Effects of anomalous language representation on neuropsychological performance in temporal lobe epilepsy

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Article abstract—Objective: To examine the effects of anomalous language representation (i.e., mixed- and right-cerebral dominant) on neuropsychological performance. Background: Right cerebral language dominance resulting from early cerebral injury is associated with relatively preserved language function with decreased visuospatial ability. However, previous reports of this phenomenon have examined patients with relatively large cerebral injuries (e.g., infantile hemiplegia) or limited sample sizes. Methods: A total of 561 patients with complex partial seizures of left temporal lobe origin were studied. Patients were classified into left (n = 455), bilateral (n = 56), and right (n = 48) language dominant groups based on Wada testing. Results: Right language dominant patients performed more poorly on multiple tests of visuospatial function, including Performance IQ (PIQ), than did left language patients. No significant group differences were detected for measures of language or general verbal function. The effects of bilateral language on PIQ differed according to handedness. Lowered PIQ was present in the bilateral nondextral group but not for bilateral dextral patients, and this pattern was observed with other visuospatial measures. Conclusions: In patients with relatively small lesions restricted to the left mesial temporal lobe, a shift in language dominance to the right hemisphere is associated with decreased visuospatial functions but preserved verbal abilities. Nondextral patients with bilateral language representation also displayed decreased visuospatial performance, although dextral patients with bilateral language did not.

Cerebral lesions that occur during brain maturation alter subsequent neural development. In patients who sustain early left hemisphere injury, a shift of language function to the uninjured right hemisphere may occur. Broca1 discussed this phenomenon in 1865, describing a case with life-long seizures and congenital right-body hemiparesis without aphasia. Autopsy showed an absence of the third left frontal convolution, causing Broca to conclude, "the third right convolution had compensated for the absence of the left" (p. 1069). Although patients with right-body infantile hemiplegia may not necessarily have language developed to the same degree compared with patients without injury, they often display relatively normal language function despite the magnitude of left-hemisphere injury.2

The transfer of language dominance to the right hemisphere does not occur without an effect on normal right hemisphere functions; visuospatial skills are generally performed more poorly than verbal skills. Teuber4 described this phenomenon as "crowding," and occurs when "one hemisphere tries to do more than it had originally been meant to do." Although studies of patients with right-body infantile hemiplegia have documented language transfer to the right hemisphere, relatively poor performance on visuospatial tasks may simply reflect greater sensitivity of these measures to lesion effects. Neuropsychological tests that are sensitive to right hemisphere injury are also generally more sensitive to diffuse impairment than are language measures.5 Additionally, language skills are relatively preserved in these patients but not at normal levels. Thus, the effect on language may be related to the lesion size studied, may reflect mild but undetected impairment of the presumably intact right hemisphere, or result from the intrinsic inability of the right hemisphere to adequately mediate language function as well as the left hemisphere. Therefore, it cannot be determined whether poor performance is due to the lesion size, undetected right hemisphere impairment, or the intrinsic inability of the right hemisphere to adequately mediate language function. It cannot be determined whether poor performance is due to the lesion size, undetected right hemisphere impairment, or the intrinsic inability of the right hemisphere to adequately mediate language function.

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Specific group performances for all neuropsychological tests included may be accessed at http://www.neuro.mcg.edu/boze/NPCrowd.html

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The transfer of language dominance to the right hemisphere does not occur without an effect on normal right hemisphere functions; visuospatial skills are generally performed more poorly than verbal skills. Teuber described this phenomenon as "crowding," and occurs when "one hemisphere tries to do more than it had originally been meant to do." Although studies of patients with right-body infarction have documented hemispheric transfer to the right hemisphere, relatively poor performance on visuospatial tasks may simply reflect greater sensitivity of these measures to lesion effects. Neuropsychological tests that are sensitive to right hemisphere injury are also generally more sensitive to diffuse impairment than are language measures. Additionally, language skills are relatively preserved in these patients but are not at normal levels. Thus, the effect on language may be related to the lesion size studied, may reflect maladjustment or presumably intact right hemisphere, or result from the intrinsic inability of the right hemisphere to adequately mediate language function as well as the left hemisphere. Therefore, it cannot be determined whether poor visuospatial function is the result of language transfer to the right hemisphere, which "crowds out" normal right hemisphere function, or whether it reflects the effect of large cerebral lesions.

Prior studies examining crowding in patients without external cerebral lesions have been limited by small sample size so that right cerebral language representation occurs rarely. Because transfer of language function typically is associated with larger lesions extending outside of the temporal lobe, it has been difficult to obtain a homogeneous sample with Wada-confined damage.

We report the results from a multicenter collaborative study designed to investigate the relationship of language representation on neuropsychological function. We hypothesized that patients with right hemisphere language would perform significantly more poorly on neuropsychological measures of visuospatial function than patients with typical left cerebral language dominance, with no group differences on measures of language function. Patients with right (i.e., nonbilateral, unilateral) language representation were anticipated to perform in an intermediate position on visuospatial tasks between left and right language dominance groups. We also investigated the effect of handedness on this phenomenon as reflected by verbal and performance IQ measures.

**Methods.**

**Subjects.** The Bozeman Epilepsy Consortium retrospective neuropsychological database served as the data pool for the current project. The Bozeman Epilepsy Consortium is a multicenter collaborative research group consisting of neurosurgeons and epilepsy centers: Cleveland Clinic Foundation, Epilepsy Care, Long Island Jewish Hospital, Mayo Clinic, Medical College of Georgia, Mount Sinai School of Medicine, University of British Columbia and University of Victoria, and Yale University. The group is named after Bozeman, MT, which was the site of the original free epilepsy surgery. The database was searched for patients with complex partial seizures of left temporal lobe origin who underwent Wada testing as part of their preoperative evaluation for possible epilepsy surgery. We restricted our sample to patients with left temporal seizure onset to increase sample homogeneity because we were interested in the effect of language shift from the left to the right hemisphere. Patients with Wais-R Full-Scale IQs lower than 68 were excluded. A total of 561 patients were identified left hemisphere dominant = 455 (81%), right hemisphere dominant = 48 (9%), left cerebral language dominance, with no group differences on measures of language function. Patients with right (i.e., nonbilateral, unilateral) language representation were anticipated to perform in an intermediate position on visuospatial tasks between left and right language dominance groups. We also investigated the effect of handedness on this phenomenon as reflected by verbal and performance IQ measures.

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We analyzed age at seizure onset effects. We analyzed age at seizure onset (onset < 5 years; onset > 5 years) on VIQ and PIQ to determine whether the crowding pattern could be attributed to age of injury rather than to shift in language representation. The early onset patients (n = 191) had a mean VIQ of 86.2 (SD = 15.9), and the late onset patients (n = 311) had an average VIQ of 89.4 (SD = 13.4). Although patients with earlier onset seizures performed more poorly, no statistical interaction was present, indicating that the negative effects of earlier seizure onset were similar for both VIQ and PIQ.

**Discussion.** When the right hemisphere assumes primary responsibility for language function in the setting of early left cerebral injury, there is a constant decrease in visuospatial ability for which the right hemisphere is typically dominant. This occurs even when the early injury is relatively restricted to the mesial temporal and away from primary perisylvian language zones. The shift to right hemisphere language dominance is not associated with a decline in language skill. On measures of visual confrontation naming, verbal generative fluency, and general verbal cognitive skills as reflected by the VIQ, no significant difference was present in patients with right cerebral language dominance when compared with their left dominant counterparts. This suggests that decreased linguistic ability in previous reports may reflect, in part, magnitude of lesion effects.
Table 2 Neuropsychological test performance for IQ measures and neuroanatomical measures reaching statistical significance

<table>
<thead>
<tr>
<th>Variable</th>
<th>Left dominance</th>
<th>Bilateral</th>
<th>Right dominance</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal IQ</td>
<td>88.5 (12.3)</td>
<td>87.4 (10.4)</td>
<td>86.0 (10.9)</td>
<td>0.13</td>
</tr>
<tr>
<td>Performance IQ</td>
<td>90.9 (13.2)</td>
<td>56.4 (14.8)</td>
<td>82.2 (10.6)</td>
<td>&lt;0.0001*</td>
</tr>
<tr>
<td>Block Design</td>
<td>8.0 (0.5)</td>
<td>7.5 (0.6)</td>
<td>7.3 (0.6)</td>
<td>&lt;0.0001*</td>
</tr>
<tr>
<td>Digit Symbol</td>
<td>7.7 (0.5)</td>
<td>6.8 (0.6)</td>
<td>5.9 (1.4)</td>
<td>&lt;0.0001*</td>
</tr>
<tr>
<td>Line Orientation</td>
<td>22.7 (0.5)</td>
<td>22.1 (0.6)</td>
<td>20.1 (0.9)</td>
<td>&lt;0.0001*</td>
</tr>
<tr>
<td>Facial Recognition</td>
<td>44.7 (5.1)</td>
<td>42.9 (6.2)</td>
<td>42.5 (1.8)</td>
<td>&lt;0.0001*</td>
</tr>
<tr>
<td>Symmetry</td>
<td>53.7 (13.0)</td>
<td>20.1 (13.2)</td>
<td>16.3 (12.5)</td>
<td>&lt;0.0001*</td>
</tr>
</tbody>
</table>

Value means (SD). Statistical significance levels are derived from one-way/threeway analysis of variance. Pairwise comparisons are indicated in the table.

value = right < left = (p = 0.001) bilateral = right = (p < 0.001) bilateral vs right = (p = 0.001) left vs right = (p = 0.001) right = (p = 0.001) left vs bilateral = (p = 0.001)

Figure. Mean performance IQ (PIQ) results for dextral and non-dextral patients. A statistically significant PIQ difference is present as a function of handedness in the bilateral language group.

Discussion. When the right hemisphere assumes primary responsibility for language function in the setting of early left cerebral injury, there is a consistent decrease in visuospatial ability for which there is no other apparent association. This decrease may occur independently of cerebral hemisphere dominance, as evidenced by the fact that the right hemisphere language dominance is not associated with a decline in language skill. On measures of visual confrontation naming, verbal generative fluency, and general verbal cognitive skills as reflected by the VIQ, no significant difference was present in patients with right cerebral language dominance compared to patients with left cerebral language dominance.

We also examined handedness on the other measures which involve visuospatial skill in patients with left and right cerebral language dominance. We found no significant differences in the measures examined for patients with left or right cerebral language dominance.

Two types of bilateral language representation demonstrated by Wada testing have been described.2 One type, demonstrated if no language alteration following either the left or right hemispheric injection and is termed bilateral autonomous language representation, occurs in patients with only a single measure (Benton Facial Recognition). Decreased visuospatial performance in patients with bilateral language representation appears to be at least in part, related to handedness. Although there was no effect of handedness on VIQ in the three language dominant groups, PIQ was significantly lower for non-dextral patients as compared to right-hand patients compared with right-hand patients with bilateral language representation. As shown in the figure, this effect was significant for non-dextral patients and was even more pronounced in the right-hand group. When considered in relation to our findings, it would be expected that the dextral patients in our bilateral language group would be more likely to display the pattern of bilateral autonomous language representation, while patients without a left or right hemisphere injury and is associated with poorer visuospatial ability. In contrast, patients with right cerebral language dominance are likely to display a pattern of bilateral dependent language. Unfortunately, this information was not collected.

Owing to an incomplete data set, we were unable to use a multivariate approach to data analysis. Multiple univariate analyses increase the risk of Type I error in proportion to the number of analyses being conducted. To decrease the likelihood of capitalizing on chance findings, we established three primary variables before and these as our primary dependent measures (i.e., VIQ, PIQ, and Block Design). These measures were chosen for three reasons. First, the summary IQ measures were based on the assumption that there is no significant difference in the absence of any group difference on VIQ could not easily be attributed to sample size and statistical power considerations in the same way that it would be in the same sample as VIQ. Although we did not expect PIQ to be the best available measure to assess right hemisphere function, being based on the same sample as VIQ, we used this measure to reduce the subject/group bias in our results. Third, Block Design was selected because it was expected to be more sensitive to the visuospatial impairment. The consistency of results across multiple measures also argues against findings being solely attributable to chance. Of the six statistically significant findings, all were associated with decreased visuospatial function.

The effect of the presence of a structural lesion could not be properly investigated because of small sample size and because structural lesions were censored in the database only as being present or absent. We did perform an analysis using PIQ with both language representation and lesion presence/absence as grouping factors and found no statistical interaction. However, future studies will be needed to more precisely determine what effects, if any, the presence of a structural lesion exerts on cognitive performance with atypical cerebral language lateralization. Results of this study confirm the presence of the "crowding" phenomenon in patients with right hemisphere language ability with extended left hemi-
Clinical correlations of occipital epileptiform discharges in children

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Article abstract—Objectives: To determine the frequency of different causes of occipital epileptiform discharges (OEDs) in children and to analyze the EEG features that help predict epileptiform type and prognosis. Methods: We identified children with occipital discharges using an EEG database at our center; the presence of generalized with OEDs was the basis for the selection of each focal discharge (GSW) or slowing was an exclusion criterion. Diagnosis, neuropsychological status, seizure semiotics, spike-wave discharges, and histologic, genetic, and psychiatric abnormalities were evaluated. Results: Of 90 children with OEDs, 50 (56%) had symptomatic seizures (18 and seizure remission status were recorded. Results: Of 90 children with OEDs, 50 (56%) had symptomatic seizures (18 and seizure remission status were recorded. Results: Of 90 children with OEDS, 50 (56%) had symptomatic seizures (18 and seizure remission status were recorded. 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