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# Somesthetic Functions in Patients with Brain Disease and Normal Subjects<sup>1</sup>

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LEVIN, HARVEY S. and ARTHUR L. BENTON. (Department of Neurology, The University of Iowa, Iowa City, Iowa 52242.) Somesthetic Functions in Patients with Brain Disease and Normal Subjects. *Proc. Iowa Acad. Sci.* 80(3) 145-149, 1973.

**SYNOPSIS:** This paper summarizes the results of a series of studies of somatosensory function in normal and brain-diseased subjects that were designed to investigate: (1) neural mechanisms in tactile resolution and masking, and; (2) cerebral dominance and somesthesia. Our results are consistent with the possibility that lateral inhibition effects influence tactile resolution and masking. Additional findings suggest that the physiologic mechanisms involved in tactile masking and obscuration in healthy subjects also mediate the pathologic expressions of these phenomena shown by patients with cerebral disease. Studies of hemispheric dominance and somesthesia have indicated that patients with right hemisphere

disease often demonstrate bilateral impairment in tactile perception of direction while this deficit is confined to the right hand of patients with left hemisphere disease. Consistent with the implications of these clinical findings, right-handed normal subjects show a left-hand superiority for tactile perception of direction. Bilateral impairment on a proprioception task was found for patients with unilateral cerebral disease of either hemisphere. However, only patients with right hemisphere lesions were unable to utilize increments in proprioceptive feedback to improve their performance. The results on tactile perception of direction and proprioceptive feedback are interpreted as consistent with findings for other sensory modalities that point to the crucial role of the right hemisphere in spatial aspects of perception.

**INDEX DESCRIPTORS:** Somesthetic functions; cerebral disease; somesthetic impairment; cerebral dominance; tactile resolution.

This paper will present a brief review of the program of research dealing with tactile and proprioceptive functions that has been pursued during the past decade in the Laboratory of Neuropsychology of the Department of Neurology at the University of Iowa College of Medicine. The two major topics which have been the focus of interest are: (1) neural mechanisms in tactile resolution and masking; (2) hemispheric cerebral dominance and somesthesia.

## *Tactile Resolution and Masking*

Our investigations of tactile two-point resolution have tested predictions derived from the neurophysiological and psychophysical studies by Békésy (1959) and Mountcastle (1957) of spatial interaction between stimuli in the somatosensory system. A gradient of sensory magnitude was postulated by Békésy to reflect lateral inhibition and central summation between adjacent receptive fields. According to this model, sensory magnitude is minimal at the center of an area of uniform stimulation because of considerable lateral inhibition produced by the surrounding receptive field. Absence of lateral inhibition associated with the surrounding non-stimulated area affords accentuation of sensory magnitude at the border of tactile or visual stimulus and produces contrast effects (Carmon, 1968; Cornsweet, 1970). This rise in gradient of sensory magnitude at the border of an area of stimulation is particularly marked in the case of an annular stimulus; a "ring" of unstimulated area interposed between the center and border reduces lateral inhibition of the border. As compared to a circular stimulus of equal intensity and area, intensity is more concentrated at the border of an annular stimulus.

Carmon (1968) investigated stimulus contrast effects in the somatosensory system by employing the electromechanical stimulator he developed in the laboratory (Carmon & Dy-

son, 1967). This instrument, which drops probes of different weights on the skin surface from a controlled distance above it, permits precise control of all relevant variables such as intensity, locus and duration of stimulation. In accord with predictions derived from a consideration of lateral inhibitory interaction effects, Carmon found that tactile resolution in normal subjects was more acute for annular than for circular stimuli. Consistent with the possibility that spreading a constant amount of intensity over a larger receptive area tends to decrease mutual inhibition within the stimulated area and accentuate contrast effects, Carmon and Benton (1969) found that tactile two-point resolution in normal subjects improved as the contact area of both stimuli was increased. Conversely, increasing stimulus intensity per area by increasing intensity applied to a small area diminished tactile resolution. This result was attributed to an increase in lateral inhibition which would be expected to decrease the gradient of sensory magnitude between stimulated and nonstimulated areas. In summary, these studies lend support to the inference that lateral inhibition influences tactile two-point resolution in human subjects.

Mechanisms of lateral inhibition and central summation or "funneling" were invoked by Békésy (1959) to explain the masking or obscuration of a tactile stimulus by other tactile stimuli presented in both spatial and temporal contiguity to it. Our studies have shown that deviation from the condition of temporal contiguity (Abramsky, Carmon & Benton, 1971) or of spatial contiguity (Levin & Benton, 1973) attenuates the degree of masking obtained. In the latter study, masking of a threshold tactile stimulus was more effective when the stronger stimulus was simultaneously applied to an adjacent locus on the same forearm as compared to the contralateral homologous locus. However, a significant masking effect obtained under both conditions in normal subjects. The finding that ipsilateral masking effects are greater in magnitude than that achieved by homologous placement of tactile stimuli accords with neurophysiological data indicating that cells in the somatosensory cortex of the monkey with concentric receptive fields on the same arm are more numerous than cells with bilaterally represented receptive fields (Mountcastle & Powell, 1959).

The clinical significance of the tactile resolution and mask-

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ing studies is reflected in the finding that double bilateral stimulation in patients with cerebral disease may reveal sensory deficit which is not detected by the use of single stimulation (Bender, 1952; Critchley, 1953). Defective responsiveness to double stimulation in patients with cerebral disease is often conceived as being the exaggerated expression of a normal physiologic mechanism wherein a stronger stimulus has the effect of inhibiting or suppressing the perception of a weaker one. However, in contrast to the clinical phenomenon which may be obtained using a suprathreshold stimulus on the affected side, test stimuli must be set at or near threshold to demonstrate a contralateral masking effect in normal subjects. For example, Bird (1964) was able to demonstrate masking of the weaker of two tactile pressure stimuli positioned on homologous sites of the two forearms in healthy subjects only when the intensity of the weaker stimulus was at a "minimal suprathreshold value," defined as the weakest intensity at which the subject detected the stimulus five times in succession. When the intensity of the stimulus was raised slightly above that value, masking was not produced.

A possible experimental approach to this discordance between clinical and normative findings was suggested by the observation that simultaneous homologous stimulation sometimes weakens the perceived magnitude of a suprathreshold stimulus presented to the patient's affected side but does not completely abolish the perception of it. This phenomenon is known in the clinical literature as "obscuration." After training healthy subjects in the method of magnitude estimation, Benton and Levin (1972) demonstrated obscuration of perception of suprathreshold stimulation in healthy subjects who failed to show complete masking of response to the weaker of the two simultaneous homologous stimuli. The finding that intact subjects reduced their estimates of the magnitude of a suprathreshold tactile stimulus when it was accompanied by a stronger contralateral stimulus was interpreted as further support for the concept that the clinical phenomena of masking and obscuration are exaggerated expressions of a normal physiologic mechanism.

In summary, these studies have suggested that neural mechanisms mediating tactile two-point resolution, masking and obscuration in healthy subjects are involved in the pathological expressions of these phenomena found in patients with cerebral disease. The hypothesis is supported by the finding that degree of tactile masking achieved in normal subjects by simultaneous homologous stimulation is increased in older persons (Levin & Benton, 1973).

#### HEMISPHERIC CEREBRAL DOMINANCE AND SOMESTHESIS

The concept of hemispheric cerebral dominance refers to a higher-level functional asymmetry of the cerebral hemispheres in man. The concept implies that one hemisphere possesses functional properties or subserves behaviors that are not equally shared by the other hemisphere.

Historically, the concept of hemispheric cerebral dominance originated in the 1860s with the discovery by Broca of an association between motor aphasia or expressive language disturbance and disease of the left frontal lobe. Subsequent clinical studies corroborated Broca's findings and demonstrated that other areas of the left hemisphere also are involved in the production of aphasic disorders. These findings established the doctrine of the dominance of the left

hemisphere for language in right-handed individuals. Still later, the concept of left hemisphere dominance was expanded to encompass higher-level praxis, aspects of the body schema, and abstract reasoning, as well as language. This state of affairs tended to relegate the right hemisphere to the status of a "minor" or "subordinate" hemisphere with regions designated as "silent" areas believed to be lacking functional significance.

However, the concept of an exclusive dominance of the left hemisphere was questioned as early as 1874 by Hughlings Jackson who postulated that emotive and automotive speech reside in the right hemisphere. Other investigators suggested that this hemisphere mediates musical language, as reflected in musical performance and in the recognition of melodies. Hughlings Jackson (1876) also postulated that the parietooccipital region of the "minor" hemisphere is particularly crucial for visual recognition and memory. Subsequent clinical studies suggested the possibility of a right hemisphere "dominance" for behavior with a spatial component (Rieger, 1909; Reichardt, 1923). Investigations during the 1940s and 1950s indicated that impairment in visual space perception, constructional performance and unilateral visual inattention more frequently occurred in patients with right hemisphere disease than in those with left-sided lesions.

In the auditory modality, Brenda Milner's research has indicated that damage to the temporal region of the right hemisphere produces a disturbance in discrimination of tonal patterns and judgments of tone quality (Milner, 1962). Left temporal lobe damage was found to impair verbal recall while sparing nonverbal auditory discrimination.

Systematic investigation of hemispheric dominance in the mediation of somatosensory performances began with the study by Semmes, Weinstein, Ghent and Teuber (1960) which assessed tactile performances in patients with unilateral cerebral lesions as well as in control patients with peripheral nerve injuries involving the lower extremities. Tests of threshold for light pressure, two-point discrimination and point localization were applied to each palm whereas the middle finger was used to determine the threshold for passive movement. Impairment was defined as a performance at or below the first percentile of the distribution of scores by control patients. Two major findings of this study were:

- 1) Many patients with unilateral cerebral lesions show somatosensory disturbance on the ipsilateral hand.
- 2) Ipsilateral defects occur more frequently in patients with left hemisphere lesions (36%) than in those with right hemisphere disease (16%).

The finding of relatively frequent occurrences of bilateral sensory deficits in patients with ostensibly unilateral lesions has been confirmed in other studies (Carmon, 1968; Corkin, Milner & Rasmussen, 1964; Vaughan & Costa, 1962; Wyke, 1966). However, the conclusion reached by Semmes et al. regarding the greater frequency of ipsilateral defects in patients with left hemisphere lesions has received only partial support (Benton, 1972). For example, the results of Corkin et al. (1964) indicated that ipsilateral defects in pressure sensitivity, two-point discrimination, and point localization occurred with equal frequency in patients with lesions of the left or the right hemisphere.

The possibility that certain somatosensory functions reflect a relative "dominance" of the right hemisphere was first suggested in a study conducted in the laboratory by Carmon and Benton (1969). Tactile perception of direction and number in patients with unilateral lesions was assessed by stimulating

the palms in nine different combinations of direction and number. Patients were asked to identify the tactile stimulus from among a visual array showing all nine combinations, either by pointing or by stating a number placed at the top of each combination. With the exception of the single-point stimulus, each stimulation could be scored for both number and direction.

The electromechanical stimulator devised by Carmon and Dyson (1967) was used to present the tactile stimuli. An arm protruding from its plunger supports a plexiglass block drilled with holes which serve as sleeves for steel rods. The rods, which were positioned 2 mm above the palm, descended on the palm when current supplied to the solenoid was interrupted. The weight of the rods thus determined the force of stimulation. Each stimulus was 3 sec. in duration. Eighteen stimulations were presented to each palm, 2 for each combination of number and direction.

Statistical analysis was based on the mean error in tactile perception of direction and number by 30 left and 30 right brain-damaged patients. Comparison with the mean errors for 56 control patients disclosed that impairment in perceiving the number of tactile stimuli applied to the palms was confined to the contralateral hand in both groups of brain-damaged patients. There was no indication of an ipsilateral deficit in either brain-damaged group. A different pattern of results emerged for perception of direction. This performance was also significantly inferior on the contralateral palm of both groups of brain-damaged patients as compared with the control group. However, perception of direction on the ipsilateral hand in patients with left hemisphere disease did not differ from control patients whereas patients with lesions of the right hemisphere evidenced impairment.

Figure 1 indicates the frequency of defective perception of number and direction in each brain-damaged group. A defective score was defined as a score poorer than all 56 control patients. This corresponded to 10 or more errors in each aspect of the task. It will be seen that a substantial proportion of each brain-damaged group (37% of the right and 20% of the left brain-damaged patients) was defective in perception of number on the contralateral hand, but not on the ipsilateral hand.

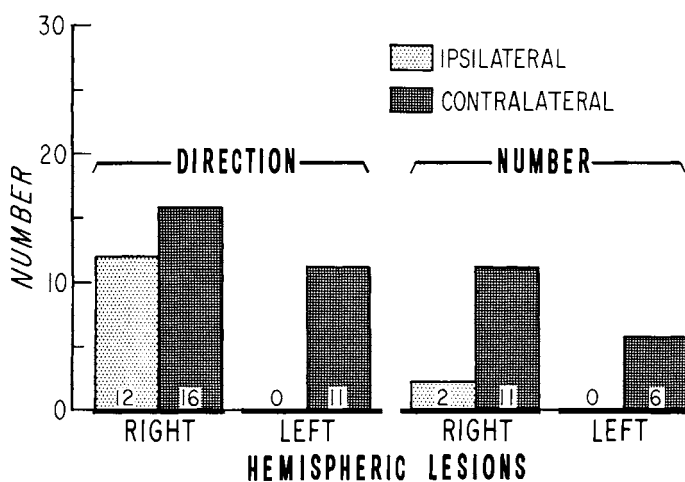


Figure 1. Frequency of defective performance (that is, below that of poorest control patient) in tactile perception of direction and number.

Consideration of defective scores in perception of direction revealed that 53% of the right brain-damaged and 37% of the left brain-damaged patients evidenced contralateral defects. No left brain-damaged patient demonstrated an ipsilateral impairment in perception of direction whereas 40% of the right hemisphere group were impaired on the right hand. Comparison of the performances of the two brain-damaged groups yielded a statistically significant difference for perception of direction on the ipsilateral hand; in this comparison, left hemisphere patients were superior to patients with right hemisphere disease.

A replication of the Carmon and Benton (1969) study has confirmed the original findings in tactile perception of direction (Fontenot & Benton, 1971). Utilizing a similar procedure, it was found that ipsilateral impairment in perception of direction was associated with right but not with left hemisphere disease.

The conclusions drawn from these studies are (1) impairment in tactile perception of number is confined to the contralateral hand in patients with unilateral cerebral disease; (2) deficit in tactile perception of direction is restricted to the contralateral hand in patients with left hemisphere disease but may occur bilaterally in right hemisphere cases; (3) at least some somatosensory performances on each side of the body are subserved by both ipsilateral and contralateral hemispheres. The obtained hemispheric difference in ipsilateral defect in tactile perception was interpreted by the authors as consistent with findings in other sensory modalities implicating a crucial role of the right hemisphere in spatial perception.

To test this inference of function from symptom we compared the hands of right-handed normal individuals for tactile perception of direction (Benton, Levin & Varney, 1973). Assuming that tactile information from the left hand is initially processed for the most part in the right hemisphere and tactile information from the right hand is initially processed for the most part in the left hemisphere, it was predicted that perception of direction would be more accurate on the left hand than on the right. Procedure was similar to that used in the clinical studies except that task difficulty was increased by reducing the stimulus duration to 1 sec. and number of tactile stimuli was held constant at 3. The four directions of stimuli used corresponded to those used in the clinical studies; a total of 24 trials were given to each hand.

As shown in Table 1, tactile perception of direction was significantly more accurate for the left hand as compared to

TABLE 1. TACTILE PERCEPTION OF DIRECTION IN 24

NORMAL SUBJECTS	
Number of Correct Choices (24 trials with each hand)	
Right Hand	18.96 (SD = 3.7)
Left Hand	21.00 (SD = 2.8)
Difference	2.04 (t=3.5; p < .002)
Within-Subject Differences (1 or more points)*	
Superior Accuracy in Right Hand	5 Ss
Superior Accuracy in Left Hand	17 Ss
Equal Accuracy in the Two Hands	2 Ss
Within-Subject Differences (3 or more points)*	
Superior Accuracy in Right Hand	—
Superior Accuracy in Left Hand	10 Ss
Equal Accuracy in the Two Hands	14 Ss
* Wilcoxon Matched Pairs Signed-Ranks Test (T = 23.5; p < .01)	

the right. This finding obtained both for differences of 1 or more points and 3 or more points. The finding of a left hand superiority in tactile perception of direction in normal subjects supports the inference drawn from studies of patients with unilateral cerebral disease that the right hemisphere is crucially involved in spatial aspects of tactile perception.

Hemispheric dominance in performances emphasizing spatial aspects of somatosensory function has also been postulated to account for the results of recent clinical studies of proprioceptive feedback performance. The literature on tracking performance by intact subjects indicates that proprioceptive information is essential to the guidance of the limbs, a behavior which presumably has important spatial determinants (Gibbs, 1954). On this basis, Carmon (1970) predicted that patients with lesions of the right hemisphere would evidence impaired utilization of proprioceptive feedback. He compared left and right brain-damaged groups to control patients on a task which required the subject to approximate a push button within a specified distance to a probe. The proximity detector used to measure this performance was developed by Dr. Carmon. The intensity of the pulse it generates increases with increasing proximity of an approaching push button and activates a millimeter which provides a visual display to the subject. Markers on the face of the meter provide boundaries within which the subject is required to maintain the pointer by regulating the push button. A spring, which resists forward motion of the push button, provided the proprioceptive feedback. Amount of time during which the push button was out of range served as the performance measure. Testing patients with unilateral cerebral disease under a condition of minimal proprioceptive feedback disclosed ipsilateral impairment irrespective of the side of lesion. Patients with left hemisphere disease significantly improved their performance to within normal range as the intensity of proprioceptive feedback was increased. In contrast, increased proprioceptive feedback did not significantly enhance performance by patients with lesions of the right hemisphere.

A replication of Carmon's study in the laboratory essentially confirmed his proprioceptive findings (Levin, 1973). Figure 2 shows that presentation of minimal proprioceptive feedback produced an ipsilateral defect in both left and right brain-damaged groups, a finding which was confirmed by statistical analysis.

It will be seen that the 16 patients with left hemisphere lesions behave similarly to the 32 control patients in that their performance significantly improved as a function of feedback intensity. Consistent with Carmon's finding, the 16 patients with right hemisphere disease failed to significantly improve their scores as feedback intensity was increased. Pairwise statistical contrasts indicated that under the 300g feedback condition, patients with right hemisphere disease were inferior in performance to both control and left hemisphere damaged patients.

The results of these recent proprioceptive studies accord with those of the tactile perception of direction experiments in demonstrating defective somatosensory function on the side ipsilateral to the compromised cerebral hemisphere. Detailed analysis has shown that ipsilateral somatosensory defect is not merely another manifestation of general mental impairment associated with cerebral disease (Carmon & Benton, 1969; Corkin et al., 1964; Semmes et al., 1960). In summary, investigation of tactile perception of direction and proprioceptive feedback performance suggest a special role of the right hemisphere in processing somesthetic information which has major spatial determinants. This tentative conclusion, which accords with findings in other sensory modalities, has prompted the undertaking of investigations to determine (1) whether performances on proprioceptive feedback and visuo-constructive tasks are correlated in patients with unilateral cerebral disease—an intercorrelation would be predicted on the basis of an assumed spatial component in both behaviors; (2) the effect of intrahemispheric locus of lesion on utilization of proprioceptive feedback in patients with unilateral cerebral disease; (3) differences between the hands of normal left-handed subjects in tactile perception of direction. Presumably, nearly 40% of this population are right hemisphere dominant for language. This fact raises the question of whether sinistrals are left hemisphere dominant in processing spatial aspects of tactile perception. This study is currently in progress and it is too early to report definitive results.

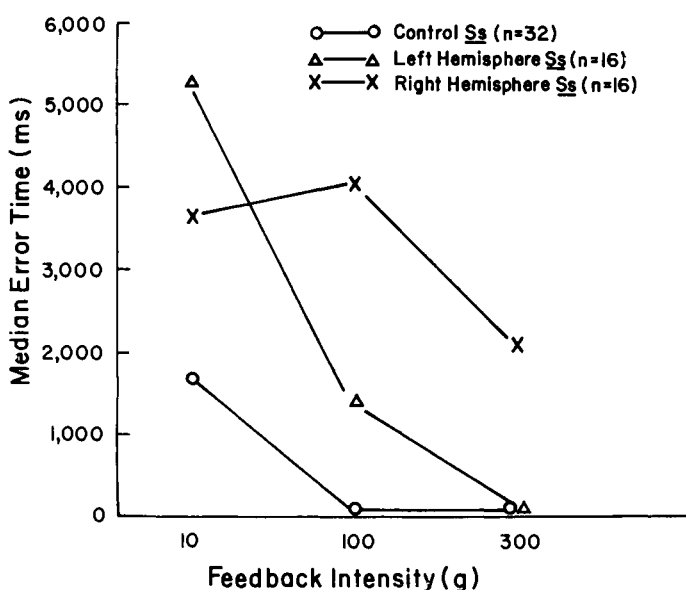


Figure 2. Median error time as a function of proprioceptive feedback intensity for brain-damaged and control patients.

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