day."[23]

The above studies reinforce the view that perceptual disturbance occurs in the central process of integrating sensory data.

Hebb[24] suggested that the temporal order of eye movements from left to right is involved in the pre-organization of incoming visual stimuli to facilitate analysis and comparison (memory) for subsequent meaningful perception.

The above observation is complemented by Chèdru *et al.*'s[25] report of asymmetry of eye movement in exploring the left

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22 Carroll, *op. cit.*, p. 11-14.

23 *Ibid*.

24 D. Hebb, "Concerning Imagery," *Psychological Review*, Vol. 75, 1968, p. 466-477.

25 Chèdru *et al.*, *op. cit.*, p. 94-111.

visual field in left hemiplegics irrespective of the presence or absence of homonimous hemianopia. This asymmetry is manifested primarily in shortened unsystematic eye movements in the left visual field. This would seem to support Hebb's proposition that peripheral factors governing eye movement significantly contribute to the overall perceptual process and, in this case, the perceptual deficit.

In view of the above research, it is not surprising to learn that on tasks of visual perception Diller _et al_.[26] reports that left hemiplegics make more errors in the left side of space, and that training in scanning of the left visual field results in better performance on such tasks.[27] Training on two of these tasks, Block Design and Digit Cancellation, was found by Diller _et al_.[28] to be highly predictive of rehabilitation success in learning daily living skills. Thus the element of visual pre-organization of stimuli can be of remedial significance in treating spatial deficit in left hemiplegics.

Hebb defines perception as "the brain process that is the cognition or awareness of the object perceived."[29]

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26 Diller _et al_., _op. cit_.

27 _Ibid_.

28 _Ibid_.

29 Hebb, _op. cit_., p. 466-477.

He proposed that perception is made up of inseparable sensory and motor events. It is a higher activity of cortico-cortico transmissions, both inter- and intrahemisphere, which occurs only under favorable conditions. These favorable conditions include supporting activation from the diencephalic arousal system and intact transcortical pathways. In a more pragmatic vein Hebb notes that we tend to perceive more readily those objects that we are already thinking about. Employing Hebb's definition, perceptual deficit would be closely tied to a state of disturbed awareness or cognition of the spatial milieu in left hemiplegics.

Additional support for Hebb's model arises from observed disturbances of conscious awareness which often accompany minor hemisphere damage. In this vein Gainotti[30] found that left hemiplegics tend to demonstrate an apparent jocular denial of impairment when confronted with failure on simple tasks. He interpreted this finding in terms of the right hemisphere's mode of thought, this being the non-symbolic, simultaneous apperception of stimuli arising from the external world. Thus his subjects could not logically analyze their failures since deficit was occurring in a form of perception that was continuous and immediate, precluding logical analysis.

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30 G. Gainotti, "Emotional Behavior and Hemispheric Side of Lesion," Cortex, Vol. 8, 1972, p. 41-54.

Haécen, Arguelles,[31] and Luria,[32] among others, have emphasized the simultaneity and continuous spatial grouping of sensory data as being intrinsic to the role of the right hemisphere. In contrast, the left hemisphere is conceptualized as dealing with discrete data in groups that are successively rather than simultaneously organized, and therefore subsume logical thought. In right hemispheric damage, the disruption of its particular mode of thought appears to lead to the spatial and stylistic problems observed in left hemiplegic populations.

Thus not only is the sensory "food for thought" of the minor hemisphere impaired by increased sensory thresholds, but also the correct processing of these data is impaired by lesions in that hemisphere.

The disorganized perceptual pattern of left hemiplegics manifests itself in other ways. Such patients were found by Birch and Belmont[33] to be incapable of integrating situational cues arising across sensory modes. While left hemiplegics often fail to differentiate relevant from

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31 H. Haécon and R. Arguelles, "La negation de la cecite au cours des lesions cerebrales," Journal of Psychology, Vol. 56, 1963, p. 381-404.

32 Luria, op. cit.

33 H. Birch and I. Belmont, "Perceptual Analysis and Sensory Integration in Brain Damaged Persons," Journal of Genetic Psychology, Vol. 105, 1964, p. 173-179.

irrelevant stimuli in the external situation they show reduced error variability when erroneous intermodal stimuli are added.[34] This leads to many paradoxes of perception.

Left hemiplegics performed better on block designs when viewed through a peephole than when the visual field is unrestricted.[35] This is contrasted by decreased efficiency on the same task among normal subjects. Similarly, left hemiplegics performed better on the rod-and-frame test of verticality when the frame was rotated than when it was absent permitting greater use of environmental cues in locating the correct vertical.[36]

These studies appear to indicate the lack of a focusing function in left hemiplegics. It is as if they are inundated by particular stimuli which they are unable to integrate simultaneously into a coherent and workable perception. These stimuli would appear to be of a non-codeable type where judgments are comparative rather than appositional or analytic. By way of summary, Table I presents a list of the

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34 H. Birch, I. Belmont, T. Reilly, L. Belmont, "Somesthetic Influences on Perception of Visual Verticality in Hemiplegia," Archives of Physical Medicine and Rehabilitation, Vol. 45, November 1962, p. 556-560.

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

36 H. Birch, I. Belmont, T. Reilly, and L. Belmont, "Visual Verticality in Hemiplegia," Archives of Neurology, Vol. 5, 1961, p. 114-123.

Table I.-

Suggested Neurodynamics of Perceptual Deficit in Left Hemiplegia.

Author[a]	Disturbed Neurodynamic Function
Lorenze and Cancro	Organization of Visual and Temporal Aspects
Levin	Disturbed Proprioceptive Analysis
Carroll	Stimulus Discrimination
Chèdru	Occulomotor Instability
Haecen, Luria	Simultaneous Spatial Grouping
Birch, Belmont	Regression in Integration of Sensory Cues
Shapiro	Sensory Inundation, Discriminant Focusing

a References are given in Appendix 1.

suggested neurodynamics of spatial deficit in left hemiplegia derived from the previous studies.

From this table it would appear that following disturbed occulomotor and central processing of sensory stimuli, proprioception, visual and tactile senses in particular are impaired. These impairments make it exceedingly difficult for the left hemiplegic to render constructive sense of his immediate spatial world. Although the element of continuous feedback and coherent sensory processing appear as key factors underlying the observed disability in left hemiplegics, the relative importance of peripheral and central factors is not clarified by the authors listed.

As the appropriate stimuli of the right hemisphere are of a sensory nature, and as in left hemiplegia there is often accompanying sensory loss, arousal of the right hemisphere would no doubt be undermined.

Giblin,[37] in 1964, found that the evoked potentials of left hemiplegic subjects were in fact different from those of normal subjects. He found a marked increase in the amplitude with a corresponding decrease in the latency of this potential. This suggests that effective arousal may be disturbed in many left hemiplegics. The maintenance of cortical

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37 D. Giblin, "Somatosensory Evoked Potentials in Healthy Subjects and in Lesions of the Nervous System," Annals of the New York Academy of Sciences, Vol. 112, 1964, p. 93-142.

arousal through the specific and non-specific activation systems depends on the integrity of these systems in particular feedback from voluntary motor behavior. This motor behavior is impaired in left hemiplegia as a result of reduced tonicity, one of the direct consequences of elevated sensory and motor thresholds. Thus the left hemiplegic is victimized by sensory and motor losses. He lacks the focusing of attention necessary to develop awareness of his misperceptions and therefore cannot discriminate correct from incorrect visuo-spatial judgments.

As Hebb[38] suggested, there is more to perception than effective arousal. The cortico-cortico transmission of signals is necessary for the construction of conscious awareness of objects in the external world. Research into the phenomenon of suppression of awareness of afferent stimulation arising on the left hemiplegic's impaired side has lent further support for Hebb's model of perception.

The next subsection examines this interhemispheric mechanism of disruption in perception and suggests two ways in which neuronal sequences are subject to interference. Subsequently techniques to restore the resultant deficit of awareness on the impaired body side are discussed.

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38 Hebb, *op. cit*.

2. Mechanisms of Perceptual Disruption.

Hemiplegics are slower to react than normal subjects. This has been observed in the form of a prolongation and increase in the variability of reaction times. Studies by DeRenzi and Faglioni,[39] Blackburn and Benton,[40] Benton and Joynt,[41] and Costa[42] have shown that, in hemiplegia, the increased latency of response on the impaired side varies with the severity of the lesion. Their findings were replicated in reference to flicker-fusion thresholds among hemiplegics by Battersby _et al_.[43] and Shure and Halstead.[44]

It would appear then that damage to the C.N.S. results in an increase in the time needed for the subject to process sensory data arising on the impaired side.

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39 DeRenzi and Faglioni, _op. cit_., p. 410-433.

40 H. Blackburn and A. Benton, "Simple and Choice Reaction Time in Cerebral Disease," _Neurology_, Vol. 15, 1958, p. 327-338.

41 A. Benton and R. Joynt, "Reaction Time in Unilateral Cerebral Disease," _Neurology_, Vol. 19, 1959, p. 247-256.

42 L. Costa, "Visual Reaction Time of Patients with Cerebral Disease as a Function of Length and Constancy of Preparatory Interval," _Perceptual and Motor Skills_, Vol. 14, 1962, p. 391-397.

43 W. Battersby, L. Wagner, E. Karp, and M. Bender, "Normal Limitations of Visual Excitability: Alterations Produced by Cerebral Lesions," _Archives of Neurology_, Vol. 3, 1960, p. 24-42.

44 G. Shure and W. Halstead, "Cerebral Localization of Intellectual Processes," _Psychological Monographs_, Vol. 72, No. 465, 1958, p. 1-40.

Anatomically, the hemispheres are connected by the forebrain commissures including the corpus callosum.[45] Thus it is not surprising that slower functioning might not be restricted to one hemisphere or to the damaged side.

Studies by Hausmanowa and Petruseiviez[46] and the antecedent work of Cohn[47] had suggested that arousal of a given region of one hemisphere tends to be followed by a mirrored activation of the homologous region in the opposite hemisphere among normal subjects. This tendency was empirically confirmed by Betchevera et al.[48] who found electroencephalographic evidence of disturbances in the homologous regions of the intact hemisphere among hemiplegics. Later, Parsons et al.[49] corroborated the possibility of cross-hemispheric interference in the behavioral mode. They found elevated flicker-fusion thresholds

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

46 I. Hausmanowa-Petruseiviez, "Interaction in Simultaneous Motor Functions," Archives of Neurology and Psychiatry, Vol. 81, 1954, p. 173-181.

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

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

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

of the intact hemisphere in patients suffering from unilateral, parietal, and temporal lobe disease.

Belmont et al.[50] hypothesized that interhemispheric interference should be found in the motor behavior of left hemiplegics. To test this hypothesis he used two groups of subjects, eighteen left hemiplegics and twenty-one controls. Using a treadle device, a separate treadle for each foot, the subjects were asked to perform foot-tapping under three conditions. These conditions were right foot only, left foot only and both feet together. They found that in the hemiplegic group bipedal action did not equalize the rates of movement in both extremeties. The intact side and the impaired side were accompanied by a marked reduction in rates of action on both sides. While bipedal action of the control group showed a clear and defined synchrony, the hemiplegic bipedal action showed marked desynchrony. Although bipedal performance was inferior to unilateral performance, the hemiplegic patients appeared to be unaware of their incoordination. This emphasizes the lack of awareness of impairment found in left hemiplegia and the apparent disruption of normal feedback.

Research was being carried out on the phenomenon of suppression of bilateral awareness in left hemiplegia. This led to the discovery of two possible conditions which would

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50 I. Belmont, E. Karp, and H. Birch, "Hemispheric Incoordination in Hemiplegia," Brain, Vol. 94, 1971, p. 337-348.

favor the transcortical inhibition of signals arising on the impaired body side.

(a) Latency.- The first condition is one of time. If sensory data arising on the impaired side were slower to arrive at the level of the cortex, then the intact hemisphere might effectively pre-arouse the impaired hemisphere to awareness of stimulation from the intact side and thereby mask the slower incoming data from the impaired sensory pathways. This would effectively block awareness of stimulation on the impaired body side. Extinction of awareness occurs most frequently when two stimuli of equal intensity are simultaneously received at homologous sensory receptors.[51] This phenomenon has been described as stimulus rivalry, masking, obscuration, and extinction.

Denny-Brown _et al._,[52] Bender _et al._,[53] and Birch _et al._[54] theorized that extinction of awareness in unilateral cerebral damage was a function of the more rapidly processed stimulation

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51 Hereafter referred to as DSS--Double Simultaneous Stimulation.

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

53 M. Bender, M. Shapiro and A. Schapell, "Extinction Phenomenon in Hemiplegia," _Archives of Neurology and Psychiatry_, Vol. 62, 1949, p. 717-724.

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

arising on the intact side inhibiting awareness of the slower impaired side signals. Thus most research concentrated on examining methods of accelerating the impaired side afferent signals in order to counteract extinction during double simultaneous stimulation.

There emerged three factors which could serve to decrease the latency of a stimulus. They are intensity, duration, and size of the area stimulated.

The first factor, intensity, was reported by Rosner[55] who observed that the nervous system response, evoked by a more intense stimulus, travels faster than one evoked by a less intense stimulus (Intensity-Latency Law). This observation was confirmed by Vaugh and Hull[56] who found that the neuroelectrical response of occipital potentials in humans decreased in latency with increases in stimulus intensity. Here, then, is a direct link between the diagnostic sensory diminution of left hemiplegics and the disruption of awareness on the impaired body side.

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55 B. Rosner, Sensory Communication, New York, Wiley & Son, 1961, p. 356.

56 R. Vaugh and H. Hull, "The Effects of Stimulus Intensity on Neuroelectrical Occipital Potential," Nature, 1962, Vol. 206, p. 714-720.

On the behavioral level Teuber and Diamond[57] found that left hemiplegic subjects required greater intensity of sound in the left ear as compared to the right, during dichotic stimulation, in order to judge a sound to be in the median plane.

The two other factors, duration and area, were observed by Denny-Brown[58] who found that increasing either the area stimulated or the duration of the stimulation resulted in the disappearance of extinction among hemiplegics. Rosenblith and Vidale[59] confirmed Denny-Brown when they reported a similar relation between latency and duration in a single neuron of the tactile thalamic region of a cat.

In summary, there are three variables which can decrease the latency of response to stimulation on the impaired side in left hemiplegics. These are: (a) increasing area stimulated; (b) increasing the intensity of the stimulus; and (c) increasing the duration of the stimulus.

For the hemiplegic with elevated sensory thresholds on one body side, signals arising on that side would be inhibited by the faster activation occurring in response signals arriving

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57 H. Teuber and S. Diamond, "Effects of Brain Injury on Binaural Localization of Sounds," Paper read before the Eastern Psychological Association, Atlantic City, 1956; "Development of Physiological Mechanisms of Auditory Localization," Psychological Bulletin, Vol. 58, 1961, p. 376-389.

58 Denny-Brown, op. cit., p. 433-471.

59 W. Rosenblith and E. Vidale, "Patterns of Neuronal Response to Area and Duration of Stimulation," in S. Koch (ed.), Psychology: A Study of Science, Vol. 4, New York, Wiley & Son, 1962, p. 416-419.

in the intact hemisphere. This would mean that hemiplegics, under daily living conditions that provide frequent D.S.S. via the duplicate sensory organs, would be receiving sensory signals that are functionally successive and therefore disruptive to the construction of a balanced perception.

The simplest way to compensate for slower processing would be to provide stimulation to the impaired side prior to the intact side. Birch *et al*.[60] found that differences of three hundred to six hundred milliseconds were adequate to eliminate electrocutaneous suppression in fourteen of nineteen left hemiplegic subjects. Further increases in the time separation of D.S.S. resulted in a decrease in the number of unreported stimulations on the impaired side and an increase in unreported intact side stimulations ($p > .001$). Thus not only was there a decrease of suppression when the latency of the damaged system was compensated, but there was a concomitant shift in suppression to the undamaged side.

Following the intensity-latency law, Birch *et al*. compensated for the sensory threshold increase on the impaired side by increasing the intensity of stimulation to that side during the D.S.S. With sixteen left hemiplegic subjects they observed no significant improvements in extinction of awareness of the impaired

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60 H. Birch, I. Belmont, and E. Karp, "Delayed Information Processing and Extinction Following Cerebral Damage," *Brain*, Vol. 90, 1967, p. 113-129.

body side. This finding led them to suggest that extinction of awareness is a cortical rather than a peripheral disruption in perception. On observing the extreme variability of response under D.S.S. they concluded that instability of awareness in the affected hemisphere "would indicate that an organizational disturbance exists on the affected side in patients with elevated single stimulus thresholds."[61]

The next subsection of transcortical interference deals with a disturbance of spatial summation of stimulus events in hemiplegia. Intensity and latency variation even with its threefold factors could not explain the extreme variability of responses to D.S.S. found in the above studies.

(b) Decreased Elasticity of the Neural Response System.- To examine the area of variability of response in left hemiplegia, Birch and Belmont[62] administered two auditory stimulations, one to the affected side and then at timed intervals of one, three, and five seconds, a second stimulation to the intact ear. The experimental group consisted of seventeen patients with a like number of controls matched for age and sex. When asked to judge between the louder of the stimuli it was found that the hemiplegic group consistently perceived the second tone as softer under bilateral stimulation. As the time interval between the tones was increased,

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61 Birch et al., op. cit., 1964, p. 19-39.

62 Birch and Belmont, op. cit., p. 173-179.

there developed a trend of decreasing underestimation of the second stimulus among the hemiplegics ($p > .001$).

Extrapolating from the performance curve of the hemiplegics, they predicted that an eight-second interval would be necessary for the hemiplegics to judge as accurately as the control group. This led to a subsequent study where a nine-second interval was required for accurate perception of tone intensity among left hemiplegics. They concluded that:

> The basic mechanisms of arousal and inhibition are the same in both normal and brain damaged subjects, but that the latency period for recovery is increased following neurological damage.[63]

Thus there are two conditions which may contribute to the perceptual deficit found in left hemiplegics. Both relate to problems in processing and analyzing incoming sensory stimuli. In the first case sensory data are slow to arrive at the level of the impaired cortex rendering the impaired cortex susceptible to appropriation of the response system by the intact hemisphere. Secondly, once data have broken the latency intensity barrier, they are slow to decay within the impaired nervous system further disrupting the continuous flow of sensory data necessary for accurate perception.

As has already been shown, stimuli arising on the impaired body side are perceived as less strong or even absent

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63 Birch *et al.*, *op. cit.*, 1967, p. 113-139.

under daily living conditions. These daily conditions provide recurrent D.S.S. via the duplicate sense organs. This results in a relatively permanent decrease in the stability of the left perceptual field through the mechanisms of increased latency and the slow decay of signals arising on that side.

Hebb[64] suggests that "the more constant the stimulation from an object is, the more readily it will be identified and responded to." In reverse, the left hemiplegic suffers from an inconstancy of object perception on the left side and therefore he may become progressively less ready to identify and respond to left-sided stimulation.

From an emphasis on learned deficits, research progressed into remedial procedures aimed at counteracting the chronic imbalance of sensory input into the two cerebral hemispheres. The following section describes some of the current research into remedial techniques for spatial dysfunction in left hemiplegia.

3. Strategies of Remediation.

It is important to note that visual perceptual deficit in left hemiplegia is a complex phenomenon. While many tasks can be used to assess the extent of deficit, training on these

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64 D. Hebb, The Organization of Behavior, New York, Wiley & Son, 1949, p. 94.

same tasks often improves the subject's rehabilitation prognosis. This indicates a high degree of interaction between rehabilitation and improved spatial awareness.

(a) Retraining.- Two studies by Diller *et al*.[65] and Lawson[66] have demonstrated the above phenomenon. Both researchers found that training in scanning from left to right improved the visual perceptual performance of left hemiplegics in rehabilitation tasks.

Diller *et al*.[67] reported a similar finding in regards to training on Block Designs via progressive cueing and subsequent improvement in physiotherapy assessments of a functional self-care profile. Although the above studies show remedial effects, it may be validly argued that the training tasks were so similar to the requirements of rehabilitation programs that a significant improvement might logically be expected.

It can be interpreted that by training subjects to scan the left visual field, the above researchers were in fact increasing the sensory input of the affected hemisphere and not improving pre-attentional vigilance as they suggest.

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65 Diller *et al*., *op. cit*.

66 I. Lawson, "Visual Spatial Neglect in Lesions of the Right Hemisphere," *Neurology*, Vol. 12, 1962, p. 23-33

67 Diller *et al*., *op. cit*.

Increasing impaired side input would partially redress the imbalance of sensory data into the affected hemisphere and render the process of awareness less vulnerable to suppression by the intact side.

(b) Sensory Treatment.- The following two studies lend further support for this link between diminished sensory awareness and problems in visuo-spatial perception in left hemiplegics.

In 1962, Birch _et al_.[68] proposed to test the hypothesis that disorders of visual judgment, in this case verticality, occurred as a consequence of asymetric sensory inputs. To this end, twenty hemiplegic patients and eighteen orthopedically handicapped subjects made twenty judgments of the verticality of a luminous rod presented alone in a darkened room. At a later date the procedure was twice repeated using a ten-pound weight applied to each shoulder on successive occasions. The results of their procedure indicated that left hemiplegics performed with reduced error variability when somesthetic feedback was increased on the impaired side. In contrast, when a weight was applied on the intact shoulder, a threefold increase occurred in the mean constant error. The control group, however, showed no significant difference between the two experimental conditions.

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68 Birch _et al_., _op. cit_., 1962, p. 556-560.

The authors interpreted this finding in support of the hypothesis that disturbance of the visual vertical in left hemiplegics is in part a consequence of somesthetic imbalance. This indicates a possible link between unilateral stimulation to the impaired body side and improved visuo-spatial functioning in left hemiplegia.

Leonoff,[69] in 1973, examined the effects of symmetrical and asymmetrical stimulation on visuo-spatial functioning in left hemiplegia. Working from the model of disturbed cerebral regulation of spatial processes, he administered a sensory and a spatial orientation battery to twenty-seven left hemiplegics. After an initial assessment, the sample was divided into three matched groups based on total degree of sensory deficit. The first group of eleven subjects received compensated asymmetrical auditory and electro-cutaneous stimulation for thirty minutes per day over fifteen consecutive days. The second group of nine subjects received symmetrical auditory and electro-cutaneous stimulation for a similar time period. The last group of seven subjects was designated as the control group and received no stimulation. Following the above procedure, all subjects were retested for spatial orientation. The results indicated a further deterioration in spatial

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69 A. Leonoff, The Effects of Asymmetrical Subfunctional Electrical and Auditory Amplification on Spatial Disorientation in Left Hemiplegia, doctoral thesis presented to the School of Graduate Studies of the University of Ottawa, Ontario, 1973, 188 p.

functioning with symmetrical stimulation, and a tendency for asymmetrical stimulation to improve spatial performance.

Of twenty-two spatial measures, only Block Design demonstrated a significant improvement between the asymmetrical and the other two groups.

The author interpreted these results to support a model of spatial deficit which is linked to a general extinction of awareness derived from interhemispheric asymmetry of functioning. The symmetrical stimulation resulted in further regression of spatial perception due to the augmented degree of neurodynamic imbalance.

In the above study, Leonoff[70] used greater intensity of stimulation on the impaired side to compensate temporarily for extinction during D.S.S. in the asymmetrical treatment condition. As he suggested, the use of unilateral impaired side stimulation may prove more effective than the asymmetric treatment used.

4. Summary and Conclusions.

Two distinct trends in research have been discussed. The first group of studies consists of clinical observations and descriptive reports which demonstrate the complexity of spatio-perceptual deficits in left hemiplegia. This research

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70 *Ibid*.

suggested that deficits extend through all modes of behavior which depend on accurate spatio-perceptual functioning. They also demonstrate that these deficits are responsible for the poor rehabilitation prognosis in left hemiplegia.

The second trend was made up of more experimental studies into the phenomenon of extinction of awareness to stimulation on the impaired side during double simultaneous stimulation in left hemiplegia. Extinction was found to be a function of cerebral conditions which included slow processing of data in the damaged hemisphere and possible defective arousal in that hemisphere. The phenomenon of extinction was observed to be multimodal and pervasive similar to the wide range of spatio-perceptual deficit in left hemiplegia.

The suggestion was then made that both these trends were observing different aspects of a common fault in the cerebral processing of left hemiplegics. Theoretical support for this proposition was provided by Hebb's model of perception. He described perception as the process which is the awareness of a stimulus. Hebb underlined the importance of arousal and reciprocal interhemispheric relations in the process of becoming aware. In Birch's studies of extinction he suggested that disruption of these same cortical conditions were the causes of suppression of awareness.

If, as suggested, extinction and spatial deficit share a common etiology in neurologic desynchrony, then a treatment which is known to decrease extinction might improve spatial functioning. Birch et al. had shown that extinction decreased when the intensity stimulation on the impaired side was increased. Thus increasing the impaired side stimulation would result in improved spatial functioning if the proposed origin of both types of dysfunction are one and the same as suggested in this study.

Finally, two studies were described which demonstrated experimental support for the proposition that extinction and spatio-perceptual deficit share a common neurological basis.

The above review of the literature would suggest the following tentative conclusions:

1. Perceptual disturbances following right hemispheric damage would seem to implicate reduced sensory input to the affected hemisphere.

2. Neurodynamically, disturbed interhemispheric processing linked to reduced sensory input may be of etiologic importance in the spatial deficit symptomatic of left hemiplegia.

3. Unilateral sensory stimulation to the impaired side may provide a therapeutic model to redress the neurological input imbalances, thus permitting harmonious interhemispheric participation essential to accurate visuo-spatial functioning.

It is hypothesized that spatio-perceptual deficit in left hemiplegia is a variant of the phenomenon of sensory suppression observed during double simultaneous stimulation. It may be remediated by unilaterally compensating for decreased sensory input. This would decrease interhemispheric desynchrony by providing increased impaired side stimulation.

5. Hypotheses.

The specific treatment hypotheses of this study in the null form are as follows:

1. There is no significant difference in the mean performance of left hemiplegic subjects on total Block Design scores when exposed to unilateral electrical stimulation and, in a sham non treatment condition.

2. There is no significant difference in the mean performance of left hemiplegic subjects on the left half of Block Design scores when exposed to unilateral electrical stimulation and, in a sham non treatment condition.

3. There is no significant difference in the mean performance of left hemiplegic subjects on the right half of Block Design scores when exposed to unilateral electrical stimulation and, in a sham non treatment condition.

4. There is no significant difference in the mean performance of left hemiplegic subjects on total Digit Cancellation scores when exposed to unilateral electrical stimulation and, in a sham non treatment condition.

5. There is no significant difference in the mean performance of left hemiplegic subjects on the left half of Digit Cancellation scores when exposed to unilateral electrical stimulation and, in a sham non treatment condition.

6. There is no significant difference in the mean performance of left hemiplegic subjects on the right half of Digit Cancellation scores when exposed to unilateral electrical stimulation and, in a sham non treatment condition.

Because of the chronic status and therefore masked fatiguability of the patient sample, only two tasks measuring spatial performance were utilized. Past research efforts in this milieu has taught that the validity of measurement correlates significantly with the brevity of the battery.[71] Two aspects or symptoms important in the total syndrome complex were therefore assessed, construction apraxia and unilateral spatial neglect.

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71 A. Leonoff, "Battery and Brevity: Psychological Assessment of the Chronic Stroke Patient," unpublished study, St. Vincent Hospital, Ottawa, 1971.

CHAPTER II

EXPERIMENTAL DESIGN

This chapter discusses the procedures involved in the investigation of the experimental hypotheses. It describes the tools of the experiment, the sample, the method of the research, and the statistical procedures used in the analysis of data.

1. The Tools of the Experiment.

A. Visuo-spatial Measures

In the assessment of treatment effects two tasks were used: Block Design[1] and Digit Cancellation.[2] The first task, Block Design, comprises one of the subtests of the _Wechsler Adult Intelligence Scale_.[3] For this study Diller _et al._'s[4] alternate forms A, B, and C were used. These alternate forms have been demonstrated to be actuarially equivalent to the original B.D. test.

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1 Hereafter referred to as B.D.

2 Hereafter referred to as D.C.

3 D. Wechsler, _Manual for the Wechsler Adult Intelligence Scale_, New York, Psychological Corp., 1955, p. 110.

4 L. Diller _et al._, _Studies in Cognition and Rehabilitation_, Grant No. RD 2666-P, Division of Research and Education Grants, Social and Rehabilitation Service, Department of Health, Education and Welfare, Washington, D.C., 1971, p. 38.

Block Design was chosen as a measure of visuo-spatial perception for the following reasons. Firstly, this test has been shown to be one of the most sensitive to right hemispheric impairment[5,6,7] and has four alternate forms in the Diller *et al*. version. Secondly, this test requires a higher order of perceptual integration of visual stimuli than Digit Cancellation. Presumably small improvements in the more basic factors underlying visuo-spatial perception would be magnified in B.D. performance, rendering it sensitive to slight improvements in perceptual conditions as found in the treatment. Finally, improvements in Block Design have been shown by Lorenze and Cancro[9] and Diller *et al*.[10] to be highly correlated with success in rehabilitation training.

Block Design consists of ten models of block arrangements which the subject must copy in the third dimension with

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

6 A. Luria, *High Cortical Functions in Man*, New York, Basic Books, 1960, p. 490.

7 J. E. Bogen, "The Other Side of the Brain: An Appositional Mind," in R. E. Ornstein (Ed.), *Nature of Human Consciousness*, San Francisco, Freeman Co., 1973, p. 112.

8 Diller *et al*., *op. cit*.

9 E. Lorenze and R. Cancro, "Dysfunction in Visual Perception with Hemiplegia: Its Relation to Activities of Daily Living," *Archives of Physical Medicine and Rehabilitation*, October 1972, p. 514-517.

10 Diller *et al*., *op. cit*.

his own blocks. This permits a total score of sixty correctly placed blocks with one point given per block. The maximum score for the right and the left sides of the designs would be twenty-four.

The order of the designs was altered so that design 2 was presented between designs 5 and 6. This arrangement was used to give the designs in the order of increasing degree of difficulty, as suggested by Diller *et al.*[11]

All designs where constructional deviations[12] occurred were scored as zero points. No time limit was imposed as the subjects were all limited to manipulating blocks with only the right hand. Instructions used were essentially those of the *WAIS* with the exception of designs 1 and 2 where no second attempt was permitted. Testing terminated after failure on three consecutive designs. Failure was defined as one or more incorrectly placed blocks on a single design, in order to avoid excessive frustration among the subjects.

The second task used was the Digit Cancellation task of Diller *et al.*[13] A measure of scanning, this test has been demonstrated to measure inattention and visual neglect in

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11 *Ibid.*

12 Constructional deviations were defined as a 45° or more rotation out of horizontal or vertical axes, linear, broken, or irregular figures out of the usual rectangular shape.

13 Diller *et al.*, *op. cit.*, p. 42.

left hemiplegics. In this task the subject is asked to make a line through the digit "8" wherever it occurs in a page of three lines of 156 digits. A sample of this test is presented in Appendix 2. There are fifty-three digits to be cancelled out with a pencil stroke. All subjects were instructed to cancel out the eights where they occur. Subjects were started on the left margin of the first line of digits and no further orientation assistance was given.

Scoring consisted of one point per unmarked eight with no time limit. Thus the higher the score, the more errors had been committed. On the left side of the digits it is possible to omit twenty-seven eights, while on the right side there are twenty-six possible errors to be made.

Little empirical evidence is available in the literature on the task. However, high clinical validity, noted in this setting as well as elsewhere, motivated its usage in the experiment. The instrument, as noted above, is simply a linear sample of stimuli and is therefore sensitive to visual neglect, a symptom often found in a chronic left hemiplegia population. Weinburg was able to classify three subgroups in terms of extent of neglect--severe, moderate, and mild. Training in visual scanning (that is, head compensation remediation) led to significant reduction or elimination of the unilateral spatial neglect in patients treated.[14] A similar treatment method has been utilized successfully at St. Vincent Hospital during the past four years.

B. Electro-cutaneous Apparatus

The equipment used to provide electro-cutaneous stimulation consisted of an electronic stimulator and isolating unit Nihon Kohden Model MSE-3R and MSE-5M. These units were attached via the positive electrodes to a multimeter EICO Model 20A-3. The electrodes consisted of ten layers of moistened gauze covering zinc electrodes 8.5 X 10 cms. This provided a dispersive stimulation when strapped in place with the anode distal to the elbow and the cathode over the wrist. The electrodes were placed on the extensor surface of the arm, permitting diffuse afferent sensation via the radial, ulnar, and median peripheral nerves.

This stimulator permitted the control of the duration of the stimulation, the interval between stimulations, and the graduated increase of amperage in steps of .25 milliamps.

The duration of the stimulus was set for 200 milliseconds for all subjects as suggested by previous research in this area.[15] The impulse was square in shape, rising

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14 Ibid.

15 H. Birch, I. Belmont and E. Karp, "The Relation of Single Stimulus Threshold to Extinction in Double Simultaneous Stimulation," Cortex, Vol. 1, 1964, p. 19-39.

directly to the amperage at which it had been set and falling perpendicularly to zero input after 200 milliseconds. This permitted fine calibration of the amperage given during each impulse and allowed for adjustment of amperage between any two impulses. During the treatment it was necessary to decrease the voltage in order to maintain a constant amperage between the anode and cathode. This phenomenon of decreasing electrical resistance across the poles after repeated stimulations had been reported by Fuher and Yegge[16] in 1973.

A square wave form of electrical stimulation was used with a one-second interval between impulses in order to prevent any recruitment effects of the shocks during the treatment period. For, as Birch _et al_.[17] had reported, the nervous system on the affected side is slower to process incoming stimulation and requires a longer time period to return to a prestimulus state of readiness to transmit different signals.

The treatment amperage to be used was established using a modified method of limits. After placement of the electrodes, subjects were instructed to say when they felt a slight tap on the back of their wrist. The experimenter indicated how this would feel by tapping the subject's intact wrist lightly three

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16 M. Fuher and B. Yegge, "Effects of Skin Impedence Changes Accompanying Functional Electrical Stimulation of the Peroneal Nerve," _Archives of Physical Medicine and Rehabilitation_, Vol. 53, 1973, p. 276-281.

17 H. Birch, I. Belmont and E. Karp, "Delayed Information Processing and Extinction Following Cerebral Damage," _Brain_, Vol. 90, 1967, p. 113-129.

times with his index finger. All subjects received stimulation at increments of .5 milliamps beginning at zero milliamps, with random trials interspersed to obviate the development of a response set to the stimulus.

Once the subjects had come to recognize the stimulus, decrements of .25 milliamps were used until no sensation was reported. The experimental stimulus was then determined at .25 milliamps above the minimum absolute threshold of awareness. Table II presents the treatment amperage used in this study. This slight increase above the threshold was necessary so that the variability of electro-cutaneous thresholds of the left hemiplegics would not render some of the impulses subliminal.

2. The Sample.

The subjects for this study were obtained from St. Vincent Hospital in Ottawa. The sample consisted of fourteen subjects all of whom had suffered cerebral thrombosis and consequent left hemiplegia. The subjects were selected from a population of forty-six 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; and (d) no evidence of previous psychiatric history or a present disease involving the central nervous system.

Table II.-

Mean, Median, Range, and Standard Deviation of the Treatment Amperage.

Subject	Milliamperes
1	3.00
2	1.50
3	3.25
4	3.00
5	2.00
6	1.75
7	1.00
8	3.75
9	2.00
10	0.75
11	3.00
12	3.50
13	2.50
14	3.25

$\bar{X}$ = 2.456
Me = 2.75
Range = 3.75 to 0.75
σ = .928

The ages of the subjects are presented in Table III. Ages ranged from forty-nine to eighty-nine years, with a mean age of sixty-nine and a standard deviation of 10.8 years, as presented in Appendix 11.

Only one of the subjects was in an active rehabilitation program. This reflects the relative severity of deficit in this sample when compared with the total population of left hemiplegics. Time since onset of stroke averaged 34.5 months indicating the chronic status of the sample group.

3. Method of the Experiment.

Initially the sample was randomly split into two groups of seven. Following this, all subjects were given a baseline assessment on the visuo-spatial battery. Immediately after this assessment, treatment amperages were established using the method of modified ascending limits. The subjects were instructed that during the next two weeks they would be receiving treatments, each lasting thirty minutes. Further, that at times they might feel some tapping and at other times it might be so low as to be imperceptible.

The treatment stimulation consisted of a 200 millisecond duration, square shaped electro-cutaneous impulse at intervals of one second and at the subject's pre-established threshold value plus .25 milliamps. This treatment for group A

Table III.-

Age, Education, and Time Since Onset of Stroke.

Subject		Age (years)	Education (years)	Time Since Onset of Stroke (months)
1		81	9	12
2		68	7	20
3		49	8	16
4		61	12	21
5		64	6	29
6		63	8	32
7		87	7	50
8		69	10	54
9		85	11	36
10		61	12	7
11		76	12	86
12		71	13	29
13		72	6	50
14		63	8	42
	$\bar{X}$ =	69	9.2	34.14
	Range =	49 - 89	13 - 6	80 - 7
	σ =	10.8	2.34	18.996
	Me =	68.5		31

was immediately followed by reassessment on the visuo-spatial tests with the electrodes still attached and functioning.

Meanwhile, group B received a sham of the treatment with the electrodes attached and the electronic stimulator functioning at zero amperage. With this exception: the seven-day period since pretesting, the thirty-minute duration, the room, the time of day, and the posttreatment visuo-spatial assessment were identical to those of group A.

Subjects were not asked to perform any tasks during the thirty minutes of treatment in order to minimize influences 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 with your problem. When I connect all this you may or may not feel something, but don't be concerned. This is part of the treatment. After the treatment I will see how you do once again.

The next week group B received the treatment and group A the sham. This resulted in a cross-over design as indicated graphically in Figure 1.

This design permitted control for subject expectancies and practice effects. It also permitted the use of change scores derived from the pretest baseline.

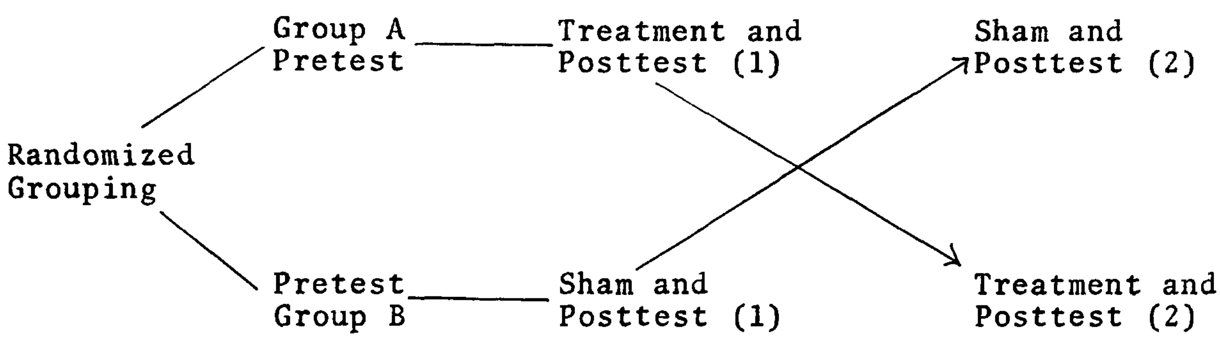

Figure 1.- Randomized Cross-over Experimental Design Used in the Testing of the Treatment Hypotheses.

4. Statistical Operations.

Change scores[17] were computed in order to reflect differences in each subject's performance during sham and treatment conditions relative to his pre-experiment performance.

The formulae used to compute the change scores were as follows:

$$\frac{\text{Sham score - pretest score}}{\text{Maximum score - pretest score}} \times 100 = \text{Sham Change Score}$$

$$\frac{\text{Treatment score - pretest score}}{\text{Maximum score - pretest score}} \times 100 = \text{Treatment Change Score}$$

Subsequently, tests for the difference between correlated groups were used to analyze for significant differences.[18] According to Campbell and Stanley[19] this approach is most applicable to these data.

In testing the hypotheses, the .01 level of significance was used. The results and ensuing discussion are to be found in chapter three.

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17 S. Howland, A. Lumsdaine, and P. Scheffield, "A Baseline for Measurement of Percentage Change," Experiments in Mass Communication, Princeton University Press, 1949, p. 149.

18 L.-T. Dayhaw, Manuel de statistique, Editions de l'Université d'Ottawa, 1969, p. 548.

19 D. Campbell and T. Stanley, Experimental and Quasi-experimental Designs for Research, Chicago, Rand McNally & Co., 1969, p. 84.

CHAPTER III

EXPERIMENTAL RESULTS

This chapter presents the results of the study and interprets their implications in view of the model of perceptual disturbance outlined in chapter one.

1. Presentation of Data.

The data describing the treatment amperage and the sample used have been presented in Tables II and III.

Raw score data prior to change score transformation are presented in Appendices 3, 4, 5, 6, 7, and 8. These include, respectively, the results of Block Design Total Scores, B.D. left, B.D. right, Digit Cancellation Total, D.C. left, and D.C. right, for pretest, treatment, and sham conditions.

Appendices 9 and 10 show the change scores of sham and treatment performance relative to pretest scores for B.D. and D.C. on total, left, and right sides of the tasks.

2. Presentation of Results.

Table IV presents the t test results for all B.D. and D.C. vectors.

The first hypothesis that no significant difference between Block Design performance under treatment versus sham

Table IV.-

Mean Differences, Standard Errors of Differences and t Values for Block Design and Digit Cancellation in Experimental-Sham Comparisons.

	Mean Difference	Standard Error of Difference	t[a]
Total Block Design	18.451	5.755	3.206*
Left Side Block Design	17.885	5.527	3.236*
Right Side Block Design	21.846	6.28	3.479*
Total Digit Cancellation	7.096	4.099	1.731
Left Side Digit Cancellation	8.024	4.408	1.82
Right Side Digit Cancellation	16.51	10.05	1.643

a t test for correlated groups
* Significant at .01 level (df = 13, = 3.012)

conditions was not accepted. The t testing for correlated groups yielded a t value of 3.206. The .01 significance level for 13 degrees of freedom is 3.012 using Fisher's table of probabilities. Thus the null hypothesis was rejected at the 99 per cent level of confidence.

The second hypothesis referred to B.D. performance on the left side of the designs. Again, the null hypothesis was rejected. As seen in Table IV, the t value arrived at was 3.2359 with $p = .01$ at 3.012 for $df = 13$.

The final hypothesis in relation to B.D. was that no significant difference would be found between performance on the right side of the designs under sham versus treatment conditions. This hypothesis was also rejected at the 99 per cent level with the derived t value being 3.478.

The hypothesis that total Digit Cancellation performance would not be significantly different under sham versus treatment conditions was not rejected. The t value derived from a comparison of the sham and treatment conditions was $t = 1.73105$.

The hypothesis that Digit Cancellation performance on the left side of the task would not be significantly improved under the sham and treatment conditions was not rejected. The t value derived was $t = 1.8203$.

The final hypothesis that Digit Cancellation performance on the right side of the task would not be significantly different under sham versus treatment conditions was not rejected. The derived t = 1.6433 was not significant at the .01 level of probability.

Conclusions.- At the end of chapter one, the experimental hypotheses were presented as follows.

Left hemiplegics, when exposed to unilateral, impaired side subfunctional electro-cutaneous stimulation versus sham of stimulation, are not significantly improved on the following variables of spatial functioning:

(a) total correctly placed blocks in Block Designs;

(b) left side correctly placed blocks;

(c) right side correctly placed blocks;

(d) total error in Digit Cancellation;

(e) left side errors in Digit Cancellation; and

(f) right side errors in Digit Cancellation.

Considering these hypotheses, the following is a summary of the results. In terms of two measures of visuospatial functioning, the null hypotheses were rejected in the case of total B.D., left B.D., and right B.D. scores at the .01 level of probability. The null hypotheses were not rejected for total D.C., left D.C., and right D.C. performance although a trend toward improvement was noted.

3. Interpretation of Results.

The results may be interpreted in support of a global deficit in spatial awareness among left hemiplegics. This would coincide with a wholistic conception of perception as a complex process. Hebb's[1] definition of perception as the process which is the cognition or awareness of an object was employed. Hebb stated that the process of perception is comprised of inseparable sensory and motor events that are a direct result of a hemispheric and interhemispheric processing of data during supporting arousal from the diencephalic system.

It was noted that so complex a process was open to disruption and subsequent perceptual deficit at many points. The suggestion was made that lack of impaired side awareness of stimulation in left hemiplegia (extinction) may have the same neurodynamic foundation as visuo-spatial deficit.

If the above were true, then treatment for interhemispheric asymmetry of processing would result in an amelioration of global visuo-spatial functioning. Whereas, if spatial deficit and subsequent improvement were confined to the spatial left side of the tasks, then one would suspect a more psychological learned deficit in attention as the basis for

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1 D. Hebb, "Concerning Imagery," Psychological Review, Vol. 75, 1968, p. 466-477.

spatial deficit in hemiplegia as suggested by Diller *et al*.[2]

The results on the Block Design task support a global interpretation of perceptual deficit. Performance did not improve differentially on the left or the right side of the designs. This is in contrast to Diller *et al*.'s[3] observation that left hemiplegics make more errors on the left than on the right side of this task. While these two observations are not contradictory, they do suggest that perceptual deficit in left hemiplegia is more complex than had previously been suggested.

The results on Digit Cancellation did not show significant improvement under unilateral treatment in contrast to Block Design performance. Task-oriented factors such as the size of the digits, the repetitive requirement of the cancellation task versus the puzzle content of Block Design may account for some of the difference. Digit Cancellation subsumes a greater lateral dimension of visual space than Block Design. This may interact with the shortened and unsystematic eye movements in the left visual field as

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2 L. Diller *et al*., *Studies in Cognition and Rehabilitation*, Grant No. RD 2666-P, Division of Research and Education Grants, Social and Rehabilitation Service, Department of Health, Education and Welfare, Washington, D.C., 1971, 204 p.

3 *Ibid*.

observed by Chèdru _et al_.[4] An added factor has already been mentioned, that of the higher order of Block Designs as a task subsuming more complex perceptual judgments than Digit Cancellation. It may be that Block Design would therefore tend to magnify small increments in spatial symmetry.

A final explanation for the improvement in B.D. performance over D.C. may lie in the organization of the cortex itself. Luria[5] points out that the more complex the perceptual task, in this case B.D., the greater the involvement of secondary and tertiary association area of the cortex. These areas are known to be more diffuse and thus have a greater probability of lying in the marginally functional regions surrounding the focus of a lesion. This would tend to render them more susceptible to suppression by the intact hemisphere's input and, in reverse, more likely to respond to a partial redressment of suppression.

In Digit Cancellation no marked left versus right side difference in performance was observed. However, a trend toward improved scanning as measured by the task was noted.

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4 F. Chèdru, M. Leblanc and F. Hermitte, "Visual Searching in Normal and Brain Damaged Subjects," _Neuropsychologia_, Vol. 11, 1973, p. 94-111.

5 A. Luria, _Higher Cortical Functions in Man_, New York, Basic Books, 1960, p. 490.

Although these results could be interpreted to indicate interhemispheric suppression as the foundation of spatial perceptual deficit in left hemiplegia, the author supports the view that suppression is but one of many factors underlying the syndrome. Diller *et al.*'s[6] training in scanning and progressive cueing in Block Designs represents a further factor, decreased visual scanning, in the left hemiplegic's spatial deficit.

While training in visual searching of the left visual field is of proven value in the remediation of perceptual deficit, the addition of unilateral treatment would appear to further augment accurate spatial awareness.

Diller *et al*. reported that improvementsin Block Design and Digit Cancellation were followed by improvements in rehabilitation assessments of daily living skills. Therefore improvements on the same tasks as found in this study would logically result in similar improvements in rehabilitation skills.

Leonoff[7] demonstrated that during double simultaneous stimulation, left hemiplegics showed a regression of spatial performance, whereas increasing the intensity of input on

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6 Diller *et al*., *op. cit*.

7 A. Leonoff, *The Effects of Electrical and Auditory Stimulation on Spatial Disorientation in Hemiplegia*, doctoral thesis presented to the School of Graduate Studies of the University of Ottawa, Ontario, 1973, 188 p.

the impaired side did not result in a similar regression. Regression of performance was attributed to increased asymmetry of interhemispheric functioning. The increased intensity of stimulation on the impaired side offsets suppression of awareness by being processed faster at a clinically significant rate.

This study would seem to have observed a variant of the D.S.S. extinction phenomenon. By stimulating the impaired side without a compensatory stimulus from the intact side, suppression was overcome. This was followed by an improvement in spatial perception. It would then appear that some of the spatial perceptual deficit found in left hemiplegia is possibly linked to the phenomenon of extinction of awareness of stimulation on the impaired body side.

The short duration of the treatment period and the low level of intensity of stimulation further suggests a neurological rather than a psychological explanation for the improvement in spatial functioning. However, chronicity is a factor in spatial awareness. In this study it was observed that ten of the fourteen subjects required stimulation at the threshold of contraction before awareness of stimulation occurred. It appeared that the subjects were learning to identify stimulation coming from a body side which had ceased to exist in their conscious awareness. This confirms Hebb's philosophical observation that we tend to perceive those stimuli which we are already thinking about. Therein, perhaps, lies a clue to the major psychological concomitant of perceptual deficit. The left hemiplegic's perception is sporadic on the impaired side, and therefore perception and pre-perceptual readiness to attend are diminished on that side. This would tend to further preclude the awareness of disability and the development of conscious and unconscious compensatory strategies.

Examining the raw scores in Appendices 3 through 8 showed no practice effects resulting from retesting. However, it reveals a paradoxical trend of regressed spatial performance under sham conditions relative to pretesting. This negative sham effect would tend to contribute to the statistical superiority of sham over treatment relative to pretest scores. Therefore the probability of a type I error is possibly greater than the significance table would indicate.

The obvious question is why should a sham of unilateral treatment result in regressed spatial performance. One answer may lie in the behavior of the subjects during the sham condition. Fully one-third of the subjects expressed dismay at not being capable of feeling the sham of treatment. This occurred despite the instructions which indicated some of the treatments might be so weak that the subject would not feel them.

The possibility of Type I error suggested further analysis of the difference between pretest, treatment, and sham conditions. The t test values for pretest to treatment on B.D. was 1.38, $p > .05$ at $t = 2.16$. However, the sham result was significantly below pretest values with $t = -2.187$.

This finding modulates the degree to which this study can be directly related to neurodynamic factors, and raises the question of motivational components playing a large role in the observed performance changes.

A further study comparing bilateral stimulation points with sham and treatment conditions would serve to clarify the possibility of motivational contamination arising out of increased somesthetic balance of stimulation.

Their nonverbal behavior suggested that they felt themselves to be more severely disabled during sham than when under treatment. Considering the usual lack of awareness of personal disability found in such patients, the above observation may be a favorable sign of increased awareness as a result of participation in the experiment. Thus a motivational component is possibly as important a contributor to the significance of the treatment as is the electro-cutaneous treatment itself.

4. Suggestions for Further Research.

Many questions are raised for further research. The theory that extinction underlies the major part of perceptual deficit in left hemiplegia must be examined using a greater variety of tests similar to these used by Leonoff in his study.

Is there an optimum level of stimulation which will maximize remedial effects? Such a study might include the use of various variables of stimulation. These could include: (a) increasing the area stimulated; (b) increasing the number of sensory modes stimulated; and (c) increasing the intensity of the area stimulated.

Further research is necessary to examine evoked potential changes between hemispheres under unilateral and bilateral stimulation. This study has presented behavioral evidence which suggests that there would be electroencephalograhic differences in arousal between the two hemispheres, particularly during D.S.S.

In this study the stimulation used was vibrant in contrast to that prosthestic weight used by Birch *et al*.[8] in 1962. It is for further investigation to examine this quality of the stimulation as it affects performance. Logically, the more active the form of stimulation, the more effective it should be.

Hopefully, further study into the use of unilateral stimulation as a remedial aid in spatial deficit among left hemiplegics will lead to the development of psychotechnic devices that may be used soon after the onset of a right hemisphere C.V.A. This usage would decrease the effect of chronic understimulation on that body side and thereby promote the rehabilitation prognosis in left hemiplegia.

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

SUMMARY AND CONCLUSIONS

This study examined the effect of unilateral sub-functional electro-cutaneous stimulation on two visuo-spatial tasks in left hemiplegia.

The discussion began by emphasizing the need for remedial research at this time. The poor rehabilitation prospects in left hemiplegia were related to the pervasive deficit in spatial functioning.

Subsequently the reviewer examined the levels at which spatio-perceptual processing may be disrupted. Since spatial deficit had been shown to be heteromodal and extensive, it was suggested that a cerebral disturbance of the perceptual process might be occurring. Theoretical support for this suggestion was found in Hebb's model of perception, particularly the role of facilitatory arousal and reciprocal interhemispheric relations in the process of perception.

The reviewer then examined a phenomenon parallel to spatial deficit. This was extinction of awareness to the impaired side during double simultaneous stimulation. Both phenomena have been considered symptomatic of left hemiplegia. Various neurodynamic conditions which result in extinction were examined with particular emphasis on techniques which temporarily overcome the suppression of awareness on the impaired side. It was observed that extinction was primarily a cerebral phenomenon, and not directly the result of peripheral elevated sensory thresholds. Extinction was attributed to interhemispheric desynchrony and inhibitory arousal by the intact hemisphere over the damaged hemisphere.

It was then proposed that extinction, as one of the salient perceptual dysfunctions in left hemiplegia, might share neurodynamic origins in common with spatial deficit.

If extinction and spatial deficit do share common neurodynamic origins, then unilateral stimulation which is known to overcome extinction and produce awareness on the impaired body side may also temporarily redress the imbalance of sensory input into the two hemispheres. The consequences would be adequate arousal in the impaired hemisphere and reduced vulnerability to suppression of the perceptual process by the intact hemisphere. This decreased vulnerability of the damaged hemisphere might permit more adequate organization of visuo-spatial inputs, thereby helping to remediate the spatio-perceptual inaccuracies found in left hemiplegics.

Two groups were randomly chosen to assess this hypothesis. Using a cross-over design, both groups received unilateral impaired-side stimulation and sham stimulation. The visuo-spatial tasks used to assess perceptual accuracy were the Block Design and Digit Cancellation tasks of Diller et al. Both tasks have been shown to be highly correlated with performance in rehabilitation, such that improvement on these tasks results in a better rehabilitation prognosis.

The results demonstrated that, as hypothesized, perception was improved globally in B.D. without left or right side differences. However, D.C. did not show significant improvement, although a trend toward improved spatial functioning in Digit Cancellation was noted. This latter finding led to the interpretation that task-oriented factors may have caused less remedial effects in Digit Cancellation. In particular, that Digit Cancellation is a speed test which is much reduced in its power to measure a behavior when time limits are extended. Further, that unilateral treatment may be redressing a cerebral imbalance, while deficit may be occurring through decreased occulomotor tonicity as suggested by Chedru et al. Thus unilateral treatment does show remedial potential, but other factors arising from the paretic condition may also contribute to spatial deficit.

In a remedial program the use of both, unilateral sensory stimulation and training in scanning the left visual field, may prove more effective in treating lack of spatial awareness among left hemiplegics.

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This study revealed on the motor level desynchony of coordination under double simultaneous movement indicating the previous neurodynamic foundation of extinction phenomenon.

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. 10-39.

This was the first research to focus upon the neurologic model of extinction used in this study. They found that extinction was not governed by peripheral increases in sensory thresholds on the impaired side, implicating cortical or intercortical disturbances of functioning.

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The authors demonstrated that the impaired hemisphere requires longer to return to prestimulus readiness to transmit and process new data. This is a further element contributing to the cortical disruption of perceptual processing.

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The authors extrapolated a curve of inhibitory recovery following a prior stimulus and the presentation of the succeeding one. They interpreted this processing inertia of the cerebrum as it would affect attentional loss and difficulties in scanning.

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

This study demonstrated that during D.S.S. extinction was the result of interference in conscious awareness of stimuli arising on the intact side appropriating the response system of the impaired hemisphere via interhemispheric pathways. Providing support for the theory of general perceptual extinction used 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.

This study was the first to suggest a link between increased sensory input on the impaired side and improvements in the spatial perception of left hemiplegics. It provided direct support for the use of a unilateral treatment paradigm.

Bogen, Joseph E., "The Other Side of the Brain: An Appositional Mind," in R. Ornstein (Ed.), The Nature of Human Consciousness, San Francisco, Freeman & Co., 1973, 514 p.

An up-to-date review of the differential modes of thought found in the major and minor hemispheres. He underlines the immediate and continuous spatial nature of the minor hemisphere's food for thought.

Diller, Leonard, Yehunda Ben-Yiskay, Joseph Weinburg, and Robert Goodkin, Studies in Cognition and Rehabilitation in Hemiplegia, Grant No. RD 2666- , Division of Research and Education Grants, Social and Rehabilitation Service, Department of Health, Education and Welfare, Washington, D.C., 1971, 205 p.

This group of investigators are the major influence in rehabilitation psychology toward remediation of neuropsychological deficits. The report summarized their retraining techniques for attentional deficits in left hemiplegia. Their development of a progressive cueing procedure for block designs and training for visual scanning show strong potential as remedial aids in the rehabilitation of perceptual deficit.

Hebb, D. O., "Concerning Imagery," Psychological Review, Vol. 75, 1968, p. 466-477.

The author discusses and defines the process of perception in contrast to sensation. He provided a model of the perceptual process which yielded rich results when combined with the previous research on the neurodynamic conditions underlying extinction during D.S.S.

Lerner, Shirley, "Lack of Movement Efficiency in C.V.A. Patients with Perceptual Dysfunction," Journal of the Canadian Physiotherapy Association, Vol. 22, 1970, p. 59-64.

In this paper the author presents clinical observations of the importance of bilateral input and feedback disorders in the functional return of mobility among hemiplegics. This point is central to the present thesis in that it highlighted the link between perceptual deficit and impeded rehabilitation.

Levin, Harold, "Motor Impersistence and Proprioceptive Feedback in Patients with Unilateral Cerebral Disease," Neurology, Vol. 23, August 1973, p. 833-841.

This study demonstrated that proprioceptive disturbance underlied spatial deficit in left hemiplegia. Further, it demonstrated that proprioception was disturbed as a result of unstable feedback. This outlined the basic sensory deficit and accompanying cerebral asymmetry as the possible source of spatial deficit.

Leonoff, Arthur S., The Effects of Electrical and Auditory Stimulation on Spatial Disorientation in Hemiplegia, doctoral thesis presented to the School of Graduate Studies of the University of Ottawa, 1973, 188 p.

The parent study to the present thesis, it demonstrated that extended D.S.S. resulted in decreased spatial orientation in left hemiplegia. Compensating for the temporal processing lag by increasing the intensity of stimulation on the impaired side above the extinction threshold in a D.S.S. treatment resulted in an observable maintenance of pretest spatial performance with a trend towards improvement. This present thesis represents a refinement of Leonoff's work and validates the trend he found.

APPENDIX 1

REFERENCES AS TO AUTHORS CITED IN TABLE I

APPENDIX 1

REFERENCES AS TO AUTHORS CITED IN TABLE I

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APPENDIX 2

DIGIT CANCELLATION TEST: SAMPLE

APPENDIX 2

DIGIT CANCELLATION TEST: SAMPLE

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

6 5 4 8 3 4 8 2 6 8 1 4 8 3 5 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 2 5 8

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

APPENDIX 3

RAW SCORE TOTAL CORRECTLY PLACED BLOCKS IN BLOCK DESIGN PRETEST, TREATMENT AND SHAM CONDITIONS

APPENDIX 3

RAW SCORE TOTAL CORRECTLY PLACED BLOCKS IN BLOCK DESIGN PRETEST, TREATMENT AND SHAM CONDITIONS

Subject	Pretest	Treatment	Sham
1	11	29	17
2	2	13	4
3	22	10	10
4	19	23	10
5	14	15	9
6	13	15	7
7	38	47	41
8	6	18	6
9	18	9	0
10	16	22	20
11	27	22	12
12	6	23	6
13	1	0	2
14	31	26	17

APPENDIX 4

RAW SCORES CORRECTLY PLACED BLOCKS ON THE LEFT SIDE OF BLOCK DESIGNS

APPENDIX 4

RAW SCORES CORRECTLY PLACED BLOCKS ON THE LEFT SIDE OF BLOCK DESIGNS

Subject	Pretest	Treatment	Sham
1	6	13	7
2	2	4	1
3	10	5	6
4	9	7	5
5	6	7	5
6	6	8	8
7	17	19	16
8	2	3	2
9	6	4	0
10	8	9	10
11	11	13	5
12	3	11	3
13	0	0	1
14	13	11	8

APPENDIX 5

RAW SCORES CORRECTLY PLACED BLOCKS ON THE RIGHT SIDE OF BLOCK DESIGN

APPENDIX 5

RAW SCORES CORRECTLY PLACED BLOCKS ON THE RIGHT SIDE OF BLOCK DESIGN

Subject	Pretest	Treatment	Sham
1	5	12	10
2	2	4	3
3	11	5	4
4	9	13	5
5	8	8	4
6	6	7	9
7	17	21	18
8	0	5	4
9	8	5	0
10	8	9	9
11	13	13	6
12	3	11	3
13	1	0	1
14	14	11	9

APPENDIX 6

RAW SCORES ERRORS ON DIGIT CANCELLATION

APPENDIX 6

RAW SCORES ERRORS ON DIGIT CANCELLATION

Subject	Pretest	Treatment	Sham
1	1	0	0
2	23	22	21
3	5	7	1
4	21	17	4
5	10	7	1
6	23	5	5
7	1	0	1
8	31	38	30
9	7	28	8
10	7	1	7
11	5	5	8
12	1	0	0
13	34	42	48
14	0	1	0

APPENDIX 7

RAW SCORE ERRORS ON LEFT SIDE OF DIGIT CANCELLATION

APPENDIX 7

RAW SCORE ERRORS ON LEFT SIDE OF DIGIT CANCELLATION

Subject	Pretest	Treatment	Sham
1	1	0	0
2	12	11	11
3	3	4	0
4	10	7	1
5	6	5	1
6	13	2	5
7	1	0	0
8	9	19	15
9	5	10	4
10	4	1	4
11	3	3	3
12	0	0	0
13	19	22	24
14	0	0	0

APPENDIX 8

RAW SCORE ERRORS ON RIGHT SIDE OF DIGIT CANCELLATION

APPENDIX 8

RAW SCORE ERRORS ON RIGHT SIDE OF DIGIT CANCELLATION

Subject	Pretest	Treatment	Sham
1	0	0	0
2	11	11	10
3	2	3	1
4	11	10	3
5	4	2	0
6	10	3	0
7	0	0	1
8	22	19	15
9	2	18	14
10	3	0	3
11	2	2	5
12	1	0	0
13	15	20	24
14	0	1	0

APPENDIX 9

INDEX OF EFFECTIVENESS FOR BLOCK DESIGN PERFORMANCE

APPENDIX 9

INDEX OF EFFECTIVENESS[a] FOR BLOCK DESIGN PERFORMANCE

Subject No.	Total		Left Side		Right Side	
	Treatment	Sham	Treatment	Sham	Treatment	Sham
1	35.42	10.42	38.88	5.56	33.33	23.81
2	18.96	3.45	9.09	-4.55	9.09	4.54
3	25.00	25.00	-35.71	-28.57	-46.15	-53.85
4	9.76	-21.95	-13.33	-26.67	26.67	-26.67
5	.24	-10.87	5.56	-5.56	12.50	-25.00
6	4.25	-12.77	11.11	11.11	5.56	16.67
7	40.91	13.64	28.57	-14.29	71.42	14.29
8	22.22	00.00	4.54	00.00	20.83	16.67
9	-21.43	-42.86	-11.11	-33.33	-18.73	-50.00
10	13.64	9.10	6.25	12.50	6.25	6.25
11	-15.15	-45.45	15.38	-46.15	00.00	-63.64
12	31.48	00.00	38.09	30.00	38.10	00.00
13	-1.69	1.69	00.00	4.17	-4.35	00.00
14	-24.14	-24.14	-18.18	-45.46	-30.00	-50.00

[a] $\left(\frac{\text{Post-Pre}}{\text{Max-Pre}}\right) 100$

APPENDIX 10

INDEX OF EFFECTIVENESS FOR DIGIT CANCELLATION PERFORMANCE

APPENDIX 10

INDEX OF EFFECTIVENESS FOR DIGIT CANCELLATION PERFORMANCE

Subject No.	Total		Left Side		Right Side	
	Treatment	Sham	Treatment	Sham	Treatment	Sham
1	-1.92	-1.92	-3.85	-3.85	0.00	0.00
2	-3.33	-6.67	-6.67	-6.67	0.00	-6.67
3	4.17	-8.33	4.17	-12.50	4.17	-4.17
4	-12.50	-53.13	-17.65	-52.94	-6.67	-53.33
5	-6.97	-20.93	-4.76	-23.81	-9.09	-18.18
6	-60.00	-60.00	-78.57	-57.14	-43.75	-62.50
7	-1.92	0.00	-3.85	-3.85	0.00	3.85
8	31.82	-4.55	55.56	35.29	-50.00	-175.00
9	45.65	2.18	22.73	-4.55	50.00	8.33
10	-13.04	0.00	-13.04	0.00	-13.04	0.00
11	0.00	6.25	0.00	0.00	0.00	12.50
12	-1.92	-1.92	0.00	0.00	-4.00	-4.00
13	42.11	73.68	37.50	62.50	45.45	81.82
14	1.89	0.00	0.00	0.00	-3.85	0.00

APPENDIX 11

MEANS, RANGES, MEDIANS, AND STANDARD DEVIATIONS FOR THE SAMPLE USED ON THE DEMOGRAPHIC VARIABLES OF AGE, EDUCATION, AND TIME SINCE ONSET OF ILLNESS

APPENDIX 11

MEANS, RANGES, MEDIANS, AND STANDARD DEVIATIONS FOR THE SAMPLE USED ON THE DEMOGRAPHIC VARIABLES OF AGE, EDUCATION, AND TIME SINCE ONSET OF ILLNESS

	Mean	Range	Median	Standard Deviation
Age (in years)	69	49 to 89	68.5	10.8
Education (in years)	9.2	13 to 6	8	2.3
Time since Onset (in months)	34.1	80 to 7	31	18.9

APPENDIX 12

ABSTRACT OF

The Effects of Unilateral Sub-functional Electro-cutaneous Stimulation on Spatial Disorientation in Left Hemiplegia

APPENDIX 12

ABSTRACT OF

The Effects of Unilateral Sub-functional Electro-cutaneous Stimulation on Spatial Disorientation in Left Hemiplegia[1]

This study investigated the use of unilateral impaired side stimulation as a remedial aid for spatial deficit in left hemiplegia.

During double simultaneous stimulation, extinction of awareness to impaired side stimulation occurs as a result of disrupted processing in the impaired hemisphere. Increased latency of processing in that hemisphere resulted in vulnerability of its functioning to arousal and appropriation of the response system by the faster processing intact hemisphere. It was postulated that unilateral stimulation on the impaired side might effectively pre-arouse the impaired hemisphere and render it less vulnerable to inhibitory suppression by the intact hemisphere. This would decrease the cerebral disturbance of awareness on the impaired side and permit improved spatial processing.

To assess this hypothesis, fourteen left hemiplegics were pretested then exposed to unilateral stimulation and to sham stimulation. Retesting was done at the end of each

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1 Michael Swords, Master's dissertation presented to the School of Graduate Studies of the University of Ottawa, Ontario, March 1975, x-88 p.

condition. Using a cross-over design, half the sample received treatment while the other half received sham, then the groups were reversed.

T tests for correlated groups between sham change scores and treatment change scores relative to pretest scores indicated significant treatment effects (p .01) on Block Design performance. No significance was found in relation to Digit Cancellation although a trend towards improvement was noted.

The results were interpreted as indicating remedial improvement in spatio-perceptual performance during unilateral impaired side stimulation in left hemiplegics. It was suggested that greater refinement of the unilateral treatment procedure, and its use in combination with other remedial techniques such as training in scanning, might further augment remedial gains. Examination of the source of significance indicated the possibility of motivational contamination within the paradigm employed in this study.

Suggestions for further research included, among others, comparison of the evoked potentials in the two cerebral hemispheres during unilateral stimulation, and an examination of spatial performance under hetermodal impaired side stimulation. These studies would serve to confirm the suggested neurological concomitants of spatio-perceptual deficit in left hemiplegia.