Chapter 5
Signers with Strokes: Right-hemisphere Lesions

As we have seen, the three signers with left-hemisphere lesions show marked sign language impairment, reflecting the essential role that the left cerebral hemisphere plays for sign language. What, however, is the consequence of right-hemisphere damage on language in the visual mode? Right-hemisphere lesions often produce pronounced visuospatial deficits. Do they also produce linguistic deficits for a language that makes such intricate use of spatial relations? Do clusters of language deficits appear, or does sign language break down by linguistic components in right-lesioned signers? Is sign language in fact bilaterally represented in the brains of deaf signers? Our studies of three signers with right-hemisphere lesions provide insights into these issues and are crucially important in helping us to understand the nature of language representation in the brain.

As with the left-lesioned signers, the three right-lesioned signers were right-handed before their strokes; they grew up signing, were intimately involved with the deaf community, and married deaf spouses. All use sign language as their primary mode of communication. They differ in occupational background. One was an artist before her stroke, another a key punch operator, and the third an airline mechanic.

5.1 *Sarah M.: The Artist*

Sarah M. is a delicate, gentle-looking woman, 71 years old at the time we saw her. Before her stroke she worked in ceramics and turned out skillful, spirited paintings. She also especially enjoyed the ancient art of egg decorating and produced over two hundred distinct and intricate designs; some samples appear in figure 5.1. Because her right-hemisphere damage produced a profound effect on her visuospatial capacities (to be discussed in chapter 7), she was not able to continue her artistic work after her stroke. Her drawings were simplified, reduced to a few unorganized lines, and she gave up her painting

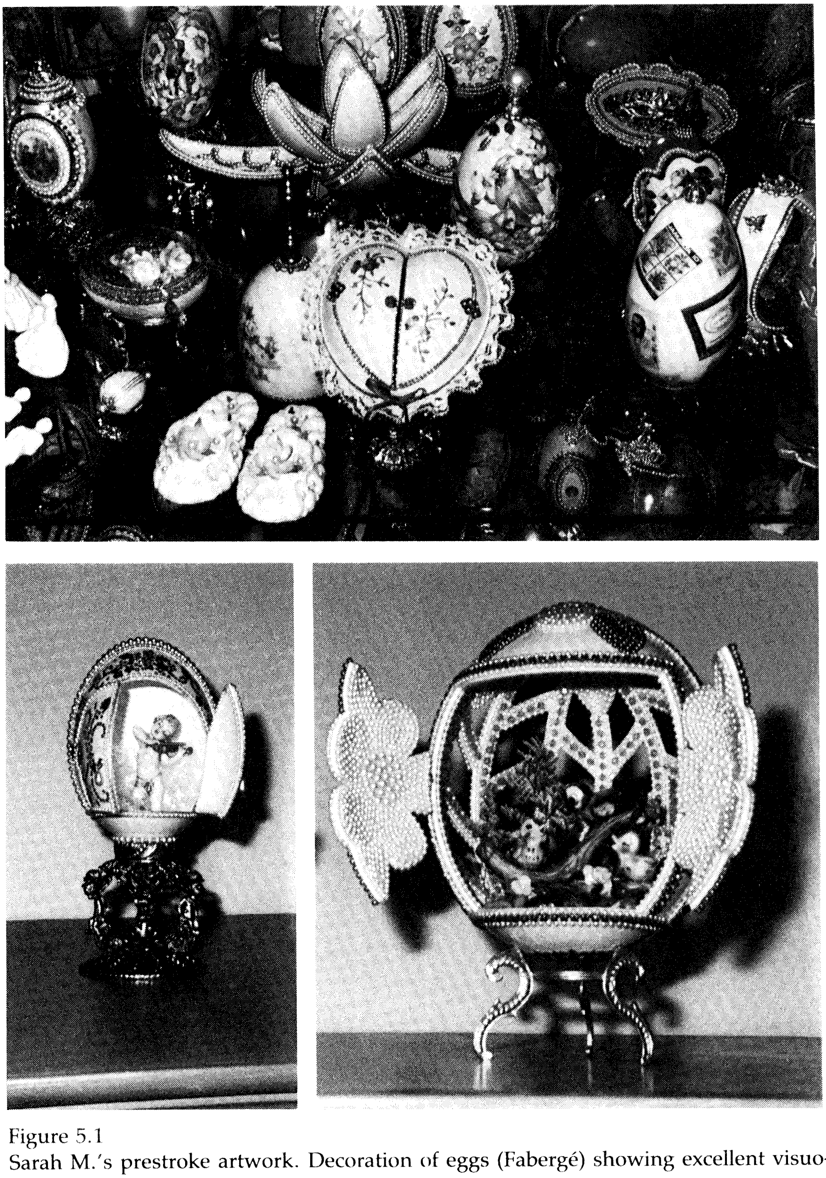


Figure 5.1
Sarah M.'s prestroke artwork. Decoration of eggs (Fabergé) showing excellent visuospatial capacities.

altogether. She did attempt ceramics, but soon gave up there as well; the relatively simple designs on the few items she started were distorted, with colors and patterns omitted, particularly on the left-hand side.

The stroke occurred a year before we saw her. Deaf from birth, Sarah M. entered a residential school for deaf children at age 11 and was graduated from high school with honors at age 21. Her husband is also deaf, and the two are members of the deaf community in a large city. They have two children, a son and daughter. The daughter works as an interpreter and counselor for deaf people and has been an interpreter for her parents since she was young.

At our first meeting Sarah M. was with her husband and daughter. The daughter was sitting on Sarah M.'s right, engaged in a signed conversation with her mother. But Sarah M. was not looking at her daughter, as the normal pattern of eye contact in signed conversation would dictate. Instead, her gaze drifted sideways and down to the floor.

In ASL conversation the person being addressed is expected to keep eye contact with the signer and to screen out visual distractions from outside the conversation. If the addressee is approached by someone announcing a phone call, for example, the addressee holds up his hand to prevent the interruption, never taking his eyes from the signer. In our own laboratory there are constant visual "noises" and distractions, people walking about, holding conversations, and the like. No matter, it is considered rude of an addressee to lose visual contact with the signer. For hearing people, looking in another direction while someone is talking is not a breach of etiquette, because receiving the linguistic information does not require that one look at the person speaking. In fact, prolonged and unrelieved eye contact between speaker and listener is unusual—reserved probably for special relations, such as two people in love—and is inappropriate for casual conversation. A short span of eye gaze is fine, but constant eye contact may make a hearing person uneasy. For deaf people direct immediate eye contact is the rule, and any violation may be interpreted as an insult.

Sarah M. is a gentle, sensitive woman. She has always had a close relationship with her daughter and would certainly not want to offend her. Although, according to the daughter, Sarah M.'s signing is quite unchanged by her stroke, one aspect of communicating with Sarah M. is disturbing, namely, Sarah M. no longer looks at the signer while she is being signed to. Figure 5.2 illustrates some aspects

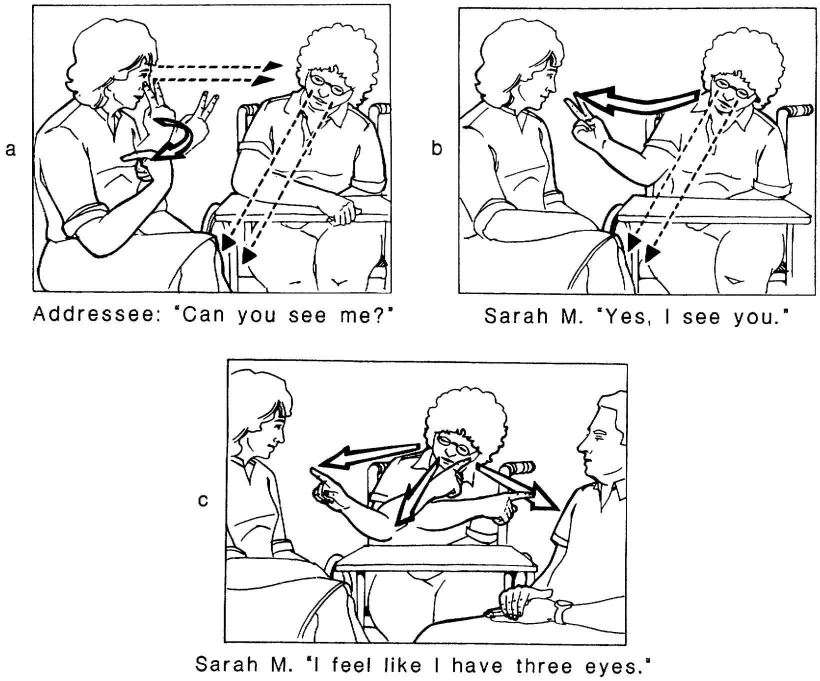


Figure 5.2
Special issues relevant to testing deaf signers with right-hemisphere lesions. (a) Note unusual downward deflection of eye gaze of Sarah M. as she reads addressee's signs. (b) The contrast between sign direction (appropriate) and eye gaze direction (inappropriate) in Sarah M.'s response. (c) Sarah M.'s own description of her unusual eye gaze patterns.

of an interchange that took place during one of our sessions after Sarah M.'s stroke. The daughter was signing to her mother, but during this time the mother kept her gaze fixed toward the floor, rather than looking at her daughter's signing. The daughter stopped, appeared upset, and asked her mother (in ASL), "Can you see me?" (figure 5.2a). Sarah M. sighed, and signed, "Yes, I see you," but she continued looking downward at the floor and not at her daughter. Figure 5.2b illustrates the unusual behavior: Sarah M.'s eye gaze is away from her daughter and downward, yet her hand, in making the sign SEE, is directed precisely toward her daughter. In sign communication Sarah M.'s gaze would be expected to be in the same direction—toward her addressee. The daughter expressed surprise that Sarah M. was able to read signs from this odd angle of eye gaze. Sarah M. went on to explain that she really could perceive signing in this way and then explained aspects of her own inner sense of the effects of her stroke: She pointed in three different directions (figure 5.2c) and signed the ASL equivalent of, "Sometimes I feel like I have three eyes. One sees directly in front of me, one sees off to the left side, and one sees off to the right."

As we will indicate, this unusual eye gaze pattern, which Sarah M. consistently uses, results from deficits produced by her right-hemisphere lesion. One would certainly expect that such markedly deviant behavior might have profound consequences leading to serious disturbances in the perception, processing, and comprehension of a visuospatial language.

5.1.1 *Neurological Findings*

A neurological examination of Sarah M. revealed paralysis of the left arm and leg and moderate increased reflexes in the entire left side. There was also a gross deficit of identification of tactile stimulation in the entire left side. Sarah M. showed a deficiency of saccadic eye movements toward her left. Right-left orientation, finger sense, and simple arithmetic ability were intact. She did not have any visual field deficits. Sarah M. appeared alert, attentive, and cooperative. A CT scan at the time of testing (figure 5.3) showed a large lesion occupying most of the territory of the middle cerebral artery:

> *CT Findings*
> The lesion extends from the frontal operculum, the homologous area of the right hemisphere to Broca's area, involves premotor,

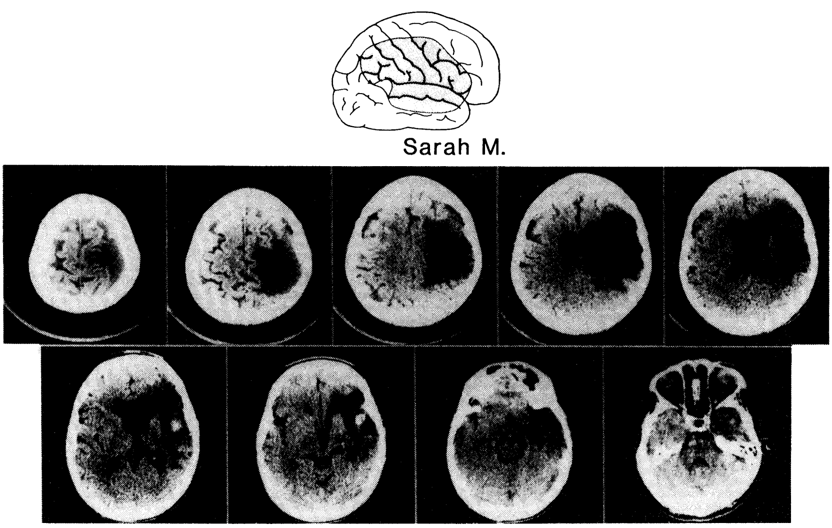


Figure 5.3
Lateral reconstruction of lesion and CT scan for right-lesioned patient Sarah M.

motor, and somatosensory areas, to include the inferior parietal lobule (supramarginal gyrus and partially the angular gyrus). The inferior portion of the superior parietal lobule is involved as well. Inferiorly, the lesion extends into the temporal lobe, involving the superior and middle temporal gyri. The most posterior portion of the superior temporal gyrus seems spared, as well as is area 37. The lesion not only involves these cortical areas, but also the underlying subcortical areas. In fact, it extends all the way to the frontal horn of the lateral ventricle anteriorly, involves all of the insula and probably the more lateral portion of the lenticular nucleus (sparing most of the caudate nucleus), and posteriorly, goes deep towards the trigone but leaves the tapetum intact; this may explain the intactness of Sarah M.'s visual fields. Sarah M.'s lesion is a massive one, with large, critical areas of the right hemisphere damaged.

5.1.2 *Preservation of Written English*

Sarah M.'s written English was good before her stroke (and her penmanship was beautiful). As evidence, she and her family provided letters and notes from her personal diary of a trip. Names have, of course, been changed to conceal identities. Even though the following sample includes many abbreviations, the English is good:

> In the eve., John and I went to their house for a while and then we all went to Juarez, Mexico. They invited us to eat out at Alfred's cafeteria. . . . Arrived in S.F. China Town. Golden Gate. It rained there and went back to S.F. . . . Saw the Capitol. Very pretty. Visited inside of the Capitol. Left for Reno. . . . Stopped at several antique shops and looked around. . . . Very pretty day but very cold.

Excerpts from a letter show Sarah M.'s good command of written English before her stroke:

> . . . to several antique shows and art and craft shows. The last art and craft show we went was two Sundays ago and we saw so many pretty pictures with wind mills and that made us think of you, and also saw a display of decorated egg shells. So plain and tacky. The price was from $8.00 to $25.00. I almost fainted. . . . Susan said that if I sold all of my perfume bottles and egg shells I'd be a millionaire.

After her stroke, when Sarah M. sent us excerpts from the diary, she enclosed a note in her own hand, in perfect English: "The notes I am sending you are all we could find." During testing, when given sentences in ASL and asked to write a translation of them in English, her writing was as good as that before the stroke. For example, she wrote: "A woman has not seen her children. A boy stole some cookies or biscuits. If a boy isn't careful, he will fall down."

The only clear irregularity in the English is in her use of the indefinite rather than the definite article, as in "If a boy isn't careful . . ." (assuming that this mention of "boy" refers to the same individual introduced in the preceding sentence). But this is a nicety of English usage that trips up many nonnative writers of English, stroke or no stroke.

We also have excerpts from a letter that Sarah M. wrote after her stroke; it shows the preservation of her written English:

> . . . Just to let you know I'm very happy at home. . . . I think of you everyday and wish to see you. . . . I'm so happy I'll not go to a nursing home any more and I hate the nursing home. We are looking forward to your coming to visit us on 28th.

5.1.3 Preservation of Signing

During the interview Sarah M. used only her dominant right hand. We present a portion of a transcript of Sarah M.'s signed description of the Cookie Theft picture (figure 2.1). As is typical of her poststroke signing, Sarah M.'s description is perfectly grammatical, without error at any level of structure. Therefore a translation into English is provided here. The remarks of the examiner are also translated into English.

> SARAH M.: It makes me think of Niagara Falls. [Pointing to the water sweeping down to the floor from the sink.] The water is overflowing from the sink. Accidentally, the boy almost slipped on the stool. He is taking the cookies and the stool almost slipped from under him.
> EXAMINER: Okay, now tell me the whole story.
> SARAH M.: The woman is washing the dishes. The boy walked over to the cupboard. He climbed up the stool and tried to reach the cookies. Accidentally, the stool slipped. . . . The woman is washing the dishes while the water is overflowing. She's stupid.
> EXAMINER: Do you see anything else? [An effort to draw her attention to the girl on the left.]
> SARAH M.: There is a window to the outside. That's all I can see.
> EXAMINER: [Points at the girl on the left.] There.
> SARAH M.: [Looks puzzled and surprised.] Oh, she has bare legs

and no socks. The girl is looking at the boy taking down the cookies.
EXAMINER: Okay, now tell the story in order again, please.
SARAH M.: There is a woman washing the dishes. It seems that the mother saw her boy climb up and take down the cookies. The girl is looking up at him. It seems to be his sister; I'm not sure. She is looking up at him. He is helping himself to cookies. Accidentally, the boy is slipping on the stool.
EXAMINER: What happened to the mother?
SARAH M.: The mother ignored them. She is still busy washing. Accidentally, the water was overflowing from the sink. Maybe she can't hear. That's strange.
EXAMINER: You're right. Maybe she's deaf. [Laughs.]

Sarah M. clearly is not aphasic. Indeed, in the language samples we analyzed, her signing is without error at any of the structural levels of ASL. Her signing has complex sentences, correct verb agreement, appropriate use of classifiers, correct morphology and syntax, and no sublexical errors. All these characteristics are in marked contrast to the aphasic signing we observed in the left-hemisphere-damaged patients.

Note that in describing the picture, Sarah M. described events from the right-hand side of the picture (the woman and the sink overflowing and the boy climbing on the stool) and then stopped as if her description were complete. In an effort to draw her attention to the girl on the extreme left-hand side of the picture, the examiner asked if she saw anything else, but Sarah M. still did not seem to notice. Finally, the examiner had to point to the girl on the left, and Sarah M. looked surprised.

This reaction, and some of Sarah M.'s other behavior, suggests that her stroke has produced a spatial disorder called left hemispatial neglect. (See Heilman (1979b) for a discussion of the disorder and its underlying mechanisms.) Discussed briefly in chapter 7, this disorder is not traceable to any elementary sensory or motor disorder. It causes some patients with right-hemisphere damage to ignore the left half of visual space—sometimes extending to the left half of their own bodies. Such a patient may, for example, fail to eat the food on the left side of the plate; when someone simply rotates the plate 180 degrees, the patient goes on to finish the entire meal with good appetite, as the food is now on the right side.

The test results presented in chapter 7 show that Sarah M. has left hemispatial neglect. The presence of this spatial disorder may explain the unusual eye gaze pattern during sign conversations. Throughout our testing of Sarah M., the examiner sat on her right side in order to mitigate the effects of any left hemispatial neglect. It appears that Sarah M.'s unusual gaze pattern is part of a strategy for coping with her neglect of left hemispace. With the examiner on her right side, Sarah M. is putting the examiner in her good right visual field by directing her gaze straight ahead instead of at the examiner. Sarah M. maintains this gaze pattern so long as there is signing addressed to her.

Additionally, while Sarah M. herself is signing and someone is at her side, as our examiner was throughout most of the videotaping, Sarah M. often looks straight ahead, not at the addressee. When she finishes signing, she looks partway in the direction of the addressee, as if to check if the addressee has understood the message. When she is not sure if the addressee is following, she looks partway in that direction (from the downward ahead gaze) and repeats her sentence or asks a question.

The phenomenon of hemispatial neglect has particular importance in the testing of signers with right-hemisphere damage. Some considerations are discussed later in this chapter.

5.2 *Brenda I.: The Keypunch Operator*

At the time of testing, Brenda I. was a 75-year-old woman who experienced a right-hemisphere stroke three years before our visits with her. She is congenitally deaf and attended a residential school for deaf children. Although she is now widowed, she had been married to a deaf man. When we visited her, she had been living in a nursing home for several years and has good friends there who sign with her. Throughout her life her primary mode of communication has been sign language. In fact, she herself evaluated her command of English as poor even before her stroke (such evaluations are not uncommon among deaf individuals). When she was younger, Brenda I. had worked as a keypunch operator.

5.2.1 *Pronounced Spatial Disorientation*

Aside from the visuospatial deficits revealed by the tests described in chapter 7, we were able to observe first-hand how pronounced Brenda I.'s spatial disorientation is. During a break in one of our testing sessions, the examiner was wheeling her in a wheelchair down the hall of the building she had lived in for a number of years. Brenda was to direct the examiner to the cafeteria, but she was disoriented and could not find her way. The examiner had to stop and ask someone else directions, even though the cafeteria was directly below them. Brenda I. shows strong evidence of topographical disorientation in a number of ways. In addition to giving inconsistent and incorrect instructions on how to get from one place to another within the building, she described the location of furniture and parts of her room in an almost helter-skelter fashion.

Brenda I. has a close friend living in the nursing home. The two have been friends since grammar school; they are the same age, grew up together, lived near each other, and now (both widows) live in the same nursing home and see each other almost every day. When Brenda explained where her friend lived in relation to herself, she pointed in entirely the wrong direction. Brenda I. indicated that she herself lives on the first floor and that her friend's room is on the floor above her. Both statements are incorrect. Indeed, there is no floor above Brenda I.'s. Thus, in both getting around in space and describing locations, Brenda I. shows severe spatial disorientation.

5.2.2 *Neurological Findings*

Brenda I. has a dense paralysis of her left arm. Her hospital records indicate that an infarction in the distribution of the right middle cerebral artery is suspected; however, a CT scan was not obtained. Because she was unable to move her left hand or arm, Brenda I. performed all tests using her dominant right hand.

5.2.3 *Grammatical Signing with a Few Spatial Irregularities*

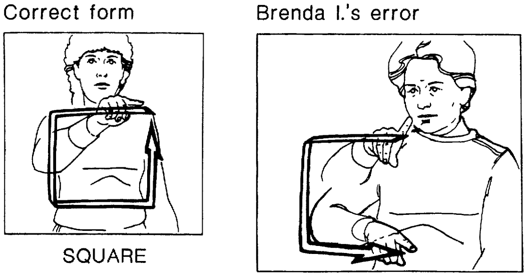
On the whole, Brenda I.'s signing and written English are good, but as we will see, her impairment in nonlanguage visuospatial functions do affect some of her sign output in subtle ways. This is shown in the portion of Brenda I.'s signed description of the Cookie Theft picture, which is translated into English in our presentation. At first, Brenda I. described only the objects and people on the right-hand side of the picture. (The other two right-hemisphere-damaged patients are similar in this regard.) She did not mention items on the left until the examiner specifically turned the card around to emphasize the left-hand side of the picture and asked her, "What about the girl and the boy?" We pick up with Brenda I.'s Cookie Theft description at this point:

> EXAMINER: What is happening in the picture?
> BRENDA I.: The woman is telling the children to get the jar. . . . The woman looks outside through the window as she washes the dishes.

EXAMINER: What about the girl and the boy?
BRENDA I.: The girl asks for a cookie, and the boy picks one up and gives it to her. Oh, the stool is falling.
EXAMINER: [Asks her to retell the story.]
BRENDA I.: The woman is washing dishes. The boy asks the girl what she wants. The girl tells the boy to take some cookies.
EXAMINER: Good, tell me more.
BRENDA I.: The boy gets up and takes cookies. The girl takes one from him and starts to eat it. Accidentally, the stool starts to slide out from under him.
EXAMINER: What is happening to the woman?
BRENDA I.: The woman looks around the yard and then dries the dishes. The sink is full of water, and it overflowed because the drain was stuck.

Although, on the whole, Brenda I.'s signing is fluent and grammatical, a few interesting formational errors were noted. These errors all had something in common: They were sublexical errors with some spatial component. For example, in making the sign for SQUARE, Brenda I. repeatedly omitted the left side of the sign. (When made with one hand, the sign SQUARE is formed by moving the index finger in a squarelike path in a plane parallel to the front of the signer's torso; see figure 5.4.) Brenda I. was the only patient to leave off half of a sign. This omission is most likely a manifestation of hemispatial neglect; it raises questions about the nature of the internal representation of such concepts as a square. Her other errors involved incorrect orientation of the hand, not the configuration of the hand itself (a common type of error in left-hemisphere-damaged signers). Aside from these few obviously spatial errors, there were no grammatical errors, no incorrect selections of lexical items, and no morphological simplifications, substitutions, or overelaborations in

Correct form Brenda I.'s error



SQUARE

Figure 5.4
Spatial error of Brenda I. Note the omission of the left-hand side of the square.

her signing, such as we found with the left-hemisphere-damaged patients.

5.3 *Gilbert G.: The Airplane Mechanic*

Gilbert G. impressed us as being both dignified and genial. He is actually loquacious in signing, eager to narrate a good story whenever he has a receptive audience. Even at age 81, after his stroke, he is quite able to care for himself and to take long trips. He is married to a deaf woman, whom he met at school, and both are active participants in the local deaf community. He is right-handed. Gilbert G. had become deaf during an attack of spinal meningitis at the age of 5. At first his parents did not send him to school because they did not know of any facilities nearby. Gilbert G. likes to tell the story about how his schooling began: One day, when he was riding in a carriage with his father to a nearby town, they picked up a hitchhiker. When the man turned to say a few words to the 9-year-old, Gilbert G.'s father explained that the boy was deaf, could not speak, and therefore could not attend school. Their companion informed them that there was, in fact, a special school for deaf children less than two miles from that very spot. It was this chance meeting that resulted in Gilbert G.'s entering a residential school for deaf children at the age of 9.

Gilbert G. was graduated from high school and went on to attend college but left after one year to return to his home state. He went to work first as a forest ranger and then as a laborer on a succession of jobs. He eventually found permanent work as a skilled technician and repairman in a company that manufactures airplanes, where he rose to the rank of supervisor. Gilbert G. read blueprints and was responsible for the plane assembly from plan to final product. He retired at age 65 but kept active in woodworking, home repair, and the like. He also spent time camping and mountain climbing. His right-hemisphere stroke at age 78 put an end to most of these pursuits.

5.3.1 *Neurological Findings*

Three and one-half years before we tested him, Gilbert G. experienced sudden weakness of the left side, fell down, and was diagnosed as having had a cerebrovascular infarct. By the time we tested him, he had recovered the use of his left side, but he continues to experience some awkwardness with his left hand; he nevertheless is able to sign with both hands without difficulty. He still walks with a slight limp, favoring the left leg. At the time of testing Gilbert G. had no visual field deficits. Neurological examination revealed lower fa-

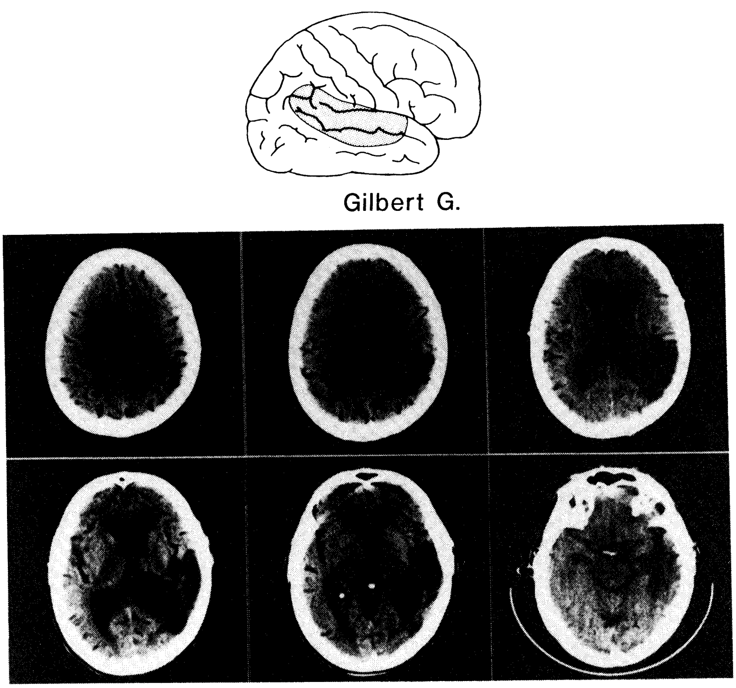


Figure 5.5
Lateral reconstruction of lesion and CT scan for right-lesioned patient Gilbert G.

cial weakness on the left side, abnormally high reflexes on the left side, and a deficit in recognizing objects felt with his left hand, but not with his right hand. These abnormalities provide indications of a damaged right hemisphere and, together with his CT scan, performed at the time of our testing, helped pinpoint the nature of his right-hemisphere lesion (see figure 5.5).

CT Findings
The scan shows a lesion in the temporal-parietal area of the right hemisphere. It involves the cortex and underlying white matter in the superior temporal gyrus, extending inferiorly to partially involve the middle temporal gyrus. Posteriorly, the lesion extends into the lower portion of the inferior parietal lobule, mainly involving the angular gyrus, and minimally, the supra-marginal gyrus.

5.3.2 *Preserved English Writing and ASL Signing*

Gilbert G.'s written English after his stroke seems unimpaired. Even without a written language sample from before his stroke, it is evident that there is no deficit. In describing the Cookie Theft picture, for example, Gilbert G. wrote in English:

> The mother was washing the dishes. Water was running in the sink. It ran over and wet the floor. The son saw a jar full of cookies. He climbed on a stool. While reaching for them, he lost his balance and fell off the stool.

Similarly, Gilbert G.'s poststroke signing is completely unimpaired, exhibiting full grammatical marking of morphology and excellent spatially organized syntax. Even immediately after his stroke, his wife reported that his signing was as before the stroke. A translation of his ASL description of the Cookie Theft picture into equivalent English is:

> The mother was washing the dishes, and the water was left running. The little girl and boy looked up at the cupboard where the cookie jar was resting. They looked at the mother to make sure that she was not looking at them. . . . The boy decided to push the stool and step up on the stool to reach for the cookie jar, but he lost his balance and started falling. . . . The girl turned and looked at her brother, saw what was going to happen to him. She was shocked to see her brother fall.

As this passage shows, Gilbert G.'s signing is impeccable, perfectly full and grammatical, and without error at any level of structure. Moreover, analysis of his free conversation, his storytelling, and elicited language samples show that after his stroke Gilbert G. had no deficits in signing whatsoever.

5.4 *Comparison of Test Results across Right- and Left-lesioned Patients*

An important aspect of our testing program is that we used the same range of tests across both the left- and right-lesioned signers; thus we can readily compare performance across the two groups. Here we compare the effects of left- and right-hemisphere lesions on the performance of our subjects on some of the tests, described in chapter 2 and briefly summarized here, that probe both comprehension and production of ASL.

5.4.1 *A Special Issue in Testing Signers with Right-hemisphere Lesions*

The phenomenon of hemispatial neglect has already been discussed with respect to two of the right-lesioned patients. In the case of Sarah M., hemispatial neglect affects her perception of others' signing, although she has managed to find a means of coping with this problem—making sure that people signing to her are in her good, right visual field.

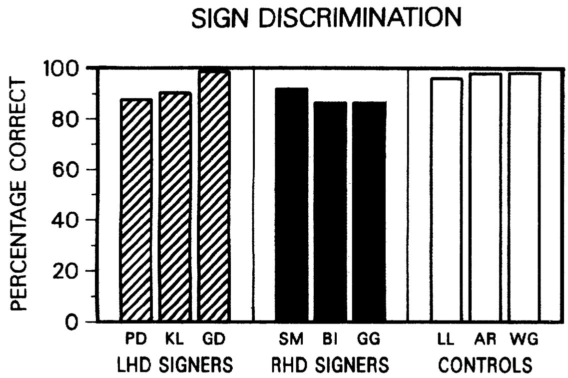
But hemispatial neglect can impinge not only on the perception of signing but also on perception and response to items on a response-choice card; that is, hemispatial neglect can lead to a misinterpretation of test scores. For example, on one comprehension subtest of the BDAE (sign discrimination), subjects are asked to demonstrate understanding of single signs by pointing to the appropriate item from an array on cards. In the testing of deaf signers the subject or patient must attend visually to the examiner's signs before scanning the response array. Deaf, signing patients with right-hemisphere lesions demonstrate slightly lower scores than control subjects (figure 5.6a). To investigate whether these are errors of sign comprehension or are instead related to the visuospatial deficits of the right-hemisphere-damaged signers, namely, to neglect of items in the response array, we rescored responses excluding all items on the extreme left and right sides of the cards. If the patient shows neglect, one would expect this to affect responses to the side of the card contralateral to the lesion, that is, on the left-hand side of the card for the right-lesioned signers and on the right-hand side for the left-lesioned signers. The scores for the left-hemisphere-damaged patients were virtually unchanged by excluding both extreme sides of the card; however, the right-hemisphere-damaged patients had nearly perfect scores. In fact, as figure 5.6b shows, 75 percent of the errors of the right-lesioned signers were for signs whose responses appeared on the extreme left; no such effect was found for patients with left-hemisphere damage or for controls. In this instance the larger percentage increase, of course, is based on a relatively small increment in absolute scores. The errors by patients with right-hemisphere damage appear not to be errors in comprehension but rather errors resulting from hemispatial neglect.

As we show in chapter 7, left hemispatial neglect is only one type of spatial disorder that signers with right-hemisphere damage show. These impairments present special issues for the language testing of signers with right-hemisphere damage because spatial relations and linguistic structure are so intimately interwoven in sign language. In the discussion that follows, such special issues are mentioned where relevant.

5.4.2 *Tests of American Sign Language Structure*

Results of Sublexical Tests

In the phonology of ASL three parameters within which sublexical distinctions occur are Hand Configuration, Place of Articulation, and a



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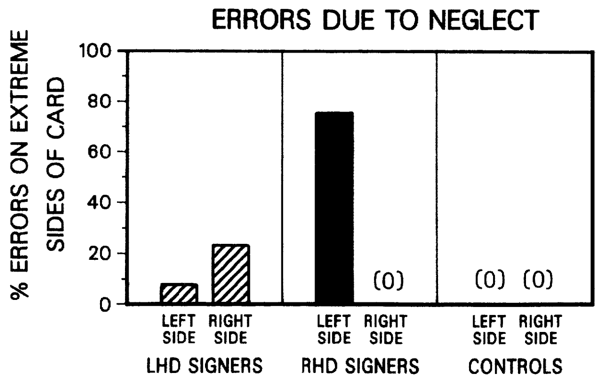


Figure 5.6
Errors related to neglect on the Sign Discrimination subtest of the Boston Diagnostic Aphasia Examination. (a) Results of left-hemisphere-damaged (LHD) and right-hemisphere-damaged (RHD) signers and controls for entire card. (b) Results for the extreme sides of the card. Note that the right-lesioned signers showed some deficits that are attributable to neglecting the extreme left-hand side of the card. (In this and subsequent figures, the abbreviations are PD, Paul D.; KL, Karen L.; GD, Gail D.; SM, Sarah M.; BI, Brenda I.; GG, Gilbert G.)

Movement. In one item of the test of decomposition of signs, for example, the experimenter signs DOLL (an /X/ handshape brushing downward) and the subject is asked to pick the one item of four pictured whose sign has the same handshape. In this particular test question the items pictured are a dog, a ball, an onion, and a fox. The correct response is the onion, because the ASL signs DOLL and ONION have the same handshape.

Another sublexical test uses the ASL functional equivalent of rhyme; the subject is asked to select the two pictures out of four whose signs in ASL are similar in all but one parameter. Figure 5.7 includes a sample item from the ASL Rhyming Test: A key, a violin, grapes, and an apple are pictured, and the correct choices for this item are key and apple, because the ASL signs KEY and APPLE are alike in all respects except one. The two signs share the same Hand Configuration and Movement, differing only in Place of Articulation; in this respect the pair are considered to be ASL equivalents of rhymes.

On these two tasks, which tap subjects' ability to decompose signs and show appreciation of sublexical structure, we find that patients with left-hemisphere lesions are impaired, whereas those with right-hemisphere lesions are not (see figure 5.7); right-lesioned Sarah M. scored 82 percent correct on one test and 100 percent correct on the other, and right-lesioned Gilbert G. scored 91 percent correct on the rhyming test and 82 percent correct on the test for decomposition.

Results of Morphological Tests

The formal marking of the distinction between noun-verb pairs in ASL is not a spatial one. When nouns and verbs that share the same root are derivationally related, the distinction between them is based on features of movement; in contrast to verbs, nouns are signed with restrained, repeated movement, which produces a more rapid and shorter trajectory. Figure 5.8 shows two sample pairs of derivationally related nouns and verbs: SIT and CHAIR, and SWEEP and BROOM. Note that the derivationally related signs in each pair share Handshape, Place of Articulation, and basic Movement shape. The two signs differ from one another only in features of movement (repetition and manner); the nouns always have movement that is restrained and repeated.

All the signers with right-hemisphere lesions performed better than any of those with left-hemisphere lesions on tests requiring processing of verbs and their derivationally related nouns in ASL; this superior performance was found on both the test of comprehension and the test of production described in chapter 2 (see figure 5.8).

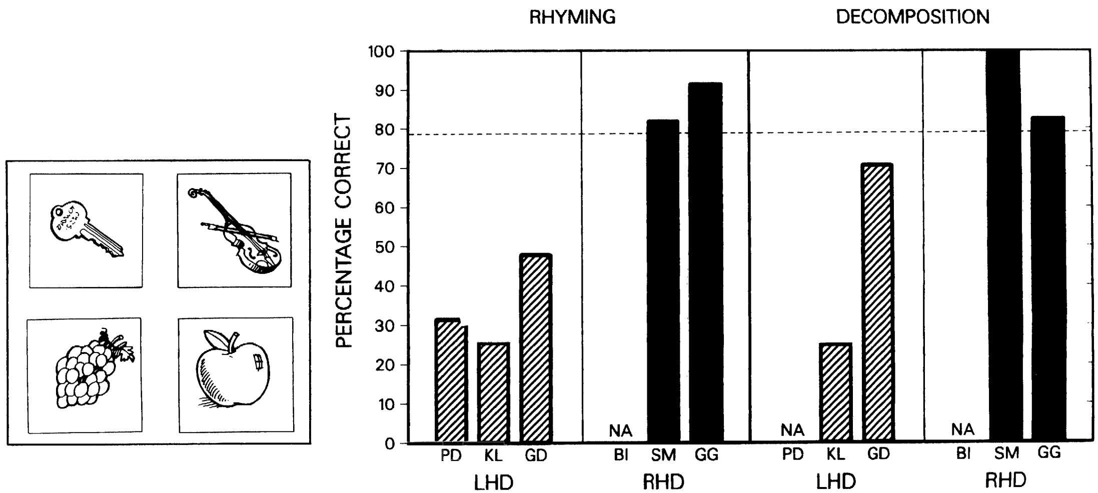


Figure 5.7
Two tests for processing sublexical structure in ASL: Rhyming and Decomposition. A sample item from the rhyming test is illustrated. The correct answers are the KEY and the APPLE, because the signs for these items share all major formational parameters but one. Right-hemisphere damaged (RHD) signers performed better than left-hemisphere-damaged (LHD) signers on both these tests.

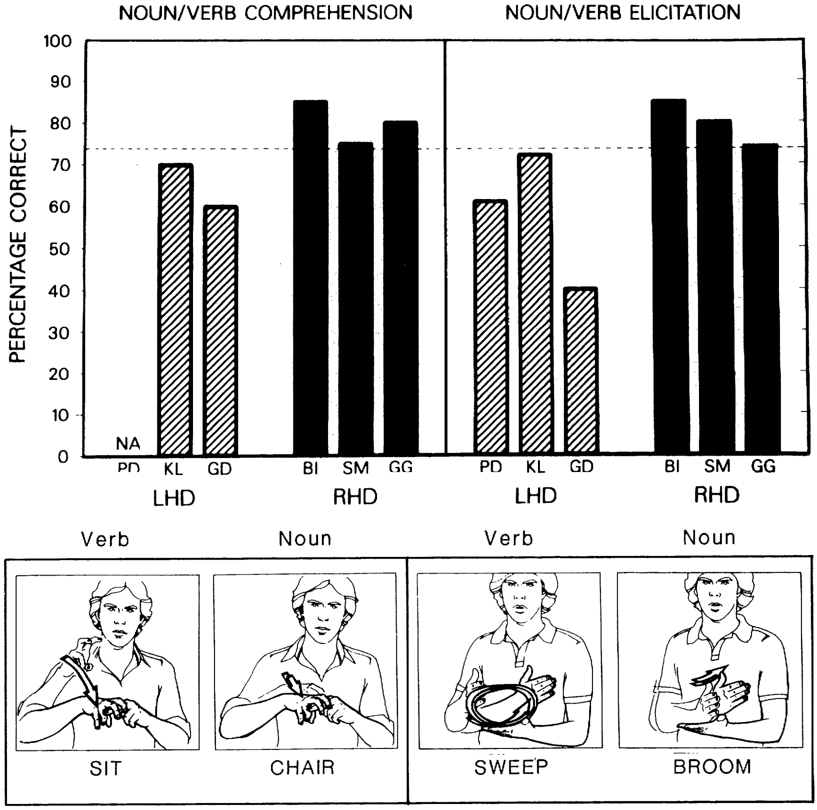


Figure 5.8
Two tests for processing ASL morphology: comprehension and elicitation of the formal distinction between nouns and related verbs. The illustration below the graph shows two pairs of derivationally related signs.

Sarah M. scored well on comprehension (75 percent correct) and production (80 percent) of this morphological distinction; Brenda I.'s scores were even higher on both tests (85 percent correct on each test), and Gilbert G. scored 80 percent correct on the comprehension test and 73.7 percent correct on the elicitation test. These tests of ASL grammatical morphology do not rely on spatial contrasts; all three patients with right-hemisphere lesions performed well on these tests and in a manner that is different from the impairment shown across the board in both tests by the left-lesioned patients. Clearly, damage to the right hemisphere does not impair the ability to control this layered morphological distinction in a visual-gestural language.

Results of Tests of Spatialized Syntax

The tests of spatialized syntax, described in detail in chapter 2, probe subjects' perception and memory for spatial loci. The test of nominal establishment requiries subjects to recall and specify where nominals have been established and what nominal has been associated with a particular locus. We have scores for two patients with right-hemisphere damage: Gilbert G. scored 87.1 percent correct, which is in the range of the control subjects, and Brenda I. scored 59.1 percent correct, well below that range. Patients with left-hemisphere damage also showed a range of scores on this test: Gail D. and Karen L. were in the control range, but Paul D.'s score was only 40.9 percent correct.

On the two tests of verb agreement (Verb Agreement with Fixed Framework and Verb Agreement with Shifting Reference), there are some gaps in our data, but we have scores for most of the patients on one or the other of the tests. Two left-lesioned patients showed poor performance and one was exceptionally good: Gail D. scored 80 percent correct on the test of verb agreement with fixed framework and 100 percent correct on the other verb agreement test; Paul D. scored 57.1 percent on the fixed framework test and 43.35 percent on the shifting framework test; and Karen L. scored 53.3 percent on the fixed framework test and 42.9 percent on the shifting framework test. On these tests the right-hemisphere-damaged patients performed worse than the controls. On the Verb Agreement Test with Fixed Framework, Sarah M. scored 64.3 percent and Gilbert G., 42.9 percent. On the Verb Agreement Test with Shifting Reference, Sarah M. scored 63.3 percent and Gilbert G. scored 60.0 percent. Unlike any of our previous processing tests, on both tests of verb agreement, the right-hemisphere-damaged patients, like the left-lesioned ones, were impaired.

In view of the flawless signing of these right-lesioned signers, who show normal processing on the tests of other components of ASL structure, their performance on tests of spatialized syntax seems surprising. Let us consider the basis for the impaired performance on these tests. The nonlanguage spatial capacities of right-lesioned signers bear much on this issue and are presented in chapter 7. Recall that processing spatialized syntax in ASL requires complex underlying nonlanguage prerequisites: processing spatial relations (spatial loci), spatial memory (association of nominals with spatial loci, and perception and memory for direction of movement of the verb between spatial endpoints), and spatial transformations (changes in spatial referential framework). Thus a deficit in the ability to process any of the underlying spatial cognitive prerequisites for the spatialized syntax of ASL might result in impaired processing on these tests.

It appears that different functions may be crucial to the production of spatialized syntax and its comprehension. Although both linguistic and spatial functions are required, the fact that patients with right-hemisphere lesions *produce* errorless signing (including spatialized syntax and discourse) is evidence that the linguistic function is the more basic one here, requiring mostly left-hemisphere processing. It is our view that the perceptual processing involved in the *comprehension* of spatialized syntax critically involves both the left and the right hemispheres; certain crucial areas in each must be relatively intact for accurate performance. Because of the spatial nature of the units of perception, right-hemisphere processing would be required; but because of the linguistic nature of the underlying grammatical representations, left-hemisphere processing would also be required. In fact, the results of our tests show that (with one exception) neither left- nor right-lesioned patients perform perfectly across the range of these tests of spatialized syntax. It is particularly striking that the right-lesioned patients appear to be impaired on these tests, for they do quite well on perceptual processing of other grammatical constructs that do not involve spatial contrasts.

It would be reasonable to suppose that the basis for poor performance is different in the two groups. In left-lesioned patients the basis may be the grammatical nature of the constructs; in right-lesioned patients the basis may well be in the spatial nature of the perception.

There are several lines of evidence that indicate that sign language is intact in right-lesioned signers. The first (and most powerful) line of evidence lies in the fact that their signing is flawless and without aphasic symptoms and is in contrast to the signing of deaf patients after left-hemisphere damage where clear and marked disruption is found. The second line of evidence comes from the right-lesioned patients' excellent performance on all grammatical processing tasks that do not involve spatial perception; morphological and phonological processing is normal in these patients. The right-lesioned signers do not show comprehension deficits in any linguistic test, other than that of spatialized syntax. Finally, the right-lesioned signers do show profound deficits with respect to perceiving, manipulating, and transforming nonlanguage spatial relations. These lines of evidence are compelling in arguing for a specifically spatial-perceptual deficit, as opposed to a linguistic deficit, as the basis for the impaired performance of right-lesioned signers. An analysis that is restricted to the behavior exhibited on a test without analysis of other factors might miss the true underlying factors resulting in the deficit.

5.5 *Profiles of Language Functions of Right-lesioned Patients*

Given their obvious perceptual deficits and their impairment on nonlanguage visuospatial tasks, one might have expected a profound effect on language functions at all levels, such as that found in patients with left-hemisphere lesions. Figure 5.9a shows the rating-scale profiles for the three left-hemisphere-lesioned signers. Note that on each scale the scores are scattered; on most of them the scores span virtually the entire range of values, pointing to the different impairments of the left-lesioned patients. As shown in chapter 4, the individual profiles of the left-lesioned signers deviate from normal in different ways and represent different patterns of sign aphasia. Recall that one left-hemisphere-damaged patient was agrammatic, another was grammatical in her signing but made sublexical errors and failed to specify her pronominal indexes, and a third was paragrammatic and had failure in spatially organized syntax. Figure 5.9b presents the rating-scale profiles of three matched deaf control subjects. This part of the figure shows that normal performance falls at the extreme right-hand side of all scales except one, sign finding, where normal performance falls at the middle value of the scale.

In contrast to the left-lesioned patients, no patient with right-hemisphere damage was aphasic. The signing of all three was fluent and varied, with conversational engagement and good understanding of everyday communication. All three right-lesioned patients, Sarah M., Brenda I., and Gilbert G., have well-formed grammatical sentences that exhibit a variety of grammatical forms. The rating-scale profiles of their sign characteristics, shown in figure 5.9c, reflect this grammatical (nonaphasic) signing; in fact, their scales are much like those of the control subjects.

5.6 *Brain, Language, and Modality*

Patterns of language breakdown and preservation in left- as opposed to right-lesioned signers led us to the following conclusions. Because the left-lesioned signers show frank sign language aphasias and the right-lesioned signers show preserved language function, it appears that it is, indeed, the left cerebral hemisphere that is specialized for sign language. This provides support for the proposition that the left cerebral hemisphere in humans has an innate predisposition for language. Thus there appear to be anatomical structures within the left hemisphere that emerge as special-purpose linguistic processors in persons who have profound and lifelong auditory deprivation and who communicate with a linguistic system that uses radically different channels of reception and transmission from that of speech. In this most crucial respect brain organization for language in deaf signers parallels that in hearing, speaking individuals.

On the other hand, our data suggest the possibility that those anatomical structures within the left hemisphere that subserve visual-gestural language differ from those that subserve auditory-vocal language. Recall that Karen L. has a lesion in the left inferior parietal lobule, an area known to function for higher-order spatial analysis (Mountcastle et al. 1984; Andersen, in press). She has both major spoken language mediating areas intact: Broca's area and Wernicke's area. Yet Karen L. has a marked and lasting sign comprehension loss, a language deficit that would not be predicted from her lesion if she were hearing.

There is other evidence that indicates that brain structures are not indelibly and unalterably wired for particular functions but rather that particular processing tasks are optimized by the brain. For example, Merzenich and his colleagues (Merzenich et al. 1984; Merzenich et al. 1983; Merzenich and Kaas 1982) have studied the cortical reorganization that occurs in the central representation of the body's skin surface after peripheral nerve injury. Experimenting with monkeys, these investigators cut the peripheral nerves that provide the brain with sensory input from skin surfaces. They found that the brain's map of these surfaces was dramatically reorganized. In that reorganization the representation of skin surfaces in cortical areas

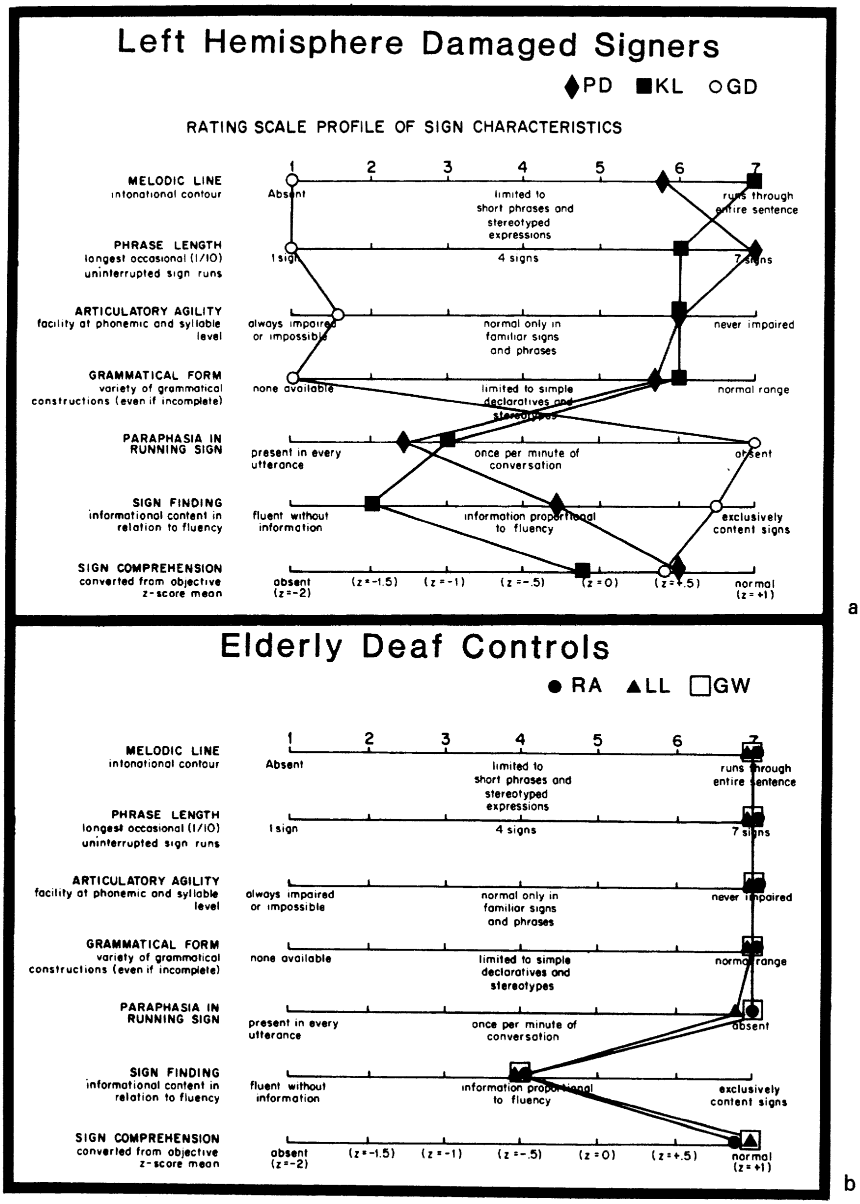
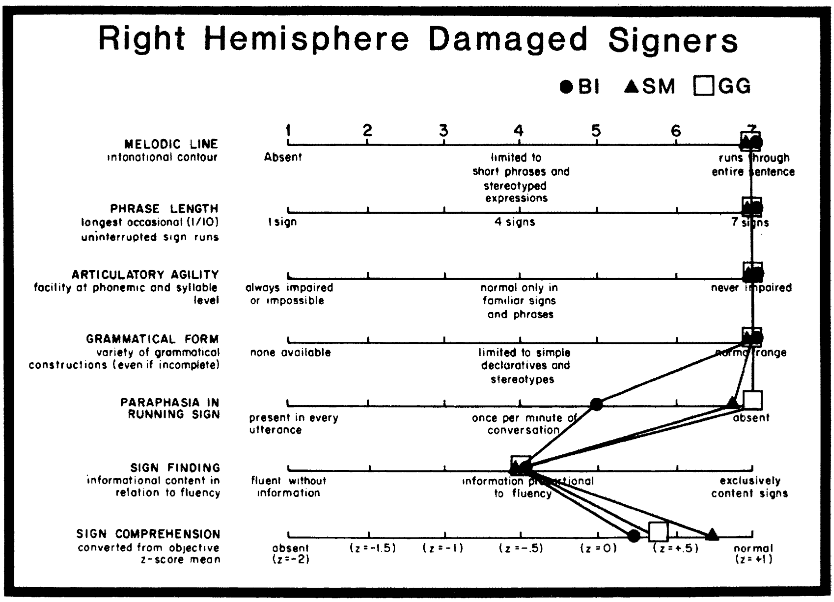


Figure 5.9
Rating-scale profiles of sign characteristics from the Boston Diagnostic Aphasia Examination for left- and right-lesioned signers and controls. Note that the right-lesioned signers are similar to the controls in performance.



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adjacent to deprived areas expanded to occupy the deprived cortical zones. Furthermore, this reorganization (and optimization) of brain function occurred after only relatively brief periods of altered somatosensory input to the brain. In a similar vein Neville and colleagues (Neville, Schmidt, and Kutas 1983; and Neville, in press) found that visually evoked brain potentials differ in deaf and hearing adults. Brain regions that subserve auditory processing in hearing subjects respond to visual stimulation in deaf subjects.

As we have said, the parietal lobes in humans function for higher-order spatial analysis, and we believe them to be more intimately involved with the processing of signed rather than with spoken language. With respect to processing the spatialized syntax of ASL, both the left and the right parietal lobes may be involved, although they play different roles. Let us review for a moment some of the differing spatial functions of the two parietal lobes in humans. It has been argued that the parietal lobes create a continually updated central neural image of the spatial surround and the body position within it (Mountcastle et al. 1984). In humans the right parietal lobe appears to mediate perception of spatial relations in extrapersonal space, that is, in the space beyond arm's reach from the body. This mediation includes perception of absolute location and of the spatial relations among objects in space. The left parietal lobe mediates processing of spatial relations in intrapersonal space; by intrapersonal space we mean the body and the space within arm's reach. The left parietal lobe seems to generate an internal representation of the body and of moving body parts and controls the accurate placement of the limbs without sensory feedback (Kimura 1979).

The CT scans for both Sarah M. and Gilbert G. show damage to the right parietal lobe. Although no brain scan was available for Brenda I., her specific spatial loss, as shown in chapter 7, is consistent with right parietal damage. Recall that the only deficits of language performance of the right-lesioned signers was in *comprehension* on our tests of spatialized syntax. Their production of these same grammatical processes was completely unimpaired. Comprehension, as opposed to production, of these spatial relations occurs in extrapersonal space. Perhaps initial preprocessing of this spatial signal is carried out preferentially by the right parietal lobe to extract spatial features. This initially processed information may then be transmitted to the left parietal lobe for linguistic decoding. Such linguistic decoding is precisely what Karen L. and Paul D., who have lesions in the left parietal lobe, could not perform. Also, of course, left-lesioned signers but not right-lesioned signers are impaired in the production of the spatialized syntax of ASL, providing strong evidence for the crucial role of the left hemisphere for the syntactic processing of ASL. It is our view, then, that not only is the left cerebral hemisphere innately predisposed for language but also anatomical structures mediating language may be linked to the modality in which language has developed.

It is important to note that we are not implying that sign language (or sign language processing) is localized in the left parietal lobe (or in a left anterior region). There are a number of cortical and subcortical brain regions that are intimately involved with spoken language processing (Damasio and Geschwind 1984), and there is undoubtedly a similarly large number of brain structures on whose integrated performance sign language functioning crucially depends.

The parietal (and frontal) lobes are heavily and reciprocally interconnected with many other cortical and subcortical structures, making them important nodes in a number of distributed systems (Mountcastle et al. 1984). It may well be that the brain's execution of the complex linguistic functions of sign language are carried out by neuronal processing mechanisms of those distributed systems. It is important to note that our data lead to the view that those distributed brain systems that underlie visual-gestural languages differ in part from those that subserve language in the vocal-auditory mode.

5.7 A Note on Hemispheric Specialization

As we have seen, the right-lesioned patients are not aphasic and do not exhibit linguistic deficits. An especially dramatic finding in our view is the case of Sarah M., who has a massive lesion to the right hemisphere that includes most of the territory fed by the right middle cerebral artery. The lesion includes areas that would be crucial to language if the lesion occurred in the left hemisphere of a hearing patient. In all likelihood, Sarah M. would have been globally aphasic if she had not been deaf and if the lesion had occurred in her *left* hemisphere. Thus there is more than ample possibility that aphasic symptomatology would have been manifested as a result of the particular lesion in this case because of the size and location of the lesion. Yet astonishingly, no aphasia for sign language resulted! Despite Sarah M.'s profound visuospatial impairment, her signing is absolutely impeccable. This underscores the complete separation in function that can occur between the specializations of the right and the left cerebral hemispheres in congenitally deaf signers. This result is particularly revealing because, in sign language, language and spatial relations participate in one and the same channel.