Lateralization of Word Discrimination Following Left or Right Stroke

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Processing of letters, words, and common objects is considered to be lateralized to the left cerebral hemisphere (LH) (Beaumont, 1982). In contrast, basic nonlinguistic functions, such as depth, colour, or shape discrimination, are reported to be initially processed by the right hemisphere (RH) (Davidoff, 1982). These conclusions have been based on several research techniques, including dichotic listening and tachistoscopic hemifield presentation, which assume that in the normal right-handed adult, information is processed initially by the hemisphere contralateral to the side of perceptual space (visual field, ear, hand).

Recent divided visual field studies have produced results conflicting with the left-linguistic, right-nonlinguistic dichotomy. Some persons showed a left visual field advantage on a test of semantic discrimination of words matched with pictures, whereas patients with unilateral RH lesions scored significantly worse than controls on this task (Gainotti, Caltagironi, and Miceli, 1984), although they obtained normal scores on phonemic and syntactic tests. Right-hemisphere-damaged patients also had difficulty in constructing sentences from word parts (Cavalli, DeRenzi, Faglioni, and Vitali, 1981), so that the RH seemed implicated in processing of meaning.

Some researchers have suggested that patients with unilateral brain damage shift processing to the undamaged hemisphere. Left-brain-damaged patients, unlike controls, showed a significant left visual field preference (RH) in a bilateral word recognition task (Moore and Weidner, 1974), and patients with unilateral RH damage showed a right visual field advantage in recognizing abstract designs (Riege, Harker, Metter, and Hanson, 1982). Both LH and RH damaged patients, however, were less able than controls to recognize meaningless designs (Bisiach, Nichelli, and Sala, 1979), so that the undamaged hemisphere appears less efficient on this task.

There have been few reports comparing LH-damaged with RH-damaged patients on the same tasks. If the RH participates in the processing of word meaning or imaging, aphasic (LH damaged) patients should have little difficulty recognizing words in pictures when words are presented tachistoscopically to the left visual field, which project to the undamaged (right) hemisphere. They are expected to be impaired with right visual field presentation. Right stroke patients, on the other hand, may be deficient on this task because word-to-picture matching may require a RH contribution. Similarly, the discrimination of designs that defy verbal coding may require a LH contribution, so that aphasic patients may have difficulties in matching nonverbal designs via the right visual field.

In this study we sought to demonstrate a component in linguistic processing which is not impaired by aphasic stroke and which may assist in language recovery. We hypothesized that in aphasic patients the processing of imaging or meaning of words is served by the RH, as demonstrated by word-picture matching, but that the RH is not involved directly in word recognition from memory. This hypothesis would be supported by finding impairments in RH damaged patients in the word-to-picture matching task, yet no impairment where the RH is less competent, such as recognition of words from memory. In discrimination of nonverbal shapes the visual field projecting to the undamaged hemisphere should demonstrate normal performance even in right stroke, if the LH contributes to such processing.

METHOD

Subjects. We tested 15 right-handed stroke patients with right cerebrovascular accident (RCVA), 13 stroke patients with left cerebrovascular accident and aphasia (LCVA), and 15 normal volunteers. All had visual acuity corrected to 20/50 in each eye and no object agnosia, homonymous hemianopsia, or visual neglect. All had stablized deficits and scored at least at the 50th percentile on the Porch Index of Communicative Ability. Groups were comparable in age (mean 59.7 years) and in education level (mean 11.9 years), although the controls had (nonsignificantly) more years of schooling (mean 13.6 years).

Procedure. Each person was given a word-to-picture matching task and a shape discrimination task. In both, a series of 40 targets were presented tachistoscopically (120 msec) and randomly to the hemifield left or right of a central fixation digit. One sec later, each target had to be selected from a choice of four pictures (words) or shapes projected on the screen. Only correct responses with correct central digit were recorded. By requiring a word-to-picture match, the task asked for a response to the meaning of words, not just to their visuospatial arrangement of letters, thus requiring semantic decoding.

Percent correct scores were tabulated as the proportion of correctly matched words to pictures or shapes to shapes in each visual field within the total number of trials with correctly identified central fixation digit. These percent correct scores (see Table 1) were evaluated with analysis of variance with repeated measures to identify the hemispheric contribution to each task.

Table 1. Percent correct scores (+/- 1 standard deviation) on tachistoscopic word and shape discrimination tasks and discriminability scores in word recognition memory.

Group	N	Words Visual Field		Shapes Visual Field		Word Memory (d')
		Left	Right	Left	Right	
Left CVA	13	48.8	39.1*	79.1	66.1*	1.631*
S.D.		25.1	24.3	9.9	20.8	.563
Right CVA	15	41.6*	55.3	71.1*	82.6	2.219
S.D.		21.1	28.5	21.8	14.7	.781
Controls	15	59.5	74.3	87.3	84.7	2.721
S.D.		20.4	20.6	10.1	9.8	1.078

*Average score significantly different ($p < 0.01$) from the corresponding control score.

A separate word recognition memory test (Riege et al., 1982) was also given. In this test, 20 common nouns were to be recognized one minute after serial presentation on slides and intermingled randomly with 20 distractors. Measures adopted from signal detection theory were employed to separate memory accuracy (d') from decision bias.

RESULTS AND DISCUSSION

The interactions were the important results of the 3-factorial analyses of covariance (with education as the covariate) in which Groups was the between factor and Task and Visual Field were the repeated measures. A significant Visual Field x Group interaction ($F=6.98$; 1,40; $p< 0.002$) demonstrated that the Visual Field projecting to the damaged hemisphere produced scores lower than those of controls, whereas the scores from the Visual Field projecting to the undamaged hemisphere were only slightly lower. A most striking finding was normal left Visual Field word-to-picture matching by LCVA patients and normal right Visual Field scores on RCVA patients in shape discrimination; that is, in responses from the visual field normally not considered preferred for these tasks. Therefore, the undamaged hemisphere seemed to contribute significantly ($p = 0.02$-0.04) to the item discrimination required by the task.

Although the RCVA patients were deficient in word-to-picture matching in the left visual field, their recognition (d') of a list of nouns from memory was not impaired (Table 1). Even with right visual field presentation, their word-to-picture matching did not attain the level of controls, so that a RH contribution seems to be necessary for this task. However, they had scores equal to controls in right visual field discrimination of nonverbal shapes. This implies unimpaired LH processing. In comparison, LCVA patients had significantly reduced scores in right visual field discrimination of both words and shapes ($p< 0.001$), as well as in recognition memory for words ($p< 0.002$). This seemed to reflect severe LH processing difficulties, consistent with the side of their lesion. Their left visual field scores (RH) in both tasks were essentially normal; therefore, their right (undamaged) hemisphere must have contributed to the discrimination of words in pictures.

Transformation of the percent correct scores into laterality 'f' scores revealed the same significant group differences ($F=8.25$, 2,39; $p< 0.001$). These 'f' scores were obtained by dividing a left/right difference score by the sum of the errors in the two visual fields. They describe the preference for one visual field over the other in a given task and are independent from overall level of performance. For these scores, a positive score means left, and a negative score means right hemisphere processing. When the range of 'f' scores was compared for each group and task, both stroke groups demonstrated a considerable change in preferred visual field on the task usually performed by their damaged hemisphere. A greater number of LCVA patients showed right laterality in word-to-picture matching, as hypothesized. Their average 'f' score reflected the RH processing of this verbal task. In discrimination of shapes, the LCVA patients were comparable to controls. In contrast, there were a number of RCVA patients who also showed right laterality in word-to-picture matching, although they had suffered unilateral damage to the RH. Their memory for imageable words was not markedly impaired; however, in shape discrimination they demonstrated a marked shift to left laterality. Thus, the LH maintains its ability to process shapes and words, if needed, relatively separately from the function of the RH.

These results indicate that after unilateral stroke the undamaged hemisphere contributes to the task usually processed by the contralateral hemisphere. The importance of this result is understood by realizing that aphasic LCVA patients had nearly normal scores in word-to-picture matching via the left visual field, although they were deficient in word recognition memory and on PICA speaking or writing tasks. Since word memory differed from word-to-picture matching mainly in the requirement to discriminate target words (or their arrangement of letters) from memory, with little need for their semantic encoding, it is likely that the right lateralization of LCVA patients (i.e., shift to left visual field advantage) in word-to-picture matching relied upon the processing of word meaning or imaging proposed for the RH. Their damaged LH was neither efficient in this task nor assisting in word recognition memory. In contrast, RCVA patients showed left lateralization for words and shapes, indicating an advantage of the right visual field and implicating preferred linguistic processing in their matching of both words with pictures and shapes with shapes. After left or right unilateral stroke processing relies upon the undamaged hemisphere even if it is not considered specialized for the task material. This seems to demonstrate that contralateral processing may assist in recovery after stroke.

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DISCUSSION

Q: Are you suggesting that the right visual field advantage for the left hemisphere damaged patients for word-to-picture matching is a shift of some sort or do you think that at the single word level the right hemisphere is competent at word-to-picture matching tasks but not necessarily beyond that?

A: It may not be beyond that. I don't believe that, based on the data presented, one can argue further than the arguments made. It may simply be that the right hemisphere is capable of matching. What is interesting here is when material is presented initially to the left hemisphere it doesn't seem to get to the right hemisphere to allow the right hemisphere to function.

Q: Using this technique?

A: Yes, with this technique.

Q: Why did you covary on education?
A: I don't know why I covaried on education.

Q: One possibility was with the left's to covary on severity of language impairment.
A: I think the reason Walter covaried on education was because there was a statistically significant difference between the left and right hemisphere damaged groups.

Q: Do you want to make too much out of the inability to perform on the memory task and the good performance on the tachistoscopic task when the two are really quite different?
A: No, I wouldn't want to make too much out of it. The only reason for focusing on it is that we had such a left-right field difference.

Q: But on the tachistoscopic task, if I remember correctly, they looked at the number in the middle and they had to say that number. That is an immediate recall task. If there is any interference at all it is in saying the number. On the memory task, there was an interference factor and it was not tachistoscopic.

A: We actually looked at the data without central fixation. Our initial design was to demand central fixation and so we carried our analysis through that way. When we examined the data retrospectively and examined all responses independent of central fixation, the data were basically the same. I agree with you, but the central fixation did not seem to change the laterality effect.

Q: Would you mind going back to your slide of the shapes? To me that is a spiral coil, a paper clip bent out of shape, a rope, another variation of a paper clip. We found that subjects could always find a name for the stimuli.
A: Well, it is always a problem to say something is nonverbal. The fact is that when given a number of relatively similar shapes made out of the same materials it will take a longer time to figure out how to verbalize those shapes than if I showed you a figure of a house or a boy. In 125 msec. it is not simple.

Q: Right hemisphere patients did equally well with words and shapes in the left hemisphere. That is the right visual field. It could be that if they were verbally mediating these, they would have done better with the left hemisphere (right visual field) versus with their right hemisphere where verbal mediation wasn't available. With the left CVAs, they did better in the right visual field and worse in the left. I am wondering if their aphasic attempts to verbally mediate these made their performance worse, because they didn't have enough language to use for mediation during the task.
A: I don't think we can totally argue that there is no verbal mediation for shapes. The big issue is how are the shapes processed and at what level of processing would such mediation enter. Asking the normal subjects whether they verbally mediated the task, most said no. I don't think that I can argue around it.