REVERSED HEMISPHERIC ORGANIZATION IN A LEFT-HANDED

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Abstract—For left-handers, cognitive functions are organized in the brain similarly to right-handers or they are more diffusely represented. In this study, we report a left-handed patient with a focal right temporal-parietal lesion who evidenced a lasting Wernicke’s aphasia and visual–spatial functioning typical of a right-hander with left-hemisphere involvement. The patient’s performance on other tasks (e.g. praxis, singing) as well as observed behavioral changes also resembled those of a right-hander with left-hemisphere compromise. This case suggests that it is possible for cognitive functions to be inversely represented in the two hemispheres.

Although Broca [1] originally thought that the right hemisphere was dominant for language in left-handers, studies conducted during the last three decades have convincingly shown that these patients do not have an inverted representation of cognitive functions in the brain [2–4]. In fact, most of the published reports have found that only 15 to 30% of left-handed aphasics have unilateral right hemisphere-damage [3]. Further, the nature of the aphasias in these patients is mixed and atypical compared to the classical aphasic syndromes seen in right-handers with focal left-hemisphere damage. Most aphasias following right-hemisphere damage are nonfluent, and in those few cases in which the aphasic speech was fluent, verbal comprehension was relatively intact. Thus, to our knowledge, an initial and persistent Wernicke’s aphasia following a right-hemisphere lesion has never been reported. In addition, left-handed aphasics with right-hemisphere compromise usually evidence severe visual–spatial impairment analogous to right-handers with right-hemisphere damage. These findings have led HÉCAEN et al. [4] to conclude that, for left-handers, (1) language is represented either in the left hemisphere or bilaterally, especially when familial sinistrality is present; (2) visual–spatial functioning is represented primarily in the right hemisphere, as it is for right-handers; and (3) there is less intrahemispheric specialization of language (i.e. aphasias following anterior vs posterior right-hemisphere damage in left-handers are less distinct than aphasias following anterior vs posterior left-hemisphere damage in right-handers).

In this study, we report a left-handed patient with a focal right temporal–parietal lesion who developed a persistent Wernicke’s aphasia and visual–spatial functioning typical of a right-handed patient with left-hemisphere damage. These results suggest that it is possible for a left-hander to have an inverted cerebral organization compared to right-handers.
METHOD

Subject

The patient, F.D., a 67-yr-old, left-handed (but with no familial history of sinistrality), college-educated, white male, suffered a right-middle-cerebral artery CVA on 17 February 1981. Initial neurological examination revealed a left homonymous superior quadranopsia, mild left central facial and arm weakness, and a fluent aphasia. CT scans taken one-week and five-months post-onset both showed a low density area within the right temporal-parietal region (Gado et al. [5]; see Fig. 1). A low density area in this same area in the left hemisphere of right-handers has been reported to be the prototypical lesion site for a Wernicke's aphasia [6, 7]. Five-months post-onset, the patient's left-sided weakness had resolved, but his quadranopsia and fluent aphasia persisted. A general medical examination did not reveal any situs inversus. He is reported to have been the product of a normal pregnancy and delivery.

NEUROPSYCHOLOGICAL TEST RESULTS

Language

F.D. was administered the Boston Diagnostic Aphasia Examination (BDAE) and Token Test (TT) both two-weeks and five-months post-onset. His results on the BDAE at two-weeks post-onset mirrored the common profile of Wernicke's aphasia outlined by Goodglass and Kaplan [8] (see Figs 2 and 3). His speech was fluent but empty (e.g. “He is doing for his little self”). Frequent literal (e.g. “kencil” for “pencil”), verbal (e.g. “money” for “wallet”), and neologistic (e.g. “mayice thas alla”) paraphasias were observed. Paraphasic errors were so prevalent that he was unable to communicate any information successfully. Prosody, articulation, phrase length and grammatical form were, however, all within the normal range. A press of speech was frequently observed. Virtually all other language functions assessed by the BDAE—naming, repetition, automatized speech, comprehension, reading and writing—were severely impaired. Figure 4a shows a literal paragraphic error elicited when the patient was asked to write “book” but produced the response “kook”. On the TT, he achieved a score of 97/163, which falls in the 35th percentile rank for aphasic populations [9].

At five-months post-onset, the most notable feature of F.D.'s neuropsychological functioning was that his spontaneous speech again reflected a Wernicke's aphasia. His speech was fluent and empty, with frequent paraphasias. Although literal and verbal paraphasias were still frequent, there were few neologistic paraphasias. As a result, he was better able to communicate everyday information though the range of topics he could convey was still limited.

Verbal comprehension also improved, but was still impaired. On the BDAE, he was able to comprehend simple declarative requests (e.g. “Show me the comb”), but did poorly on more complex questions (e.g. “Is a hammer good for cutting wood?”). His TT score was higher (125/163) but still fell in the 50th percentile rank for aphasic populations.

Confrontation naming also showed improvement, but literal and verbal paraphasias were occasionally generated before he arrived at the target word. These speech errors also handicapped his performance on repetition and automatized speech tasks. Reading comprehension was better at five-months post-onset, even for complex material. He did better on reading comprehension than on auditory comprehension; however, he was allowed to study the written questions for several minutes before giving his answers. Although writing
FIG. 1. Sequential CT cuts five-months post-CVA. Note the low density lesion involving the right temporal lobe and temporal–parietal junction with extension into the parietal lobe. The pre-Rolandic region is spared.
FIG. 2. Results on the Boston Diagnostic Aphasia Examination which are prototypical of Wernicke's aphasia.

also showed considerable improvement five-months post-onset, it still contained para-
grammatical structure (see GOODGLASS and KAPLAN [5]) and literal paragraphic errors (e.g. he wrote “tishes” instead of “dishes”; see Fig. 4b), both of which are features of Wernicke's aphasia.

Praxis

Two weeks post-onset, ideomotor and ideational apraxia were observed. Buccofacial errors consisted of vocal substitutions for the requested act (e.g. he said “cough” while trying to cough). He was also unable to produce sequences of oral movements even to imitation (e.g. produce the sequence pucker lips, stick out tongue, open mouth), although single movements were performed correctly to imitation. On limb commands, he frequently made body-part-as-object errors and had difficulty on sequential motor tasks (e.g. the sequence flat, fist, edge of hand). Whole-body commands (e.g. “Stand up”) were performed correctly. This pattern of apractic deficits is frequently seen in right-handed aphasics with left-hemisphere damage [10–13]. Five-months post-onset, he was still impaired in producing sequential oral and appendicular movements. Limb commands elicited an occasional body-part-as-object response, and individual buccofacial commands were now carried out perfectly. A dressing apraxia was never observed.
### Z-score profile of aphasia subscores

<table>
<thead>
<tr>
<th>Name:</th>
<th>Date of exam:</th>
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<tbody>
<tr>
<td>Severity rating</td>
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<tr>
<td>Fluency</td>
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<td>Auditory compreh.</td>
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<td>Naming</td>
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<td>Oral reading</td>
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<td>Repetition</td>
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<td>Paraphasia</td>
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<td>Autom. speech</td>
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<tr>
<td>Reading compreh.</td>
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<td>Writing</td>
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<td>Music</td>
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<td>Parietal</td>
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### Subtests

#### Fluency
- Artic. rating
- Phase Length:
- Verbal agility

#### Auditory compreh.
- Word discrim.
- Body part ident.
- Commands
- Complex material

#### Naming
- Responsive naming
- Confront. naming
- Animal naming
- Body part naming

#### Oral reading
- Word reading
- Oral sentence

#### Repetition
- Repetition (wds.)
  - Hi prob.
  - Lo prob.

#### Paraphasia
- Neolog.
- Literal
- Verbal
- Extended

#### Autom. speech
- Autom. sequences
- Reciting

#### Reading compreh.
- Symbol discrim.
- Word recog.
- Compr. oral spell.
- Wd. picture match
- Read. sent. parag.

#### Writing
- Mechanics
- Serial writing
- Primer. dict.
- Wrt. confront. naming
- Spelling to dict.
- Sentences to dict.
- Narrative writ.

#### Music
- Singing
- Rhythm

#### Parietal
- Drawing to command
- Stick memory
- Total fingers
- Right-left
- Arithmetic
- Clock setting
- 5 dim. blocks

### Scores

- **-25**
- **-2**
- **-1**
- **0**
- **1**
- **2**
- **2.5**

### Figures
- **Δ Two – weeks postonset**
- **〇 Five – months postonset**

**FIG. 3.** Results on individual subtests of the Boston Diagnostic Aphasia Examination.
HEMISPHERIC ORGANIZATION

FIG. 4(a). Writing sample at two-weeks post-onset illustrating a literal paragraphic error when the patient was asked to write "book".
(b) Writing sample at five-months post-onset illustrating paragrammatical language and a literal paragraphic error ("dishes" was written as "tishes").

Calculations

Two weeks after the CVA, F.D. made many errors even in calculating two-digit addition and subtraction problems. On the Boston "Parietal Lobe" test [8], his score on the calculation subtest was 1/32. Knowledge of primary arithmetic facts was disturbed. He also made paranumeric errors (e.g., he said "7" as he wrote an "8"). These types of calculation deficits have been reported in right-handers with left-posterior lesions [14]. His performance improved after five months: His score on the Boston "Parietal Lobe" Test was 25/32. In solving these problems, he spatially aligned the columns of numbers correctly, but made errors by occasionally breaking set and performing the wrong operation (e.g. by adding when he should have multiplied).

Singing

Although he had much difficulty singing lyrics, F.D. was able to hum songs with full melodic range during both testing periods. Preserved singing ability has previously been reported in right-handed aphasics with left-hemisphere lesions [15, 16].

Recognition

Visual, color, and auditory agnosia, as well as prosopagnosia and anosognosia, were not observed.

Visual–spatial functioning

Figure 5 shows drawings done two-weeks and five-months post-onset (he drew with his nonpreferred right hand at two-weeks post-onset due to left-arm weakness, but was able to draw with his preferred left hand at five-months post-onset). As can be seen, the three-dimensional perspective is maintained in his drawings and left neglect is not evidenced. Patients with right-posterior lesions, even among left-handed populations, rarely show such intact visual–spatial functioning [4, 17]. Figure 6 shows his copy of the Rey-Osterrieth Complex Figure. The top drawing in the Figure shows the lines he drew first, and the bottom shows his final drawing. This figure reveals his configural strategy in constructing the design:
FIG. 5. Drawings to command (a) at two-weeks and (b) at five-months post-onset.

the outermost lines were drawn before the internal lines and details were constructed. KAPLAN [18] and KAPLAN et al. [19] have reported that this type of configural strategy is commonly found in right-handed patients with unilateral left-hemisphere compromise.

F.D. was also given other spatial tasks of the Boston “Parietal Lobe” Test five-months post-onset. His performance on clock setting and map orientation was intact. On the Block Design subtest of the Wechsler Adult Intelligence Scale, he successfully assembled all of the designs and achieved an above-average score (peer scaled score equals 11; population mean equals 10). In assembling the blocks, he never broke the two by two or three by three configuration. Rather, he tended to make single-block rotational errors en route to the correct solution. This type of block construction error is commonly seen in left-hemisphere-damaged right-handers [19, 20].

Behavior

As noted above, F.D. was not anosognostic. He showed concern about his language and motor problems by frequently asking, in paraphasic language, if they would improve. He did
show, however, a lack of awareness of his difficulty in communicating information to other people. He spoke in a press of speech and proceeded in conversation as if the listener understood his empty, paraphasic language. His behavior on the ward and at home was noted to fluctuate between jocularity and suspiciousness. These behavioral features—press of speech, euphoria and suspiciousness—have been reported in Wernicke's aphasics following left-temporal lesions in right-handers [21].

**Hemispheric size asymmetries**

Given that F.D. evidenced reversed hemispheric organization of cognitive functions, we also examined whether he had reversed hemispheric size asymmetries. The right occipital–parietal region was found to be considerably wider than the left occipital–parietal

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**Fig. 6.** Patient's copy of the Rey Osterrieth Complex Figure. Note the patient's strategy in copying the outermost lines of the figure first. (a) First lines drawn. (b) Completed drawing.
area (6.7% wider). This asymmetry is found in only 10% of right-handers and 19% of non-familial left-handers (LEMAY [22]; LEMAY and KIDO [23]). Thus, the occipital-parietal region did show reversed size asymmetries compared to most right-handers and nonfamilial left-handers.

**DISCUSSION**

Even though F.D. sustained a temporal-parietal lesion in the right hemisphere, his most prominent neuropsychological deficit was a lasting Wernicke's aphasia. Other deficits which were severe initially but resolved into mild impairments five-months post-onset were apraxia and difficulty in calculations. F.D. never showed left neglect, dressing apraxia, amusia, or constructional difficulty on blocks and simple drawings. For more complex drawings (e.g. the Rey-Osterrieth Figure), his configural strategy in constructing the design has previously been reported in right-handers with left-hemisphere compromise. In addition, his behavioral changes—press of speech, euphoria, and suspiciousness—have also been found in right-handed Wernicke's aphasics following left-temporal lesions.

In attempting to explain the cerebral specialization of right-handers, several researchers have concluded that the neural organization within the two hemispheres is qualitatively different. The right hemisphere is thought to have more diffuse representation of functions, whereas the left hemisphere is thought to have more focal representation [24, 25]. The results of F.D. indicate that his cerebral organization is reversed compared to that of right-handers, which is also a rare finding even for left-handers. Not only did language appear to be lateralized in the right hemisphere, but there also appeared to be the same type of intrahemispheric specialization within his right hemisphere that is typically found in the left hemisphere of right-handers (i.e. a right posterior lesion resulted in a distinct type of aphasia). F.D.'s lack of classic right-hemisphere deficits suggests that his left hemisphere subserves these functions. The finding that F.D.'s occipital-parietal region was wider on the right than on the left side is consonant with the notion of reversed cerebral organization.

The variability in cerebral organization of language functions in left-handed populations has been difficult to explain. One model proposes that language is either represented unilaterally in the left hemisphere, as it is for most right-handers, or it is represented more bilaterally, especially for left-handers with familial sinistrality [26]. A problem with this model is that it does not account for a rare case such as F.D.'s in which language appears unilaterally and focally represented in a reversed manner compared to most right-handers (i.e. in the right hemisphere). Another model proposed by SATZ [27] posits three different types of cerebral organization of language in left-handers: (a) a unilateral left-sided group (15%); (b) a unilateral right-sided group (15%); and (c) a bilateral group (70%). This model better accounts for F.D.'s results by predicting that language can be unilaterally represented in the right hemisphere.

It is difficult to explain why F.D. showed reversed hemispheric organization given that he has no familial history of sinistrality. Familial sinistrality, as well as left-handedness, are thought to correlate with an increase in representation of language in the right hemisphere [28]. In an extreme case such as F.D.'s in which language appears focally represented in the right hemisphere, one would predict that both factors would be present. Perhaps this rare finding of reversed hemispheric organization occurs only in nonfamilial left-handers such as F.D. If so, this would indicate that the factor familial sinistrality correlates only with bilaterality. It would also indicate that left-handedness correlates with either bilaterality or,
in rare cases, when familial sinistrality is absent, with reversed specialization. Of course, more case studies similar to F.D.'s are necessary to determine how left-handedness and familial sinistrality are related to an inverted representation of language.

Finally, evidence has been accumulating which suggests that inherent to the left hemisphere is a biological uniqueness for specialization of language functions [29]. Findings cited to support this notion are: (1) the planum temporale has been found to be larger and to have a different cytoarchitectonic structure in the left hemisphere than in the right [30]; the left occipital-parietal region is typically wider in CT scan studies [23]; children with left-sided damage later show significantly lower verbal aptitude than children with right-sided damage [31]; and, in the past, more pronounced intrahemispheric focalization of language abilities has been found in the left hemisphere than in the right [4]. Although the overall evidence still supports this notion, a theory of the special privilege of the left hemisphere for subserving language must be tempered by the present finding that it is possible for the right hemisphere to become as specialized for language as the left hemisphere.

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REFERENCES

**Résumé**

Chez les gauchers, l'organisation cérébrale des fonctions cognitives est semblable à celle des droitiers ou implique une plus large représentation. Dans ce travail, est rapporté le cas d'un malade gaucher avec une lésion focalisée temporo-pariétale droite : il présentait une aphasie de Wernicke persistante ainsi que des fonctions visuo-spatiales typiques d'un droitier porteur d'une atteinte de l'hémisphère gauche. Les performances du malade dans d'autres tâches (tâches praxiques, chant, etc...) ainsi que les modifications du comportement ressemblaient également à celles d'un droitier avec lésion gauche. Ce cas suggère donc la possibilité d'une représentation inversée des fonctions cognitives dans les deux hémisphères.

**Zusammenfassung**

Bei Linkshändern sind die kognitiven Funktionen im Gehirn ähnlich wie bei Rechtshändern organisiert oder aber sie sind mehr diffus repräsentiert.