HEMISPHERIC SPECIALIZATION FOR LINGUISTIC

AND NONLINGUISTIC TACTUAL PERCEPTION

IN A CONGENITALLY DEAF POPULATION

by

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List of Tables & Figures

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Abstract

Two groups of congenitally deaf and two groups of hearing right-handed subjects identified pairs of nonsense shapes and letters after simultaneous bilateral tactual exploration. In response to shapes, left and right hand pointing to multiple choice arrays were compared. Three response modes, writing and left and right hand fingerspelling, were compared for letters. A tendency for right tactual field superiority for shapes was observed in all groups. Groups initally exposed to letters showed significant right field superiority across response modes for shapes. No left-right asymmetries were observed for letters. Differences due to deafness were not observed. The results were discussed in terms of attentional asymmetries, verbal cues, order effects, and neural control of learned movements.

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Introduction

Present knowledge of functional specialization within the human brain indicates speech and language functions to be strongly lateralized to the left hemisphere whereas the evidence suggests a relative right hemispheric dominance for visuo- and tactuo- spatial perceptual functions. The results of several representative studies follow. For example, Hécaen (1962) in reviewing studies of patients with localized cerebral lesions, contrasted disturbances of verbal functions with impairment of personal and extrapersonal spatial abilities. He reported that disturbances of verbal functions were especially associated with lesions of the left hemisphere whereas altered personal and extrapersonal spatial abilities were most frequently observed after right hemispheric lesions. White (1972) examined 15 clinical experiments in which nonverbal visual stimuli were presented to patients with damage of either the right or left hemisphere. Of these experiments, 13 suggested that performance on nonverbal perceptual tasks was selectively impaired by right hemisphere damage. Studies of patients following commissurotomy have provided further evidence of lateral specialization of function. From their work with commissurotomized patients, Sperry and Gazzaniga and Bogen (1969) concluded that speech and writing are almost exclusively represented in the left hemisphere. On the other hand, Gazzaniga (1970) presented evidence indicating comprehension of some written and spoken language by the right hemisphere, though the efficiency of the right was below that of the left hemisphere. In contrast, Gazzaniga also reported right hemisphere superiority for visuo-constructive tasks such as copying block designs,

constructing complex puzzles and drawing figures which required representation of perspective. Milner and Taylor (1972) found commissurotomized patients to be vastly superior with left as opposed to right hand delayed matching-to-sample of tactile forms thus indicating specialization of the right hemisphere in perceiving spatial patterns.

Work with neurologically intact subjects also appears consistent with left hemisphere dominance for speech and language abilities. Kimura (1967) reported several studies with normal subjects using Broadbent's (1954) dichotic listening procedure. Generally, she found that children as young as five years of age manifest right ear (left hemisphere) superiority in reporting dichotically presented digits. Using simultaneous bilateral input, McKeever and Huling (1971) tachistoscopically presented words in the visual half-fields with a central digit for fixation control. With this approach subjects showed right visual half-field (VHF) superiority. Hines and Satz (1971) obtained similar results for recall of unilaterally presented sequences of digits in an experiment also requiring report of centrally presented digits for fixation control.

Results of experiments in which normals have been presented with nonverbal visual hemifield stimuli have been less consistent. For example, Kimura (1966) reported left half-field superiority for a dot enumeration task, and Schell and Satz (Note 1) found significantly better recognition for block designs in the left half-field. Recently, Klein, Moscovitch and Vigna (1976) found highly significant left VHF dominance for faces presented bilaterally to normal right-handers. In contrast, Hines (1975) reported right hemifield dominance for unfamiliar shapes resembling ink-blots but found no significant differences between the half-fields with a face recognition task. With tactile tasks requiring bilateral simultaneous exploration of letter pairs or pairs of nonsense shapes, Witelson (1974) found that right-handed boys recognized significantly more nonlinguistic stimuli with the left hand. The right hemisphere superiority suggested by this result was seen in boys as young as six years of age.

Present knowledge of cerebral localization of function in the congenitally deaf with profound hearing loss is limited. Only a few reports of congenitally deaf individuals who became aphasic are in the literature (Critchley, 1970). The scant evidence from these cases along with the difficulty of generalizing from brain injured patients, greatly limit conclusions regarding normal brain functioning. Thus far, little relevant work has been done with deaf but otherwise neurologically intact subjects.

The work of Kimura (1967) and more recently a study by Geffner and Hochberg (1971) suggest that environmental factors may influence cerebral lateralization of function. Both studies found that hearing children from lower socioeconomic groups manifested delayed development of left hemispheric superiority on a dichotic digits task. It seems possible that environmental influences may result in quite different dominance relationships in the deaf than are found in hearing individuals. The environment experienced by the congenitally deaf is one in which adaptive encounters depend heavily on accurate perception of spatial relationships. For example, the native language of the deaf, American Sign Language (ASL), a highly effective

communication system, is composed of visuo-spatial elements. Apparently, ASL is an independent linguistic system with elements that have concepts as referents rather than some other language. This independent status of ASL is supported by the work of Klima and Bellugi (Note 2) and of Stokoe (1972, 1973). Educationally, the deaf are exposed to other visuo-spatial stimuli invented specifically to represent single English letters or whole words. The manual alphabet is such a representational system for single English letters.

Considering the extensive dependence of the congenitally deaf on nonverbal learning functions and the visuo-spatial nature of their linguistic systems, representation of spatial analytic functions may be predominant in their cerebral organization.

Recently, Manning, Goble, Markman and LaBreche (Note 3) compared the response of congenitally deaf subjects to simultaneous bilateral tachistoscopic representation of ASL and English words. A slight, nonsignigicant tendency was observed for better left-half field recognition of bilateral signs whereas right half-field scores were superior, though again not significantly so, for words. In response to words, a hearing comparison group manifested the significantly greater right hemifield scores typically found with this procedure. In another visual half-field study by Manning, Goble, Markman and LaBreche (Note 4) congenitally deaf subjects responded to line drawings of manually represented English letters by writing the recognized letters on half the trials and by fingerspelling (forming the manual referents) on the remaining trials. When subjects responded with fingerspelling, superior left VHF recognition was found but no difference between half-fields was observed when letters were written.

The results of these studies suggest that at least among the congenitally deaf, the cerebral mechanisms involved in processing visuo-spatial linguistic stimuli may have bilateral representation.

The present study was concerned with cerebral representation of tactual perceptual mechanisms, both linguistic and nonlinguistic, in the deaf. The present study used a procedure similar to that described by Witelson (1974). However, in Witelson's study, assessment of the right hemisphere's ability to deal with tactually presented letters was confounded by the limited response mode of talking. Subjects responded only by saying the perceived letters, thereby involving the left hemisphere. To correct for this limitation, the present study used three potentially different modes of responding which are available to the deaf users of the manual alphabet; fingerspelling with the left and right hands, and writing. With the American version of the manual alphabet, all letters are formed with one hand, either the left or the right, and although individuals tend to fingerspell with their preferred hand, they typically are also capable of using the other nonpreferred hand. While the central control for fingerspelling is presently uncertain, the evidence pointing to strong bilateral representation of manual letter stimuli (Manning, et al., Note 4) further suggests that associations within the contralateral hemisphere may be sufficient to guide the responding hand. In addition to contrasting left with right hand fingerspelled responses, a third condition was employed in which subjects wrote the perceived letters.

Method

Subjects. Twenty-four congenitally deaf students from the Tennessee School for the Deaf served as subjects. All were profoundly deaf with a loss of at least 85 db in their better ear.

A comparison group was composed of twenty-four hearing student volunteers from a local public high school (Burke Co., N.C.). All comparison Ss had learned to fingerspell in a manual communications course offered in their school. Half of the Ss in each group (12) were exposed to two shape recognition tasks followed by three letter recognition tasks (shapes-letters Ss). The remaining Ss in each group (letters-shapes Ss) were exposed to these tasks in the reverse order; that is, the other half of the Ss in each group (12) were exposed to three letter recognition tasks followed by two shape recognition tasks (letters-shapes Ss).

An objective lateral dominance questionnaire by Reitan indicated all Ss to be right-handed. Mean age and IQ for the deaf and hearing subgroups are presented in Table 1. The mean Wechsler Performance IQ is reported for each deaf subgroups whereas the nonlanguage IQ from the California Test of Mental Maturity is reported for the hearing subgroups. Significant differences among the subgroups were present for age ($F = 14.66$; $df = 3/44$; $p < .001$) and for IQ ($F = 6.46$; $df = 3/44$; $p < .005$). Comparisons of the subgroup means with Duncan's Multiple Range Test (Duncan, 1955) indicated the deaf subgroups did not differ significantly from each other nor did the hearing subgroups differ significantly on either variable. However, for both age and IQ, each hearing subgroups differed significantly from each deaf subgroup.

Apparatus. Two types of stimuli were used, plexiglass nonsense shapes and plastic letters. Each of ten 1½ x 1½ x 3/16 inch nonsense shapes, identical to those employed by Witelson (1974), was mounted centrally using white double-faced tape on six inch squares of beaver board. Each shape had from four to eight sides. Five pairs of shapes

Table 1

Mean Age and IQ for the Deaf and Hearing Subgroups.

Group	Stimulus Order[a,b]	Age	IQ
Deaf	SL	15.5	90.3
	LS	15.1	95.6
Hearing	SL	17.0	110.5
	LS	17.3	107.8

[a] SL = Shapes-Letters; LS = Letters-Shapes

[b] n = 12 for each subgroup

were selected for presentation, so that members of a pair were similar with regard to number of angles and curved surfaces.

Each of twenty 1½ x 1 x 3/16 inch block type upper case letters (Fisher Price Toys) was mounted centrally on beaver board squares. The letters I, O, Z, M, T, and V were not used to permit a comparison with Witelson's (1974) study. Three different sets of 20 letter pairs were selected for presentation. The letter pairs within a set were all different.

All materials were presented using a wooden shield which was 20 x 8½ inches on the subject's side and tapered to a 20 x 15 inch opening in the examiner's side (See Figure 1). The subject's side was closed except for two, 3 inch radius semicircular holes which extended upward from the floor of the shield. A line was painted on the floor at the entrance of each hole. Four aluminium tracks into which the stimulus boards were inserted were mounted on the floor of the shield. These permitted parallel positioning of the stimulus pairs with 8¼ inches, center to center, between the stimuli. Linear markings etched on the tracks and an adjustable forward stop facilitated consistent placement of the stimulus boards.

Procedure. Under all conditions in the study, Ss were required to engage in bilateral simultaneous exploration of pairs of stimuli. Exploration was limited to use of the index and middle fingers so as to initially limit input from each hand to the contralateral hemisphere. Ss were fitted with wrist bands and instructed to place their hands under the shield so that the wrist bands rested on the painted lines at the entrance. They were further instructed to keep their wrists steady while exploring stimuli. With the S's hands in position, two sample stimulus boards were inserted to determine the forward stop

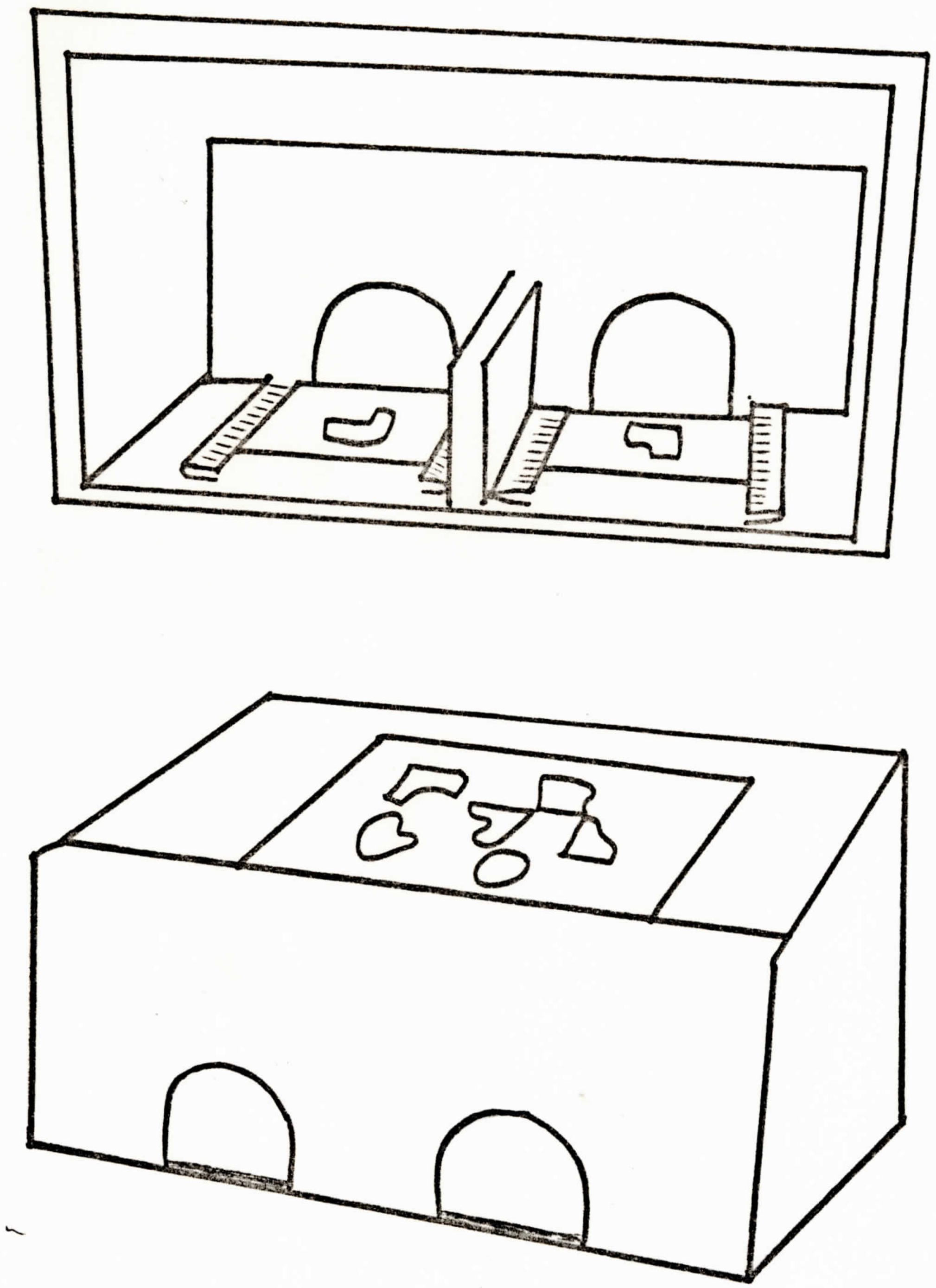

Figure 1. Test apparatus (Top) Examiner's side with shape stimuli in place. (Bottom) Ss side with a response board in place.

position which would place stimuli directly under the S's finger.

For the shapes conditions five pairs of nonsense shapes were used to generate two sets of ten test trials. Within a set, each pair appeared twice with left-right position counterbalanced so that each stimulus was presented once to each hand. An exploration time of 10 seconds was used for all shapes trials. Multiple choice response boards with four incorrect and the two correct choices were prepared for each trial. Ss responded to one set of trials by pointing to the perceived shapes with their left index finger. The right index finger was used for the other set of shapes trials. Response hand order was counterbalanced within each deaf and hearing subgroup (See Table 2). When Ss were in doubt, guessing was encouraged. No feedback was given.

For the letters conditions, each of the three sets of 20 letter pairs was presented once. Each letter within a set was presented once to the left and once to the right hand. All pairs were presented for two seconds. S's responded to one set of 20 trials by forming the manual referents of the perceived letters with their right hand. For a second set of trials manual referents were formed with the left hand. Ss wrote their responses to the third set of trials. Each S in the deaf group was randomly assigned to one of the six possible orders of response mode utilization (See Table 3). Hearing Ss were assigned to the same response orders chosen for the deaf Ss. When Ss were uncertain of the letters they had examined, guessing was encouraged. No feedback was given.

In order to assure competence with the procedure, a maximum of 24 training trials, with feedback immediately preceded both the shapes and the letters conditions. Four pairs of shapes and four

Table 2.

Order of Shape (S) and Letter (L) Presentation and Response Order for Deaf and Hearing Ss.

Group	Stimulus Order	Shapes Responses Order
Deaf	SL(N=12)	LHR-RHR[a]
		RHR-LHR
	LS(N=12)	LHR-RHR
		RHR-LHR
Hearing	SL(N=12)	LHR-RHR
		RHR-LHR
	LS(N=12)	LHR-RHR
		RHR-LHR

[a] N = 6 for each subgroup

LHR = Left Hand Response

RHR = Right Hand Response

Table 3.

Response Orders for Letters Condition.

1[a]	2[b]	3[c]
2	3	1
3	1	2
3	2	1
2	1	3
1	3	2

[a] 1 = Left Hand Signing

[b] 2 = Right Hand Signing

[c] 3 = Right Hand Writing

pairs of letters not presented on test trials were used for training. At the onset of each trial, the Ss hands were in position under the shield with fingers raised. Ss were signaled to begin exploration of the stimuli by a tap on the back of each hand. Exploration continued until a signal to stop was given. For the shapes condition, a multiple choice response board was immediately placed before the S. Ss responded by pointing with the right hand on half of the training trials and with the left hand on the remaining trials. For letters, left and right hand finger-spelling was given equal practice. The written response to letters was not practiced. To prevent extraction of kinesthetic patterns that might be used to guide the written response, exploration proceded from the top to the bottom of each letter with minimal lateral movement of either of the fingers used for exploration.

Results

Table 4. presents the mean shape and letter recognition scores for each tactual field for each group. Separate mixed analyses of variance with one between (order of stimulus presentation) and two within subjects variables (response hand and tactual field) were conducted for each group for shapes and letters. Analysis of the Deaf group's responses to shapes failed to reveal significant differences for order of presentaion ($F = .826$; $df = 1/22$; $p > .20$) or response hand ($F = 1.76$; $df = 1/22$; $p > .10$). Although scores for the right tactual field tended to be larger than those for the left, the overall difference between tactual fields also was not significant ($F = 3.376$; $df = 1/22$; $p > .08$). No interactions were significant. However, post hoc comparisons (Duncan Range) indicated, that across response modes, the right tactual field was significantly

Table 4.

Mean Recognition Scores For Each Tactual Field For All Conditions.

		Shapes				Letters					
		Response Hand				Fingerspelled				Written	
		Left		Right		Left		Right			
Group	Stimulus Order[a]	Left Field	Right Field	Left Field	Right Field	Left Field	Right Field	Left Field	Right Field	Left Field	Right Field
Deaf	SL	4.6	5.5	5.3	5.2	6.9	7.5	8.0	8.0	7.3	7.7
	LS	5.1	5.8	5.1	6.4	8.0	6.8	7.8	8.8	8.1	8.2
Hearing	SL	5.6	6.0	5.9	6.3	10.7	10.3	10.1	10.6	10.3	11.0
	LS	4.7	5.7	5.5	6.4	8.7	8.5	9.4	8.8	10.3	10.5

[a] n = 12 for each subgroup

superior ($p > .05$) to the left for the letters-shapes subgroup, the subjects initially exposed to the letters condition.

For the hearing comparison group, a significant difference favoring right over left hand responding was revealed ($F = 6.33$; $df = 1/22$; $p < .025$). Further, overall recognition of shapes presented to the right tactual field was superior ($F = 7.05$; $df = 1/22$; $p < .025$). F-ratios for order of presentation and for all interactions failed to reach significance. Again, however, post hoc comparisons revealed, that across response modes, the right tactual field mean was superior to the left ($p < .05$) for the letters-shapes subgroup.

Analysis of variance performed on the Deaf group's letters data failed to reveal significant differences for either the main effects of any interaction.

Similar analysis of the Hearing group's data yielded a significant F-ratio for response mode ($F = 3.49$; $df = 2/44$; $p < .05$). Pairwise comparisons of the differences between means indicated the mean for writing to be significantly greater than those for right and left hand fingerspelling ($p < .05$) but that the scores obtained with fingerspelling did not differ from one another. Comparisons of the subgroup means for the three response modes indicated that although the letters-shapes subgroup's means for left and right hand fingerspelling did not differ significantly, each was significantly lower than each of the other means ($p < .01$). No other differences between means were significant.

To provide some indication of the relative difficulty of the letters and shapes tasks, percent correct responding to each stimulus type was calculated. For each group, the response to shapes (Deaf,

53.6; Hearing, 57.6) was greater than to letters (Deaf, 38.7; Hearing, 49.6).

Among the factors used to explain lateral perceptual differences, Kinsbourne's (1970) attentional model suggests that in addition to hemispheric specialization, tasks that differentially involve the hemispheres result in an attentional set or bias favoring the sensory field opposite the more active hemisphere. To more closely assess the influence of potentially biasing variables such as the order in which linguistic and nonlinguistic materials were presented as well as to directly assess differences between the Deaf and Hearing groups, several multiple regression analyses were performed. Because of the significant differences between the Deaf and Hearing groups for IQ and age previously described, a regression model was used with which these variables were statistically controlled (Kelly, Beggs, McNeil, Eichelbeiger and Lyon, 1969). Five laterality coefficients (LC), one for each experimental condition, were computed for each S in the manner specified by Marshal, Caplan and Holmes (1975). These ranged from -1 to +1 with negative scores indicating left tactual field superiority and positive scores indicating right tactual field superiority. Regression analyses were completed for each condition with the LC's associated with a given condition as the criterion variable and the following variables serving as predictor variables: group (Deaf vs. Hearing), order of stimulus presentation (shapes first vs. letters first), shapes response hand, and letters response mode order.

The analyses showed that the variables separately and combined accounted for an insignificant portion of the variance under each condition. For example, the maximum R^2 associated with each of the main effects was .06 for group, .06 for order of stimulus presentation,

.08 for shapes response hand order and .02 for letters response mode. Thus, it would appear that neither group membership nor attentional factors resulting from order effects were significantly determinants of tactual asymmetries in so far as this was reflected by the laterality coefficients.

Discussion

The results of this study indicate that in the subgroups initially exposed to letters, overall right tactual field recogniion of nonlinguistic materials was significantly superior. The data further suggest a tendency with both left and right hand responding for better right field perception of nonsense shapes by hearing and deaf Ss. These findings are in contrast to Witelson's (1974) report of superior left tactual field recognition of shapes when a left hand response was used and when shapes were presented prior to a letters condition. The right field superiority found in the present study is also contrary to expectations based on the work of Semmes, Weinstein, Ghent and Teuber (1960) and of Ghent (1961) indicating the presence in right handers of differential sensitivity favoring the left hand.

Although all subgroups manifested a tendency for better right field recognition of shapes, differences between fields attained significance only for those Ss first exposed to linguistic materials. In the letters condition, Ss were presented with a total of sixty test trials in contrast to only twenty trials for shapes. Conceivably an attentional bias favoring the right tactual field may have been engendered as a result of activation of the left hemisphere by the linguistic tasks. However, the results of the regression analyses failed to support this possibility in that the order in which the

shapes and letters conditions were presented predicted an insignificant fraction of the variance associated with the laterality coefficients for shapes.

The use of verbal cues may account for the observed right field superiority. Shapes stimuli were chosen so as to limit the use of verbal cues, however, they did not totally preclude verbal mediation. Ss in the present study were older than those utilized by Witelson and possibly also better able to employ verbal cues.

No significant differences were observed between the tactual fields for letters with any response mode. The cerebral mechanisms accounting for these results remain obscure. It would appear that with fingerspelling the task was indeed linguistic in nature. For Ss to produce the correct manual referents, it would seem that the spatial information derived from tactual exploration had to evoke the English letter counterparts. Among the possible conditions of hemispheric specialization and interhemispheric relationship, one could assume that linguistic mediation between tactual spatial code and manual letter referent can take place solely within the hemisphere contralateral to the tactual field. In this case the recognition of stimuli within the tactual field corresponding to the response hand might be expected to be more efficient. An additional assumption underlying this line of reasoning is that the fine motor movements required of the response hand are controlled by the contralateral hemisphere. Recently in discussing the neural control of learned motor behaviors, Geschwind (1975) has suggested that the mechanisms for such control are subserved by one hemisphere, the left in dextrals, and that the hemisphere controlling motor skills need not be the same as the one controlling language. If the motor control programs for fingerspelling are in the left hemisphere, callosal transmission required for left hand responding may have diminished left tactual field efficiency. On the other hand, a greater right field advantage should have been realized with right hand fingerspelling. Another possibility is that involvement of the left hemisphere is required for linguistic analysis. In this case right field superiority should be obtained, particularly with right hand fingerspelling. With regard to the written response, the use of neurologically intact right handers suggested a priori that writing would require greater involvement of the left hemisphere and possibly result in a right tactual field advantage. The data fail to support any of these possibilities.

The failure to find differences between tactual fields for recognition of letters may simply indicate that for the intact brain, the task demands associated with each of the letters condition were not sufficiently complex to tax the spatial and linguistic resources of each hemisphere. Obviously, letters of the form used are highly familiar linguistic stimuli and at the same time are relatively simple spatial stimuli. However, examination of percent correct responding to shapes and to letters indicates that the deaf and hearing groups were both less accurate in response to letters than to shapes, yet lateral differences were observed with shapes.

The results revealed similar left versus right tactual field differences for deaf and hearing Ss. Under both of the shapes conditions and all letters conditions, group membership proved an insignificant factor affecting tactual field superiority. These results suggest that at least within the tactual modality the cerebral

organization of congenitally deaf and hearing individuals is not differentially influenced by environmental factors. On the other hand, evidence from visual half-field studies (Manning, et al., Note 4) suggests that in response to English words, congenitally deaf may be less strongly lateralized than hearing Ss. These studies further suggest nearly equivalent bilateral representation in the deaf of their visual-spatial linguistic system (ASL). Comparable data from hearing individuals, skilled with ASL, should help determine the influence of factors associated with deafness, per se, on ASL representation. Unfortunately, such data is currently not available.

Reference Notes

1. Schell, B., & Satz, P. "Nonverbal" visual-half-field perception and hemispheric asymmetry. Proceedings 78th Annual Convention, APA, 1970, 187-1-8.

2. Klima, E.S., & Bellugi, U. Perception and production in a visually based language. Conference on Developmental Psycholinguistic and Communication Disorders, January 24-25, 1975, New York Academy of Sciences, New York City.

3. Manning, A.A., Goble, W., Markman, R., & LaBreche, T.M. Lateral cerebral differences in the deaf in response to linguistic and nonlinguistic stimuli. Manuscript submitted for publication, 1976a.

4. Manning, A.A., Goble, W., Markman, R., & LaBreche, T.M. Cerebral lateralization of manual English letter referents with signed and written responses. Unpublished manuscript, 1976b.

References

Broadbent, D.E. The role of auditory localization in attention and memory span. Journal of Experimental Psychology, 1954, 47, 191-196.

Critchley, M. Aphasiology and other aspects of language. London: Edward Arnold Pub., LTD, 1970.

Duncan, D.B. Multiple range and multiple F tests. Biometrics, 1955, 11, 1-42.

Gazzaniga, M.S. The bisected brain. New York: Appleton-Century-Crofts, 1970.

Geffner, D.S., & Hochberg, I. Ear laterality performance of children from low and middle socioeconomic levels on a verbal dichotic listening task. Cortex, 1971, 7, 193-203.

Geschwind, N. The apraxias: Neural mechanisms of disorders of learned movements. American Scientist, 1975, 63, 188-195.

Ghent, L. Developmental changes in tactual thresholds on dominant and nondominant sides. Journal of Comparative & Physiological Psychology, 1961, 54, 670-673.

Hécaen, H. Clinical symptomatology in right and left hemispheric lesions. In V.B. Mountcastle (Ed.) Interhemispheric relations and cerebral dominance. Baltimore: John Hopkins Press, 1962.

Hines, D. Independent functioning of the two cerebral hemispheres for recognizing bilaterally presented tachistoscopic visual half-field stimuli. Cortex, 1975, 11, 132-143.

Hines, D., & Satz, P. Superiority of right visual half-fields in right-handers for recall of digits presented at varying rates. Neuropsychologia, 1971, 9, 21-26.

Kelly, F.J., Beggs, D.L., McNeil, K.A., Eichelberger, T., & Lyon, J. Research design in the behavioral sciences: Multiple regression approach. Carbondale, Southern Illinois University Press, 1969.

Kimura, D. Dual functional asymmetry of the brain in visual perception. Neuropsychologia, 1966, 4, 275-285.

Kimura, D. Functional asymmetry of the brain in dichotic listening. Cortex, 1967, 3, 163-178.

Kinsbourne, M. The cerebral basis of lateral asymmetries in attention. Acta Psychologica, 1970, 33, 193-201.

Klein, D., Moscovitch, M., & Vigna, C. Attentional mechanisms and perceptual asymmetries in tachistoscopic recognition of words and faces. Neuropsychologia, 1976, 14, 55-66.

Marshall, J.C., Caplan, D., & Holmes, J.M. The measures of laterality. Neuropsychologia, 1975, 13, 315-321.

McKeever, W.F., & Huling, M.D. Lateral dominance in tachistoscopic word recognition performances obtained with simultaneous bilateral input. Neuropsychologia, 1971, 9, 15-20.

Milner, B., & Taylor, L. Right-hemispheric superiority in tactile pattern-recognition after cerebral commissurotomy: Evidence for nonverbal memory. Neuropsychologia, 1972, 10, 1-15.

Semmes, J., Weinstein, S., Ghent., & Teuber, H.L. Somatosensory changes after penetrating brain wounds in man. Cambridge: Harvard University Press, 1960.

Sperry, R., Gazzaniga, M.S., & Bogen, J.E. Interhemispheric relationships: The neocortical commissures; Syndromes of hemisphere disconnection. In P.J. Vinken & G.W. Bruyn (Eds.) Handbook of Clinical Neurology. Amsterdam: North-Holland Publishing Co., 1969.

Stokoe, W.C., Jr. Semiotics and human sign languages. Hague, Mouton, 1972.

Stokoe, W.C., Jr. Sign syntax and human language capacity. The Florida FL Reporter, 1973, 11, 4-6 & 52-53.

White, M.J. Hemispheric asymmetries in tachistoscopic information-processing. British Journal of Psychology, 1972, 63, 497-508.

Witelson, S.F. Hemispheric specialization for linguistic and nonlinguistic tactual perception using a dichotomous stimulation technique. Cortex, 1974, 10, 1-17.