

## Unexpected recovery of language function after massive left-hemisphere infarct: Coordinated psycholinguistic and neuroimaging studies

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This case study exploits recent advances in analysis of language disorder and neuroimaging technique to revisit issues of assessment, localization of function, plasticity, and recovery of function. We tested the limits of spared language capacities and investigated the neural basis of sparing in three cases of large left-hemisphere infarct resulting from stroke that had occurred more than 10 years earlier. Lesion analysis implicated Broca's and Wernicke's areas and other structures within the distribution of the middle cerebral artery. Each case shows significant recovery of function in the face of massive damage to the left hemisphere.

HW, age 65, is a high-school educated male. JN, age 80, and BN, age 62, are college-educated females. HW and JN were right handed prior to stroke; BN was ambidextrous. Each case presents a left-sided lesion implicating portions of inferior frontal, dorsolateral frontal, pre- and post-central region, insula, inferior parietal, superior temporal, as well as some subcortical structures; in one case (BN) a small area of subcortical infarction is also present in the right hemisphere.

### Method

Each individual received a standard test for assessment of aphasia and tests specially constructed for the purpose of assessing word retrieval and grammatical competence. The latter tests assessed competence by minimizing memory demands and providing strong contextual support, a strategy that has been successful in assessing children's grammatical knowledge during language acquisition (Crain & Thornton, 1998). The following tests were administered: comprehension of sentences containing relative clauses; elicited production of relative clauses and passives (Ni, Shankweiler, Harris, & Fulbright, 1997), elicited production of nouns, adjectives, verbs, and verb past tense forms (Ni, Shankweiler, Conway-Palumbo, Thornton, & Crain,

1998; Ni, Shankweiler, Conway-Palumbo, Fulbright, & Harris, 2001). fMRI mapping of language sites required subjects to respond to spoken sentences and pairs of tones and to retrieve words in response to pictures.

### Results

Despite the extent of left-hemisphere damage, no case presents with global aphasia or dementia, as evidenced by the results of clinical aphasia testing (BDAE mean percentile: BN 74; HW 73; JN 48) and by the findings of psycholinguistic studies. Each is agrammatic, speaking in fragmented phrases (maximum phrase length: BN 7 words; HW 5 words; JN 4 words), but with some sparing of syntactic function as revealed by elicited production and targeted comprehension tasks. All are impaired in supplying past tense verb inflections (JN failed completely). All retain varying degrees of word retrieval ability in context, including retrieval of verb stems. The most severely affected case, JN, has the largest lesion, more extensive than the others in anterior and middle portions of the superior temporal gyrus and in middle and inferior temporal gyri. JN's lesion also extends furthest frontally, implicating the lateral and posterior orbital gyrus. These temporal and frontal regions, which have been implicated in research on production and use of nouns and verbs, respectively (e.g., Tranel, Adolphs, Damasio, & Damasio, 2001), may be mediating BN's and HW's better performance in word retrieval. BN and HW, while closely matched in severity, differ in particulars. BN is the more fluent, arguably reflecting greater sparing of premotor areas. The unexpected degree of spared function in all three cases prompted us to ask whether surviving portions of the left hemisphere are still functional. fMRI mapping identified sites that responded selectively to language inputs in the left hemisphere at the margins of the lesion. As expected, right hemisphere activity was also observed. Fig. 1 shows activation for sentences minus tones for Case HW, axial slice transecting the inferior frontal gyrus and superior temporal gyrus.

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Fig. 1. Example axial slice for Case HW, showing sites that responded selectively to language input.

## Discussion

The findings address these questions:

- (1) How can we best assess sparing and loss of language capacities? Because setting appropriate goals for treatment depends on accurate diagnosis, we should assess language competence as well as performance. It matters whether an ability is lost or merely weakened. To assess competence we must support performance. The elicited production method tests the limits of language function under conditions that maximize the opportunity for a structure to occur in pragmatically meaningful contexts. All three individuals showed benefits from this support, producing structures that did not occur spontaneously.
- (2) What can we gain by coordinating behavioral-psycholinguistic study, lesion analysis, and functional imaging toward clarifying the big issues of localization, plasticity, and recovery of function?
  - (a) Psycholinguistic study revealed no language function lost in its entirety despite destruction of much of the left hemisphere.
  - (b) The observed recovery of function and patterns of sparing and loss in these cases suggest greater plasticity of the mature brain

than is often assumed, while also confirming that there are limits to plasticity (Rasmussen & Milner, 1977).

- (c) The evidence of continued use of the left-hemisphere in the face of massive damage to that hemisphere is strong support for left-hemisphere dominance.
- (d) Yet each individual showed some active sites in the right hemisphere, as are commonly observed in intact subjects. The role of the right hemisphere in mediation of residual language function remains unclear. It is noteworthy that the case with the strongest overall language function (BN) shows the least evidence of right hemisphere participation in language processing, despite a history of ambidexterity.

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