Chapter 4

Language across Left-lesioned Signers

The left cerebral hemisphere is closely connected with speech. In patients with split brains (that is, persons whose corpus callosum has been severed, with consequent elimination of neural transmission between the two hemispheres), the left hemisphere has total control over speech production and phonological processing (Sperry 1974; Zaidel 1977). The planum temporale, a portion of the auditory association cortex known to mediate language, is larger in the left hemisphere than in the right, even at birth (Geschwind and Levitsky 1968). Prelingual infants show left-hemisphere specialization for speech sounds (Entus 1977; Molfese, Freeman, and Palermo 1975). Thus the question arises of whether the specialization for language of the left hemisphere is unique for speech and sound: What is the effect of brain damage to the left hemisphere in persons whose primary language is in a different modality, a language not of the vocal tract and ears but of the hands and eyes?

To address this question, we first compare the language behavior of the three signers with left-hemisphere lesions in order to bring out the nature of the differences in their language impairments. We administered a wide array of tests (described in chapter 2), some of which were adapted from standard tests used with hearing brain-damaged patients and some that were specifically developed for use with deaf signing patients. The entire battery was administered to all six brain-damaged signers and to matched deaf controls. A native ASL signer administered all tests, with responses videotaped for later analysis. In addition to storytelling, picture description, and analysis of free conversation, the tests involved the following four areas:

1. The BDAE (Goodglass and Kaplan 1972). The BDAE provides a careful assessment of aphasia. The ASL version of the BDAE is not a direct translation but an adaptation we made for use with deaf signing patients.
2. Structural levels of ASL. We have developed a series of tests that assess the capacity to produce and comprehend indi-

vidual structural components of ASL. Specifically, we test for the capacity to process sublexical structure, grammatical morphology, and spatial syntactic structure.

3. Apraxia. We assessed capacities for both representational and nonrepresentational arm and hand movements in order to investigate the relationship between apraxia and aphasia for a gestural language. This will be further elaborated in chapter 6.

4. Nonlinguistic visuospatial processing. We selected an array of standard tests that assess capacity for visuospatial analysis. Hearing patients with right-hemisphere damage tend to be impaired on these tasks. This will be further elaborated in chapter 7.

4.1 Standardized Assessment of Aphasia: The Boston Diagnostic Aphasia Examination

4.1.1 Fluency, Comprehension, and Paraphasia

The BDAE provides a z-score profile for a variety of language subtests, standardized for a large group of hearing aphasics. Figure 4.1 presents profiles for our three deaf patients and three matched deaf control signers on three key BDAE subtests: fluency, comprehension, and paraphasia. This figure presents a general picture of the aspects of the patients' language behavior. The dashed line at $z = 0$ in the figure represents the mean score of hearing aphasics on each task (Goodglass and Kaplan 1972). Positive z-scores reflect performance that is a given number of standard deviations above the mean; negative scores indicate performance below the mean. Thus, except for paraphasias, the farther the score is to the left-hand side of the profile, the more impaired the performance. The opposite is true for paraphasias, because positive z-scores reflect an increased number of paraphasias and hence impaired performance.

As figure 4.1 indicates, the performance of elderly control signers is generally accurate. The three left-lesioned patients, however, show impaired sign performance. All three patients were tested well after their strokes, so the deficits we see are stable. The severity of the communicative impairment ranges from moderate to severe. Gail D. is the most severely impaired. Her fragmentary expression requires extensive inference, questioning, and guessing by the examiner (severity rating of less than 1). For Gail D. the range of information exchanged is severely limited and the listener carries the burden of communication. Paul D. received a severity rating of 3, indicating that he is able to discuss most everyday problems with little assistance. Even so, his impairment in production makes conversation difficult at

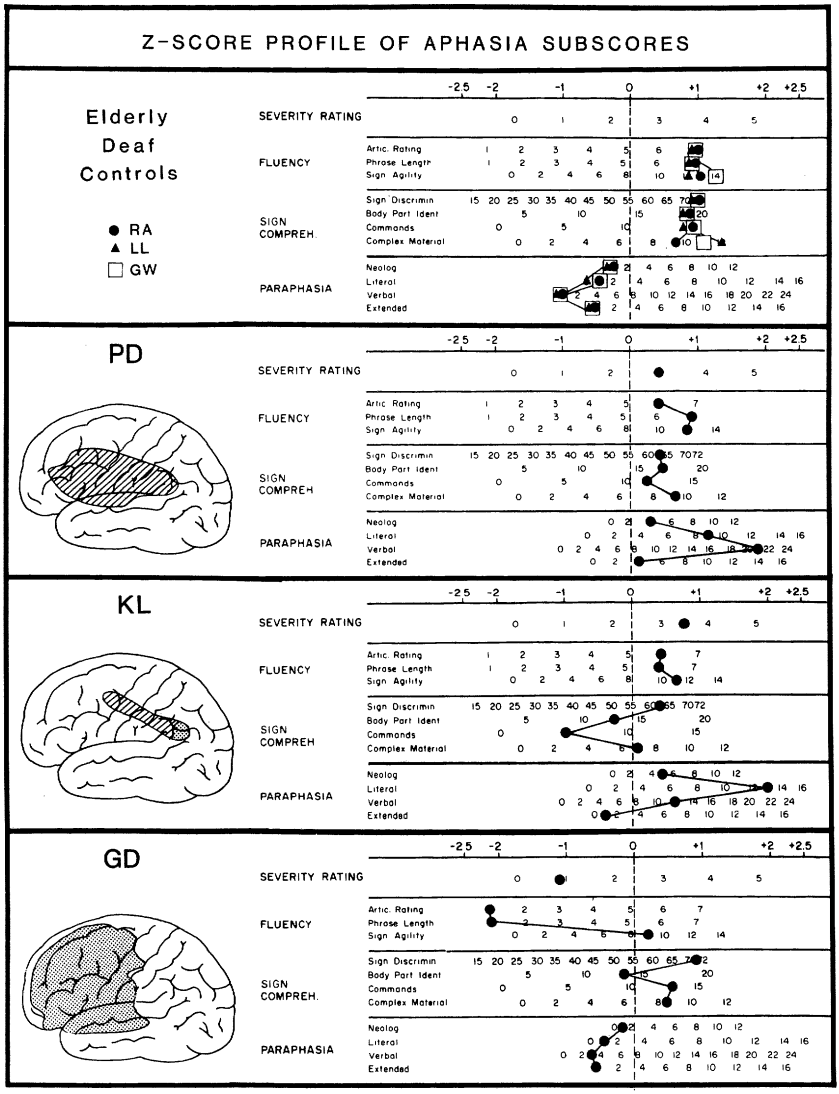


Figure 4.1
Standardized assessment of aphasia. *z*-score profiles of subscores from the BDAE for three deaf, left-lesioned signers and three deaf controls. PD stands for Paul D.; KL, Karen L.; and GD, Gail D.

times. Karen L. is slightly less impaired than Paul D., receiving a severity rating of 3.5, which indicates obvious losses in signing ability and, in particular, in sign comprehension.

The three brain-damaged signers have extremely different patterns of language breakdown. Paul D. and Karen L. have fluent sign output, whereas Gail D. is dysfluent. In contrast to her severe dysfluency in spontaneous signing, Gail D. showed only moderate impairment on a test of sign agility, which requires rapid serial repetitions of single signs varying in formational complexity. Gail D.'s relatively preserved ability to repeat signs rapidly and continuously indicates that her sign dysfluency cannot be accounted for by a peripheral motor dysarthria.

Tests of sign comprehension revealed a different pattern of breakdown. These subtests consist of a multiple-choice sign recognition test (sign discrimination), identification of body part names, the capacity to carry out sign commands varying from one to five significant informational units, and tests of complex ideational material, which require yes/no answers to simple factual material (such as "Will a cork sink in water?") and to brief questions testing comprehension of short signed stories. Paul D. and Gail D. showed only mild impairment in sign comprehension; Karen L.'s impairment was more marked, with a notable lack of comprehension of sign commands.

The patients' comprehension of printed English closely paralleled their comprehension of ASL. Paul D.'s mean z-scores for sign comprehension and reading comprehension were $+0.54$ and $+0.50$, respectively; Karen L.'s were -0.18 and -0.06, respectively; and those of Gail D. were $+0.47$ and $+0.38$, respectively.

The paraphasia scores show that Paul D. has a preponderance of semantic paraphasias, although he also produces some sublexical paraphasias (figure 4.1); Karen L., in contrast, produces almost exclusively sublexical paraphasias. Gail D. has few paraphasias of any kind.

In summary, Paul D. has fluent sign output with fairly well-preserved comprehension but with many semantic paraphasias. Karen L. also has fluent sign output, but her comprehension is impaired and she produces many sublexical paraphasias. Finally, Gail D.'s sign production is extremely dysfluent, with relatively well-preserved comprehension and few paraphasias. We argue that the language deficits of the three aphasic signers are, in general, related to impairment of specific linguistic components of ASL, rather than to an underlying motor disorder or to an underlying disorder in the capacity to express and comprehend symbols of any kind (this will be discussed further in chapter 6).

4.1.2 *Rating-scale Profiles*

The BDAE also provides rating scales for assessing a patient's spontaneous, natural signing in six aspects of sign production (melodic line, phrase length, articulatory agility, grammatical form, paraphasias in running sign, and sign finding) and in sign comprehension. Five of the six rating scales provide a 7-point scale in which 7 stands for normal and 1 for maximally abnormal language characteristics. Both extremes of the scale for sign-finding ability reflect deviant language production. Our ratings closely follow the principles specified for hearing patients, outlined in Goodglass and Kaplan (1972), but adjusted for characteristics of ASL. To obtain the ratings, we transcribed and tabulated characteristics of signing in 10-minute samples of each patient's conversation and expository signing. We measured phrase length, noted paraphasias, and classified and counted all grammatical and lexical morphemes. Figure 4.2 presents these rating-scale profiles for the brain-damaged signers and for the controls.

The profiles clearly show that the three left-lesioned patients have impaired sign language. (The elderly control subjects show normal sign characteristics, indicating that the impairment in the left-lesioned patients is not due to age.) The patterns of impairment of the three left-hemisphere-damaged patients are different. Karen L.'s phrasal grouping of signs (melodic line) is normal, Paul D.'s is near normal, but Gail D.'s is absent. This contrast between normal or near normal levels for Paul D. and Karen L. and extreme impairment for Gail D. is also characteristic of phrase length (six and seven occasional uninterrupted sign runs for Paul D. and Karen L., respectively, but utterances of only one sign for Gail D.). In articulatory agility Paul D. and Karen L. have fluent signing, whereas Gail D.'s signing is effortful and awkward. In a variety of grammatical forms Paul D. and Karen L. show a wide range of grammatical inflections and syntactic constructions (although not without error). Gail D., however, is decidedly agrammatic, producing only single sign utterances.

Both Paul D. and Karen L. have many paraphasia-type substitutions in running conversation. Gail D. was assigned a rating of 7 (no paraphasias), because she has no runs of fluent signing. Figure 4.2 shows that all three patients differ from one another in sign finding, the informational content of signs in relation to fluency. Paul D. has a rank of 4.5, reflecting his relatively high proportion of substantives to grammatical forms. Karen L., however, has a rank of 2.0, reflecting the absence of content signs in her otherwise grammatical signing; these missing signs make for vague communication. In contrast, Gail

RATING SCALE PROFILE OF SIGN CHARACTERISTICS

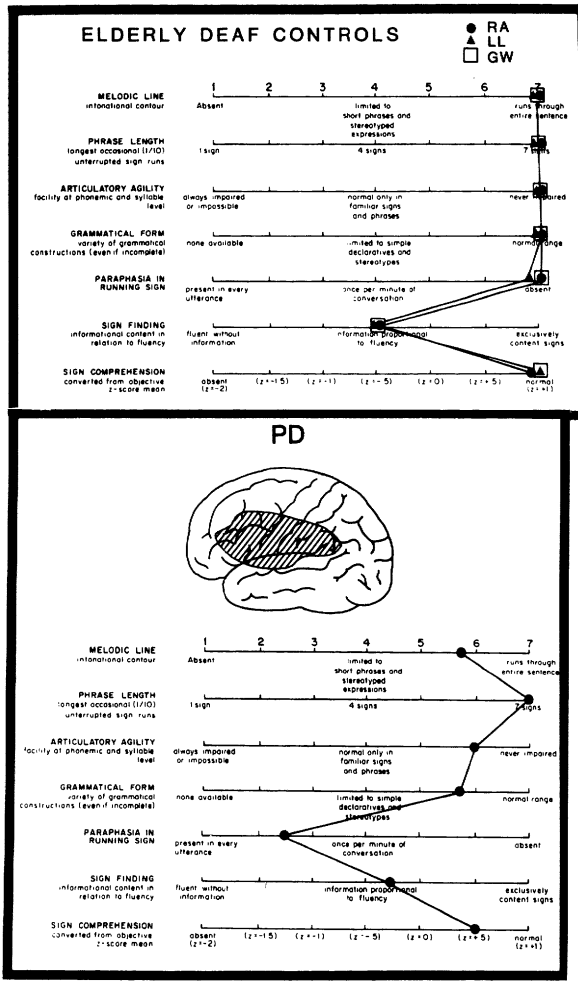
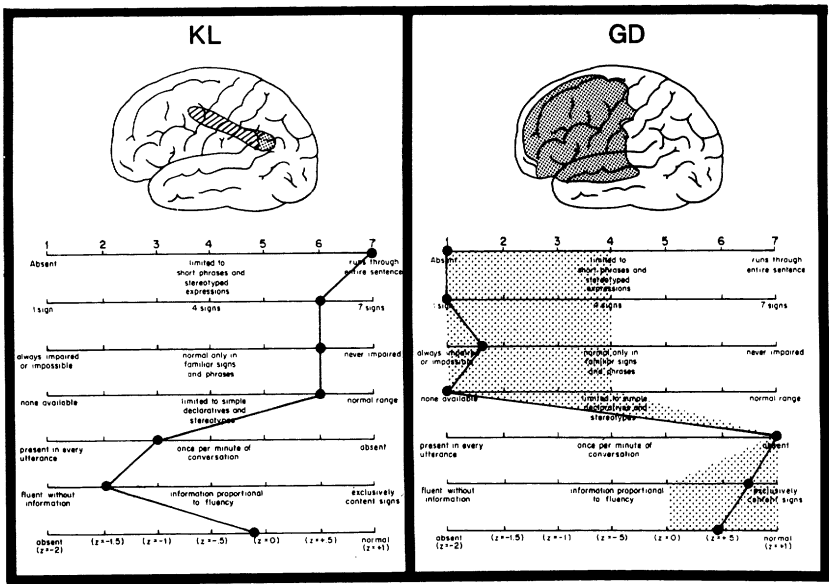


Figure 4.2
Rating-scale profiles of sign characteristics from Boston Diagnostic Aphasia Examination. Three deaf left-lesioned signers show marked sign impairment in comparison to deaf controls. PD stands for Paul D.; KL, Karen L.; and GD, Gail D.



D.'s rank of 6.5 reflects her almost exclusive use of substantives and action signs. Finally, the sign comprehension ranking is the mean z-score of the four comprehension subtests of the BDAE. Here, Gail D. is no longer differentiated from the other two patients. Her comprehension is quite good. Both Gail D. and Paul D. have sign comprehension scores that fall just below those of the control subjects. Karen L., in contrast, has a more marked sign comprehension loss, with a mean z-score of -0.18.

Clearly, all three left-lesioned patients have impaired signing relative to the elderly deaf control subjects, but what is significant for our studies is that their signing did not break down in a uniform manner. The shaded area shown on Gail D.'s profile in figure 4.2 reflects the range of profile ratings characteristic of hearing Broca's aphasics (Goodglass and Kaplan 1972). Gail D.'s pattern of sign impairments—severely dysfluent, agrammatic sign production with relatively preserved sign comprehension—makes her profile of sign impairment classically similar to those of hearing Broca's aphasics. Paul D. and Karen L. show patterns of sign impairment markedly different from that of Gail D. and also different from each other in specific areas. Both are motorically fluent with fairly good phrase length, melodic line, and variety of grammatical forms, but Karen L.'s sign comprehension is considerably worse than Paul D.'s; in fact, her mean z-score across the comprehension tests fell more than two-thirds of a

standard deviation below Paul D.'s. He makes a substantial number of semantic paraphasias, whereas Karen L. does not. Finally, Karen L. has less informational content relative to fluency than Paul D. These differences between the rating-scale profiles may not appear dramatic, but our linguistic analysis of these patients' signing, reported in what follows, reveals important differences in the layers of structure affected.

4.2 *Tests of American Sign Language Structure*

We tested patients across the range of structural levels of ASL. In general, consistent with their impaired performance on the BDAE, the patients with left-hemisphere damage showed breakdown on our tests assessing specific structural levels of ASL, with some individual sparing of capacities that we report here. We turn first to tests at the sublexical level, including a test in sign language that is analogous to rhyming in spoken language; next we look at tests of morphological distinction in ASL; and finally, we turn to tests of processing aspects of the spatial syntax.

4.2.1 *Sublexical Tests*

Two tests were designed to probe the subjects' abilities to decompose signs into parts: a Decomposition test and a test that taps the functional equivalent in ASL of rhyming. In the Decomposition test subjects are presented with a sign made by the experimenter and with four pictures of items. In the test for Decomposition of Handshape, for example, the subject is asked to choose the picture that represents a sign made with the same handshape as the presented sign. In the Rhyming test the subject is presented with four pictured items and is asked to select the two pictures representing signs that are similar in all but one parameter (Hand Configuration, Place of Articulation, or Movement). On the Decomposition test Gail D. scored 70.6 percent and Karen L., 57.1 percent; Paul D. did not take the test. On the Rhyming test Gail D. scored 47.8 percent; Karen L. did not take the test, and Paul D. obtained a very low score of 31.6 percent. In these sublexical tasks all three left-lesioned patients were impaired on one or the other test compared to normal signers and our control subjects.

4.2.2 *Morphological Distinction*

There is a productive morphological process in ASL by which noun-verb pairs are derivationally related; in these pairs (for example,

CHAIR and SIT, COMPARE and COMPARISON), the signs share the same handshape, place of articulation, and movement root; they differ from one another only in features of movement. In a test of elicitation of the formal distinction between nouns and verbs, the three left-hemisphere-lesioned patients performed quite poorly: Paul D. scored 61.1 percent; Karen L. scored 72.2 percent; and Gail D. had the low score of 40 percent. Two of the left-lesioned patients took the test of comprehension of the formal noun/verb distinction: Karen L. scored 70 percent and Gail D., 60 percent. Control subjects on both these tests performed well, none lower than 85 percent. Thus left-hemisphere damage appears to impair the capacity to comprehend and to produce this nonspatial derivational distinction.

4.2.3 *Processing Spatialized Syntax*

Sentence structure in ASL is specified in part by the way in which verbs, nominals, and pronominal indexes are related to one another in space; spatial contrasts play a central role in specifying grammatical relations. To evaluate comprehension of spatial syntax, we administered three tests: one test for Nominal Establishment and two tests for Verb Agreement.

The Nominal Establishment test evaluates perception and memory for the spatial loci associated with specific nominals in a horizontal plane of signing space, a part of the spatial referential framework of ASL. In this test the examiner establishes nouns at distinct spatial loci in signing space. The subject is then asked two kinds of question: (1) where a certain nominal has been established (which the subject answers by pointing to a specific locus), and (2) what nominal has been established at a certain locus (which the subject answers by signing the nominal). Paul D.'s performance on this test was extremely poor; he scored 40.9 percent correct overall. This level of performance is less than half that of the lowest scoring elderly deaf control signers who also took the test. Karen L. and Gail D. performed well (overall average of 84.1 percent and 81.1 percent correct, respectively). Thus Karen L. and Gail D. do not seem impaired in the primary ability to perceive and remember spatial loci and their referents. Paul D., however, is quite impaired, having poor immediate memory for locations and their associated nominals.

For the two tests of processing verb agreement, correct performance requires perception of spatial location, memory for spatial locations and for direction of movement of the verb between spatial endpoints, and appreciation of grammatical relations, such as subject and object of the verb signaled by spatial relations. In one test, Verb

Agreement with Fixed Framework, the experimenter signs a sentence describing an event with two participants, establishing locations for the two noun arguments and indicating grammatical relations through the direction of movement of the verb between the spatial endpoints. The subject's task is to answer by pointing to the picture described by the examiner's spatially organized sentence. The spatial arrangement of the items in the pictures need not match the spatial arrangement set up in the sentence. Similar items have been used in tests of the grammatical knowledge of hearing children to investigate the appreciation of grammatical relations signaled by word order (Brown, Fraser, and Bellugi 1962). The same pictures can serve to investigate preservation of grammatical relations signaled by spatial relations in ASL. On the test of Verb Agreement with Fixed Framework, two of the left-lesioned patients scored poorly and one scored well. Paul D. scored only 57.1 percent correct, and Karen L. scored only 55.3 percent; however, Gail D.'s score is surprisingly high—80 percent correct.

The second test, Verb Agreement with Shifting Reference, requires the additional ability to shift spatial framework in order to process correctly grammatical relations. In this test the experimenter signs a sentence involving nominals and their associated spatial loci and an action verb, whose spatial endpoints mark subject and object with respect to the spatial loci. The spatial relations indicated in the question involve a shift in spatial reference. On this test two left-lesioned patients were greatly impaired: Paul D.'s score was only 43.3 percent, and Karen L.'s was 42.8 percent. Gail D. performed extremely well on the test, obtaining a perfect score.

The results of these two tests are interesting in view of these patients' performances in other situations. Paul D. appears to have memory problems in general; thus it is not surprising that he performed so poorly on the Nominal Establishment Task. Paul D.'s low performance on the Verb Agreement tests converges with our linguistic analysis of his use of verb agreement in signing, discussed in the following section. As noted earlier, Karen L. has an ASL comprehension deficit. Her low scores on the Verb Agreement tests are consistent with her profile on the BDAE but show that at least part of that deficit lies in her comprehension of particular spatially realized grammatical relations in ASL. Karen L. makes spontaneous and widespread use of space for grammatical purposes, proliferating pronouns and indexed verbs. Her general visuospatial abilities are relatively intact (see chapter 7). In addition, she showed good performance on the Nominal Establishment Test, which taps the processing of spatial locations that can later be used linguistically. Thus her problem with

the Verb Agreement tests may well lie in extracting the syntactic relations. Gail D., in contrast, shows surprisingly intact comprehension on these tests in the face of flawed, agrammatic, and sparse production.

Thus, on the tests that we developed to isolate processing of specific structural layers of ASL, equivalent to phonology, morphology, and syntax in spoken language, signers with lesions to the left hemisphere generally perform poorly (with the exception of Gail D. on the verb agreement tests). The implications of these patterns for hemispheric specialization become much clearer after linguistic analysis of the subjects' spontaneous language.

4.3 *Linguistic Analysis of Aphasic Signing*

The formal language testing just reported yields standardized measures of language capacities, with profiles of language impairments. The results indicate frank sign language aphasia in each of the three left-lesioned signers. In the nature of their language impairments, they differ greatly. In order to contrast the grammatical deficits of the three patients with left-hemisphere damage, we turn to a linguistic analysis of their signing.

4.3.1 *Gail D.: Agrammatic Signing*

Gail D.'s description of the Cookie Theft picture (figure 2.1) is characteristic of her signing output and stands in marked contrast to the responses of the other two patients: Gail D.'s responses were starkly abbreviated, and continuous prompting by the examiner was required to obtain some small output. Her sparse description is not due to any reluctance to communicate on her part but to the extreme effort her signing seems to require; she is clearly frustrated in her attempts to communicate. She tries to produce not just signs but also gestures, mime, fingerspelling, and the mouthing of English words; however, she is no better at producing these other means of communication than she is at signing. Gail D. can at times make single signs fluently and with little hesitation, for example, as single sign responses to comprehension tests. In expository conversation, however, she experiences great difficulty in expression; her narratives are severely limited, effortfully produced, and without any of the grammatical apparatus of ASL.

The following is a sample of Gail D.'s attempt to convey an incident from her childhood:

EXAMINER: What else happened?
GAIL D.: CAR . . . DRIVE . . . BROTHER . . . DRIVE . . . I . . . S-T-A-D. [Attempts to gesture "stand up."]
EXAMINER: You stood up?
GAIL D.: YES . . . I . . . DRIVE . . . . [Attempts to gesture "wave goodbye."]
EXAMINER: Wave goodbye?
GAIL D.: YES . . . BROTHER . . . DRIVE . . . DUNNO . . . . [Attempts to gesture "wave goodbye."]
EXAMINER: Your brother was driving?
GAIL D.: YES . . . BACK . . . DRIVE . . . BROTHER . . . MAN . . . MAMA . . . STAY . . . BROTHER . . . DRIVE.
EXAMINER: Were you in the car?
GAIL D.: YES.
EXAMINER: Or outside?
GAIL D.: NO.
EXAMINER: In the car.
GAIL D.: YES.
EXAMINER: You were standing up with your mother?
GAIL D.: NO . . . BROTHER . . . DRIVE . . . . [Points in back.] . . . DEAF BROTHER . . . I . . . .
EXAMINER: Your brother didn't know you were in the car?
GAIL D.: YES.
EXAMINER: Your brother was driving and saw you in the back seat?
GAIL D.: YES, YES. [Laughs.]
EXAMINER: Oh, I see.

It is clear that communication with Gail D. proceeds largely by guesswork on the part of the addressee. Gail D. does not, however, have difficulty indicating whether the examiner's interpretations are correct or not.

The most salient characteristic of Gail D.'s signing is that it is agrammatic and effortful; it is composed of short utterances, largely single, open-class items. She omits all grammatical formatives, including most pronouns (with the exception of I), all inflectional and derivational processes, and all aspects of spatially organized syntax.

Toward a Model of Gail D.'s Sign Aphasia

In the spontaneous signing that we recorded of Gail D., most of the utterances consisted of only a single lexical item and there were no utterances with more than three lexical items. Many of the lexical items that occurred were fingerspelled English words. These fingerspelled items are particularly interesting because of the rela-

tively long, rich gestural sequences that they represent, for each fingerspelled letter is, in form, a separate signlike gesture. Thus the fingerspelled item G-A-V-E, which Gail D. used in describing the Cookie Theft picture, consists of a sequence of four separate handshapes; her somewhat scrambled T-E-O-W-L, meaning 'towel,' consists of a sequence of five handshapes. We must conclude, then, that an incapacity for linearly sequencing separate gestures is not at the heart of Gail D.'s language difficulty. This being the case, it is all the more striking that her multisign utterances give no indication of having an internal sentencelike structure; rather, they appear to be a simple concatenation of signs.

There are two explanations suggested by these observations. One is in terms of formal structure. The utterances that show any complexity in terms of the number of concatenated units are largely limited to those with the simplest type of internal structure: mere concatenation. What is largely absent is hierarchical structure. This is true of both fingerspelled words and utterances consisting of a sequence of lexical signs. There is little evidence of the sort of hierarchical structure characteristic of sentences.

The other explanation is semantic in nature (and may in fact be simply the semantic counterpart of the formal structural explanation). The individual gestures of the multigesture fingerspelled words are the mere concatenation of meaningless items. Within a given fingerspelled word, there is no combination of meanings into a meaning of the whole; the meaning of the fingerspelled word is not compositionally derived from any meaningful subparts. Similarly, few of Gail D.'s multisign utterances give any indication of having a sentence structure, whereby the meaning of the sentence as a whole is derived in a principled way from the meanings of the parts and their syntactic function in the sentence, for example, as subject, predicate, and direct object.

Either explanation provides a possible key to another irregular aspect of Gail D.'s sign production: the nearly complete absence of any of the inflectional morphology of the language, even though such inflectional morphology is not conveyed "horizontally" through a linear sequence of units but rather "vertically" through the layering of form components. Thus a unified account of major aspects of Gail D.'s impairment begins to emerge. Central to that account is her difficulty in combining separate meaningful components hierarchically. The basis for combination, whether it is linear, as in many spoken languages, or layered, as in ASL, does not seem to be a crucial factor.

4.3.2 *Karen L.: Grammatical Signing with Sublexical Impairment*

Karen L.'s signing output has always been rich and fluent, even after her stroke. She communicates well and freely, carrying on a conversation (indeed, a monologue) with normal rate, flow, and range of grammatical structure. Karen L. signs freely without prompting. What follows is a sample of her signing that relates some incident in her past.

> KAREN L.: *THERE$_a$ NOT-YET SEE. *THEY$_{b\text{-}c}$ SAY PRETTY *THERE$_a$. THIS$^{[+\text{to front}]}$ BETTER THAN *THAT$_d$. TROUBLE *THERE$_d$ THAN HERE. QUIET HERE, *THERE$_e$ TROUBLE. RIOTS$^{[\text{Allocative}]}$ DRINK$^{[\text{Habitual}]}$.

An English translation equivalent is:

> KAREN L.: I have not yet seen what's over there. They [unspecified] say it is pretty there [unspecified]. This is better than that [unspecified]. There was more trouble over there [unspecified] than here. It's quiet here. Over there [unspecified] was trouble—riots in different places and regular boozing.
> EXAMINER: Where was the trouble? [Examiner is lost in terms of the referents of the conversation.]

On viewing the videotapes of this exchange, the examiner, and other researchers as well, indicated that it was often impossible to tell what Karen L. was talking about because she used pronominal indexes so freely without specifying in any way their antecedents. Of the three left-lesioned patients, Karen L.'s signing appears to be the least impaired. Her signing is grammatical with appropriate morphological inflections, including those for indexing. We noted that she frequently uses pronouns and verb indexing. Yet her signing shows two specific deficits: paraphasias in ongoing signing involving substitutions within the parameters of signs and failure to specify the nominals associated with her indexes.

4.3.3 *Paul D.: Paragrammatic Signing*

We asked Paul D. to describe the Cookie Theft picture in ASL and in written English. His written description is:

> I see a kitchen where a girl washes *his dishes and a big cookie jar *jarring a boy in the kitchen and a young girl *outstretching her arms *at the cookie and *jar the cover and I notice the *award of the water washing toward the floor.

Paul D. was asked to describe the scene in ASL, and part of his response is:

> PAUL D.: GIRL SPILL (THERE) [points to woman in picture]. WATER OVERFLOW, WATER. (SHE) [points to woman] *CARELESS[Predispositional]. (HE) [points to boy] *FALL-LONG-DISTANCE-DOWN. (SHE) [points to woman] *GIGGLING. (SHE) [points to woman] WORK, THERE. (SHE) [points to woman] *SPILL-ALL-OVER-SELF.

Paragrammatisms in each passage are starred (*) and include a number of forms that are inappropriate or ungrammatical for the context. An English translation of Paul D.'s signing is:

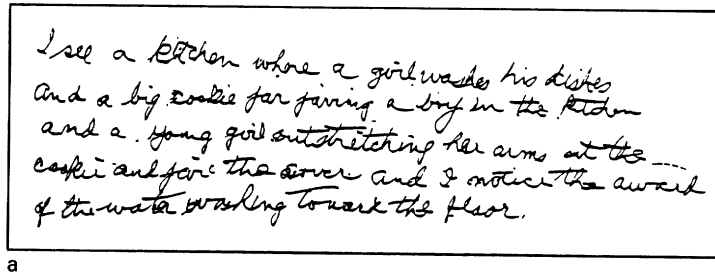
> The girl spilled there [pointing to the woman]. The water overflowed, the water. She is always careless by nature. He [referring to the boy] fell in a double somersault to the ground. She [referring to the woman] is giggling. She [referring to the woman] is working; she spilled water all over her dress.

Before his stroke Paul D. was articulate, even eloquent. After his stroke his output was still fluent but filled with inappropriate signs. Both his writing and his signing display errors of selection at the lexical and morphological levels. His written description contained inappropriate selections, such as "jar *jarring," "girl *outstretching her arms," "and *iar the cover," and "the *award of the water." Similarly, instead of a sign meaning 'starting to fall,' he used a form that means 'fall a long distance'; instead of a sign form meaning 'spill on the floor,' he signed a form that means 'spilled all over herself,' and so forth. Figure 4.3 shows Paul D.'s written version of the story and an error from his signed version. He used the morphologically complex form meaning 'characteristically careless,' when the sign form that would have been appropriate for the context is CARELESS (the uninflected form).

Paul D.'s aphasia is shown primarily in an abundance of lexical and morphological paraphasias. He often uses an appropriate root form but an inappropriate inflection or derivation. On occasion he substitutes one inflectional form for another and even produces nonsense inflections.

4.4 *Spatial Syntactic Breakdown in Signing*

In this section we focus specifically on the left-lesioned patients' capacities for spatialized syntax because it is in this domain that the three patients differ most dramatically.



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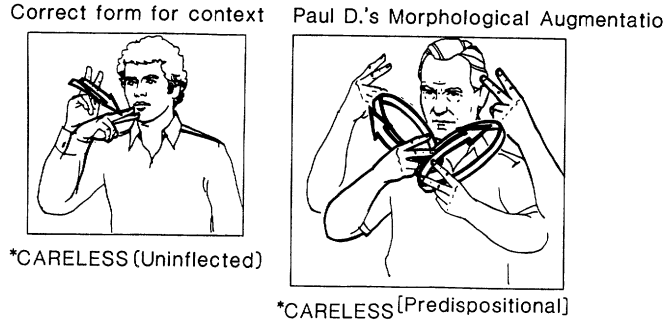

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Figure 4.3
(a) Paul D.'s written version of the Cookie Theft picture and (b) an error from his signed version. Note the morphological errors in both.

1. Gail D.'s signing is the most impaired, and indeed she is completely agrammatic. There are no spatially indexed pronouns in her signing, and the few verbs she produces never have any spatial marking; the verbs that occur are either fingerspelled or in uninflected form only. Given this extreme paucity of signing, there is no possibility of any form of verb agreement or any other aspect of spatially organized syntax.

2. Karen L. is at the other extreme from Gail D. She is garrulous and loquacious, converses freely, and uses the spatial organization underlying signing profusely and, so far as we can ascertain, correctly in terms of verb agreement markings.

3. Paul D.'s deficits are particularly telling in this domain. We therefore discuss his use of all aspects of syntax in ASL in some detail here, in order to bring into focus the nature of his deficits.

One way to characterize the differences among the patterns of impairment of language in the three left-hemisphere-damaged patients comes from their patterns of communication. The same deaf researcher performed all three examinations. After we analyzed the videotapes, we found that the examiner played a different role in

communicating with each of the three patients. With the agrammatic patient, Gail D., the interviewer had to guess, prod, probe, and finally supply much of the information at each point to understand what Gail D. wanted to impart. In contrast, with Karen L. and Paul D. the interviewer was able to maintain a flowing conversation, although she could not always follow the gist of their signing because of their linguistic impairments. With Karen L., whose signing is grammatical, the interviewer frequently asked, "Who are you talking about?" or "What is at that point?" because Karen L. often failed to specify the subjects of her many established pronouns. With Paul D., on the other hand, the interviewer sometimes had to ask, "How does this connect with what you said before?" This puzzlement on the examiner's part reflects the lack of explicit connections in Paul D.'s discourse, which we now discuss.

In order to understand the nature of Paul D.'s deficits in connected discourse, we first examine a domain in which he is not impaired, namely, the use of sign order to convey syntax. ASL allows a powerful test of brain mechanisms for syntax that may in part be modality bound. Within ASL syntactic relations can be conveyed in two different ways: by spatial organization, as we have discussed, and by the use of temporal sequence, or sign order. Thus, within one and the same language, we can contrast sentential relations conveyed by spatial relations (in which sign order is relatively free) with those conveyed by order of signs within the clause.

We looked at Paul D.'s syntax to uncover his use of sign order. Although it was sometimes difficult to follow the thread of his conversation because of his frequent paragrammatisms and lack of connections between topics, we found no instances of sentences that were ungrammatical because of an incorrect *sequence* of signs. His use of sign order to convey syntactic relations is well preserved. Where noun phrase arguments are specified, they are never in inappropriate order in his signing. Thus there is a similarity in his signing and his English writing in the preservation of syntax conveyed by order. We previously noted an equivalency between the kinds of paraphasia in his signing and in his English writing at the level of lexicon and morphology. Clearly, then, these language capacities and impairments are independent of particular transmission modalities.

Paul D.'s correct use of order to convey syntactic relations stands in marked contrast to his use of spatial relations to convey syntax and discourse functions. One important use of space is the placement of a nominal in a given locus in the signing plane, with subsequent references to that noun by referring back to that locus with, for instance, a pronoun sign. Paul D. showed an unusual pattern of use of nouns

and pronouns. For example, in one passage of signing Paul D. used 105 nouns and only 8 pronouns. He uses the same nouns repeatedly when use of a pronoun is called for. This high ratio of nouns to pronouns is characteristic of his conversational and narrative signing. The paucity of the pronouns in his signing led us to investigate his use of verb agreement, the verb movement between spatial loci that is integral to the spatialized grammatical relations in ASL. In several passages of signing, all verbs that could be indexed spatially were examined. In one passage Paul D. used seventy-four verbs that could be indexed, thirty-five of which were made in citation form. Of those thirty-five, thirteen should have been indexed; these were failures of omission, using a citation form where an indexed form was appropriate and required. Paul D. did index thirty-nine verbs, but ten of those were *incorrectly* indexed! Thus there were failures not only of omission but also of commission in Paul D.'s use of verb agreement for spatialized syntax.

Some examples of his failure to maintain spatial agreement are given in table 4.1 and in figure 4.4. In signing the ASL equivalent of "We arrived [in Jerusalem] and stayed there," he produced the signs ARRIVE, STAY, and THERE, indexed to three different spatial loci, when, of course, all three signs should have had the same locus. Figure 4.4 shows Paul D.'s signing of this sentence and the correct way of signing it.

4.4.1 *Different Breakdown in Sign and English Syntax: Order versus Space*

The fact that Paul D. suffered a breakdown in spatialized syntax but retained intact his use of sign order to convey syntactic relations implies that his syntactic difficulties in signing are not general but are intimately connected with the requirements of that aspect of syntax in ASL that is specifically spatialized. Paul D.'s preservation of sign order to convey grammar is in agreement with our findings about his written English. Although he makes many incorrect selections of lex-

Table 4.1
Paul D.'s Agreement Errors

Error	Correct form
*ARRIVE$_a$ STAY$_b$ (THERE)$_c$	ARRIVE$_a$ STAY$_a$ (THERE)$_a$
*$_a$PARK-OVER-THERE$_b$, WALK, $_c$GO-THERE$_b$	$_a$PARK-OVER-THERE$_b$, WALK, $_b$GO-ELSEWHERE$_c$
*GET-OUT-OF$_a$, $_b$PEOPLE-FILE-OVER-TO$_c$	GET-OUT-OF$_a$, $_a$PEOPLE-FILE-OVER-TO$_b$
*$_a$GO-HOME$_b$, $_c$DRIVE-AWAY$_d$	$_a$GO-HOME$_b$ $_b$DRIVE-AWAY$_c$
*RUN$_a$ $_b$THROW BASKETBALL	RUN$_a$ $_a$THROW BASKETBALL

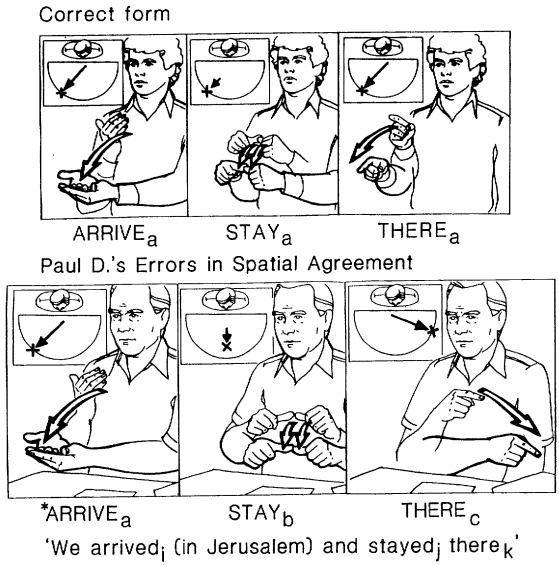

Figure 4.4
Paul D.'s failure to maintain spatial indexes in ASL.

ical items, the syntactic structures of English are generally well preserved in his writing and in his fingerspelling. In his written English, verbs are appropriately inflected for tense and number, and Paul D. makes few noticeable omissions.

The preservation of word order and of sign order in Paul D.'s spontaneous production shows that he is able to assign to a given nominal a position in the order of sentence constituents that is appropriate to its grammatical function as subject or object of the verb; that is, his stroke did not impair his conceptual system or framework at the level of abstraction of grammatical relations (grammatical subject and object). Also intact is that part of his *realization* system that involves among other things the relative order of constituents to express these grammatical relations. There is obviously a marked difference in Paul D.'s impairments across the differing possibilities offered by the language modalities: Where order information is required for syntactic purposes, whether in English or in ASL, his language is unimpaired; where spatial manipulation is the basis for syntactic organization (as in ASL, in certain contexts), Paul D. shows a marked deficit.

To understand Paul D.'s deficit, it is instructive to note that in conversation he rarely asks questions and does not seem to be exchanging information or really communicating with the addressee.

His conversation wanders, leaving gaps in information, even within sentences. It is as if he expresses one proposition at a time, with the next proposition somewhat related but not connected across a stretch of discourse. There is a clear parallel between this characteristic and his verb agreement errors: Even when he does establish the nominals associated with indexes, he is inconsistent in maintaining them. It is as if he cannot maintain referents during a discourse. As suggested in what follows, such problems may well be related to the organizational requirements of spatial planning and spatial memory involved in planning discourse.

In ASL the formal means for indicating pronominal reference is negotiated on-line and is spatialized. One aspect of this processing is that the signer has to negotiate the placement of points as he or she goes along, because there are no predefined points to choose from in sign. (In English and in most spoken languages there is a closed set of pronouns.) The abstract pronominal indexes in and of themselves are semantically empty; that is, they have no semantic content or value outside of the particular linguistic context. Thus for spatial indexes in ASL there is no related family of items in the internal lexicon that can be activated.

A second aspect of this processing requires that the signer plan ahead to establish abstract loci so that they are suitably placed for subsequent reference. And, of course, a signer must remember where each locus exists in the signing plane. Sign language interpreters (people performing on-line simultaneous translation from spoken language to signed language) often report that they have certain special problems in translating into ASL. A sign interpreter made the following comment to us:

> Very often when interpreting into ASL for deaf people, we don't know what the speaker has in mind or how he is going to present the information. So we sometimes find ourselves setting up a situation where the people or things involved are set up in the wrong locations, or we find that they introduce new information that should change the relationships among points in space. Then we need to reorganize, and must change the spatial locations. This mostly comes into play when we are using directional verbs, and we need to get from one locus to the other, and we would have done it differently if we had known how it was planned.

In recasting a system of fixed pronouns into a system of loci negotiated on-line, interpreters have difficulties because they do not know in advance how many distinct contrasting loci will be required and

what the relationships among them will be. Thus they frequently find themselves with inappropriate spatial reference; they find themselves locked in, lacking enough hands, signing in crowded spaces, and the like. In ASL each individual point is referentially distinct, so that there is no ambiguity of pronominal reference.

As we have seen, Paul D. has difficulty with the entire system of spatial indexes in ASL. He underuses the spatial indexes for purposes of pronominal reference and verb agreement, and he incorrectly indexes verbs. He also performed poorly on a test of the comprehension of nominals and their associated spatial loci and on a test of spatially organized syntax. Paul D.'s difficulties here may be due in part to the special requirements of spatially organized syntax in sign—spatial memory, spatial planning, and syntactic and discourse structure.

4.5 *Brain Mechanisms and Language Modality*

In summary, the three left-hemisphere-damaged patients are clearly aphasic for sign language. This is demonstrated by converging evidence from multiple sources: a standardized aphasia examination adapted for sign language, formal language testing of different structural layers of ASL, and linguistic analysis of subjects' spontaneous signing.

The impairments of these signers are not uniform. They show remarkably different patterns involving impairment at different structural layers of the language. One left-hemisphere-lesioned patient (Gail D.) is grossly impaired. She is the only signer whose output is nonfluent, in sharp contrast to her prestroke signing. Her signing is limited to single signs in an utterance. Her output is effortful, and she often gropes for the sign. Her difficulties are clearly not due to peripheral motor problems, because she produces the same signs normally in some contexts. There is not a trace of the grammatical apparatus of ASL in her signing; signs are made singly and in uninflected form, with selection almost exclusively from referential open-class signs. She produces primarily nouns and some verbs but with no grammatical inflection, no grammatical use of space, hardly any closed-class items, and none of the spatial apparatus that links signs in sentences. This language profile is identical with that of hearing Broca's aphasics.

The second left-hemisphere-lesioned patient (Karen L.) has fluent signing and communicates well and freely. She can carry on a conversation (indeed, a monologue) with normal rate and flow and can

exhibit a full range of grammatical structures. Her deficits in expression are confined primarily to impairment in the *sublexical* level (the equivalent of phonemic errors in spoken language). She shows no tendency to make semantic or grammatical errors in her ongoing conversation; indeed, she has relatively preserved grammar (but impaired comprehension). In many ways her signing appears to be the least impaired of the left-hemisphere-lesioned patients; however, she frequently fails to specify who or what is the subject of her freely and correctly used indexical pronouns and indexed verbs.

The third left-hemisphere-lesioned patient (Paul D.) also shows fluent, effortless signing after his stroke. He carries on conversations smoothly and with nearly normal rate and flow and does not appear frustrated, although he has occasional sign-finding difficulties. The content of the conversation, however, is revealing. His expressive language deficit is shown primarily in an abundance of paragrammaticisms, including semantically bizarre constructions and neologisms. Furthermore, he has a tendency to use morphologically complex forms where simple ones would be appropriate, for example, adding an inflection for the temporal aspect or using a derivationally complex form. And yet, at the same time, he fails to use the spatialized syntax of ASL (pronominal indexes and verb agreement markers). His signing is marked by an overabundance of nominals, a lack of pronominal indexes, and the failure to mark verb agreement correctly or at all. This appears to be an impairment of spatially organized syntax and discourse. Thus two left-hemisphere-lesioned patients have primary impairment at the *grammatical* level, the one agrammatic (Gail D.) and the other *paragrammatic* (Paul D.).

How are lesions of these signers related to their differing language breakdowns? Recall that Paul D. has a large subcortical lesion with a primary focus in the frontal lobe and extending to under the anterior portion of the parietal lobe. This lesion is not a commonly occurring one (or at least not a commonly reported one); it is entirely subcortical, and, in addition, no clearcut syndrome is classically associated with it. There is little basis for predicting the effects of such a lesion in a hearing person. We do note, however, that subcortical lesions can cause language impairment in hearing individuals (Damasio 1983b). Furthermore, the lesion involves portions of the left frontal lobe, an area that has been considered important for planning of activities (Damasio 1983a). This might be related to Paul D.'s difficulties in negotiating and planning discourse in signing, given the particular problems that ASL presents in negotiating the spatial underpinnings of syntax and discourse. In addition to Paul D.'s lesion, there is cortical atrophy, compatible with his age, which cannot be excluded as a

contributing factor to the total picture. The severity of Paul D.'s language impairment, however, is unlikely to be attributable to such age-related factors alone. His case is an important one, not so much because it illuminates particular brain-behavior relations with respect to sign language but because of the intriguing modality-specific grammatical deficits that he exhibits.

Gail D., however, has a massive lesion that in hearing persons is typically associated with a lasting agrammatic aphasia. Her lesion involves not only the traditional Broca's area but also much of the surrounding cortex of the frontal lobe. Gail D. has a severe agrammatic aphasia for sign language. Her case points to the fact that there is an anterior region of the left hemisphere that is important for sign language. Whether or not this will turn out to be the same as the anterior region for speech is not clear, because her lesion is so large that it includes not only Broca's area but also much of the surrounding cortex. Broca's area is adjacent to that part of the motor strip that controls movement of the vocal tract. An analogous area that controls movement of the hands is located just superior to Broca's area, and Gail D.'s broad lesion includes both of these areas. Whether or not the same sign symptomatology would appear if one or the other were spared cannot be answered from this case. Gail D.'s case is an important one, however, because a comparable lesion in hearing people is typically associated with agrammatic aphasia. Indeed, she has a clear-cut aphasia for sign language that is remarkably similar to that of hearing agrammatics. Furthermore, she was young at the time of testing (38 years), and thus her symptoms are not complicated by the possible effects of advancing age. In these respects Gail D.'s case is different from Paul D.'s.

The case of Karen L. points to a possible difference between those neural structures that may underlie spoken language and those for signed language. Her lesion is in the left parietal lobe (supramarginal and angular gyri) with a subcortical extension into the frontal lobe. Her lesion is well circumscribed and spares the traditional Broca's and Wernicke's areas. Although a hearing patient with this lesion might have some initial speech comprehension difficulties and might suffer from word-finding difficulties, we would not expect a lasting speech comprehension deficit. Karen L., however, has such pronounced and lasting deficit in the comprehension of sign language. It may well be that anatomical structures of the inferior parietal lobule of the left hemisphere play a greater role for sign language than for spoken language. These structures are intimately involved with higher-order spatial analysis as well as with gestural control and may have been recruited in the service of sign language, because in sign language

grammatical relations and spatial relations are so intertwined. Both Leischner (1943) and Chiarello, Knight, and Mandell (1982) have speculated on the special importance of anatomical structures in the left parietal lobe for sign language. If anatomical structures underlying languages in the two modalities do in fact differ, then it will be clear not only that structures within the left hemisphere are crucial for language in its various guises but also that the modality in which a language occurs may influence how the left hemisphere is organized for processing language.

Having examined these three left-hemisphere-damaged patients, we are warranted in coming to the following conclusion: Certain areas of the left hemisphere are crucial to language function in deaf signers whose primary language is a sign language. Without examining the effects of right-hemisphere damage, however, we cannot conclude that the left hemisphere is dominant for sign language, and we certainly cannot conclude that the left hemisphere is specialized specifically for sign language functioning. In fact, the brains of deaf signers might be bilaterally organized with lesions to the right hemisphere producing similar aphasias, or other aphasias, but aphasias nonetheless. We explore in the next chapter the different results produced by damage to the right hemisphere in deaf signers.