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# Dissociation between Linguistic and Nonlinguistic Gestural Systems: A Case for Compositionality

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This paper addresses the issue of the separability of disorders of sign language from disorders of gesture and pantomime. The study of a left-lesioned deaf signer presents one of the most striking examples to date of the cleavage between linguistic signs and manual pantomime. The left-hemisphere lesion produced a marked sign language aphasia disrupting both the production and the comprehension of sign language. However, in sharp contrast to the breakdown of sign language, the ability to communicate in nonlinguistic gesture was remarkably spared. This case has important implications for our understanding of the neural mediation of language and gesture. We argue that the differences observed in the fractionation of linguistic versus nonlinguistic gesture reflect differing degrees of compositionality of systems underlying language and gesture. The compositionality hypothesis receives support for the existence of phonemic paraphasias in sign language production, illustrating structural dissolution which is absent in the production of pantomimic gesture. Understanding the neural encoding of compositional motoric systems may lead to a principled anatomical account of the neural separability of language and gesture. This case provides a powerful indication of the left hemisphere's specialization for language-specific functions. 

The study of sign language offers a unique opportunity for insight into the nature of brain organization for linguistic and nonlinguistic gestural systems. Since sign language and gesture are transmitted in the same modality, the breakdown of the two can be directly compared. American Sign Language (ASL) is primarily a visual gestural system passed down from one generation of deaf people to the next. It has evolved into an autonomous language with its own internal linguistic mechanisms for relating visual form with meaning. These linguistic mechanisms are not derived from English or any spoken language, but rather are deeply rooted in the visual modality. A recent program of studies has provided clear evidence that in deaf signers, left-hemisphere lesions lead to sign language aphasias, whereas right-hemisphere lesions do not. At the same time, the right hemisphere of deaf signers shows a complementary specialization, in that nonlanguage visuospatial functions are grossly impaired following lesions to the right, but not to the left hemisphere (Poizner, Klima, & Bellugi, 1987; Bellugi, Poizner, & Klima, 1989). This is particularly significant since sign language expresses essential grammatical relations via spatial manipulation.

ASL is a natural language used by most of the deaf community in North America. Studies by Stokoe, Casterline, and Croneberg (1965), Klima and Bellugi (1979) and others have identified the basic organizational structure and grammatical components of ASL. ASL exhibits formal organization at the same levels found in spoken languages, including a sublexical structure analogous to the phonemic level (Battison, 1978; Stokoe et al., 1965), and a level that specifies the precise ways that meaningful units are bound together to form complex signs and signs to form sentences, analogous to the morphological and syntactic levels (Padden, 1983; Supalla, 1982). ASL also shares other important underlying principles of organization with spoken languages, such as lexical levels, syllables, segments, distinctive features, rules based on underlying forms, and recursive grammatical processes (Bellugi, 1980; Wilbur, 1987). Thus, the research on ASL has shown conclusively that human languages are not restricted to the speech channel (Bellugi et al., 1989; Klima & Bellugi, 1979).

Studies investigating the relationship between nonlinguistic gestural abilities and spoken language have revealed many parallels in ontology (Bates, Bretherton, & Snyder, 1988) and in patterns of dissolution (Geschwind, 1965; Goodglass & Kaplan, 1963; Kimura, 1976, 1977; Kimura & Watson, 1989; Duffy, Duffy, & Mercaitis, 1984). With respect to patterns of breakdown, there exits a strong correlation between aphasic impairments and impairments in manual gestural ability (apraxias) following left-hemisphere damage (Hecaen, 1975; Kimura, 1982). However, it is still unknown whether these correlations arise from disturbance of a common underlying mechanism or rather reflect independent disorders. The co-occurrence of aphasia and apraxic disorders may simply reflect damage to anatomical areas which are in close proximity but nevertheless subserve independent processes (see Feyereisen & Seron, 1982; Marshall, 1980 for reviews).

The study of hand movements which accompany spoken language has also suggested commonalities in the programming of oral and manual movements. Several studies have found that spontaneous free movements of the right hand increase in frequency during speech (Kimura, 1973; Lomas and Kimura, 1976). More recent interpretations of the role of gestures which accompany speech suggest that these gestures may be a reflection of imagistic representations (McNeill, 1992). In this view, successful production of an utterance thus reflects an integration of verbal and imagistic representations. Moreover, examination of aphasic subjects and one split-brain subject have led Pedelty and McNeill (1991) to conclude that in the intact brain both left and right hemispheres make their own contribution to the integration of speech and gesture. They suggest that the left hemisphere alone is incapable of producing the close temporal, semantic, and functional relationships of speech to gesture that appear with the normal speaker.

The present paper addresses the problem of the separability of disorders of language from disorders of gesture and pantomime from a unique vantage point, the investigation of sign language aphasias. Since nonlinguistic gesture and linguistic symbol are transmitted in the same modality by users of a sign language, the strongest case for existence of independent neural processes mediating linguistic gesture (sign language) from nonlinguistic gesture (pantomime) may come from functional dissociations in brain-damaged deaf signers.

In a previous study Kimura, Battison, and Lubert (1976) reported that in a deaf aphasic they tested, both sign language and imitation of meaningless gestures were equally impaired. However, more recent studies have begun to suggest dissociability between sign language capacity and nonlanguage gestural control. Poizner, Bellugi, and Iragui (1984) reported language and apraxia data from three left-lesioned deaf signers and one right-lesioned deaf signer. Of the three left-hemisphere-damaged signers, all of whom were clearly aphasic for sign language, only one showed evidence of ideomotor apraxia. The other two signers were unimpaired on ideomotor apraxia tests. However, one of these signers did show some evidence for a motor sequencing impairment. The right-hemisphere-damaged patient was unimpaired in both language and gesture testing. In addition Poizner, Bellugi, and Klima (1989) report that all of these subjects performed normally on tests of pantomime recognition. These findings suggest that in principle, sign use may be dissociable from gestural capacity.

Important converging evidence comes from three experimental studies comparing deaf native signers, hearing native signers and hearing nonsigners on hemispheric specialization for linguistic, symbolic, and motor functions (Corina, Vaid, & Bellugi, 1992). These studies show that nonlinguistic gestures—either symbolic or nonsymbolic—are processed equally by both hemispheres, but the linguistic signs are processed primarily by the left hemisphere in skilled signers.

This paper presents a case study of a left-lesioned deaf signer whose poststroke behavior has important implications for our understanding of the relationship between language and gesture. We report the case of W.L., who shows a remarkable propensity for nonlinguistic gestural ability in the face of severe sign language aphasia. The dissociation shown in this case provides some of the strongest evidence to date for the separability of sign language aphasia from generalized impairments in nonlinguistic manual gesture. This finding presents a challenge to theories which attempt to tie disturbance of language and gesture to an undifferentiated motoric basis. Importantly, the paper advances a principle which may provide a basis for a separation between linguistic and nonlinguistic gesture. We begin with a brief introduction to the structural properties of visual–gestural linguistic systems and contrast formal gestural linguistic systems with communicative pantomimic gesture.

## LANGUAGE IN A VISUOSPATIAL MODALITY

*Phonology without sound.* Research on the structure of lexical signs in ASL has shown that signs are fractionated into sublexical elements just like the words of spoken languages. The contrasts that distinguish signs from one another are a small set of handshapes, movements, and locations that co-occur throughout the sign. Recent analyses focus on segmental structure of signed languages, suggesting a sequential structure analogous to phonemes and syllables of spoken language (Liddell & Johnson, 1989;

Perlmutter, 1989). Moreover analyses of the phonological structure of ASL argue for the importance of hierarchical systems of features to account for phonological processes such as assimilations and slips of the hand (Corina, 1990; Sandler, 1989). Signed languages differ from one another, much as do spoken languages, and there are many different signed languages. We note that ASL and British Sign Language are mutually incomprehensible, having independent histories. Furthermore, analyses of unrelated signed languages reveal not only differences in lexicon and grammar, but even systematic phonetic differences that may cause native signers from one sign language to have an "accent" in a newly learned sign language (Klima & Bellugi, 1979; Fok, Bellugi, van Hoek, & Klima, 1988).

*Vertically arrayed morphology.* The grammatical mechanisms of ASL take full advantage of the spatial medium and of the possibility of simultaneous and multidimensional articulation. Like spoken languages, ASL has developed grammatical devices that serve as inflectional and derivational markers. These devices are regular changes in form across syntactic classes of lexical items associated with systematic changes in meaning. In ASL, families of sign forms are related via an underlying stem: the forms share handshape, location, and movement shape. Grammatical processes represent the interaction of the stem with other features of movement in space (dynamics of movement, directions of movement, spatial array, and the like) all *layered* with the sign stem (see Fig. 1A).[1]

In ASL, such grammatical processes can apply in combinations to signs, creating different levels of form and meaning. In these combinations, the output of one morphological process can serve as the input for another, and there are alternative orderings producing different levels of semantic structure as well, as Fig. 1A shows. The creation of complex expressions through the recursive application of hierarchically organized rules is also characteristic of the structure of spoken languages (Chomsky, 1982). However, the form such expression takes in a visual–gestural language is unique: the sign stem is embedded in the pattern created by a morpho-

[1] Notation conventions used in this paper include:

SIGN: Words in capital letters represent English glosses for ASL signs. The gloss represents the meaning of the unmarked, unmodulated, basic form of a sign out of context. Multiword glosses connected by hyphens are used where more than one English word is required to translate a single sign.

$\text{SIGN}_{[\text{Exhaustive}]}$: Morphological processes in ASL are indicated by the specification of grammatical category of change or by the meaning of the inflected form. $\text{GIVE}^{[\text{:Exhaustive}]}$ and $\text{GIVE}^{[\text{'to each'}]}$ are alternative ways of representing the same grammatical process.

/W/, /@/: For specifying sublexical parameters of signs, we refer to notation within slashes, using symbols from Stokoe, Casterline, and Croneberg (1965).

${}_{i}\text{SIGN}_{j}$: Subscripts from the middle of the alphabet are used to indicate spatial loci involved in the spatially organized syntax of ASL, for abstract reference and coreference.

#W-A-V-E: A fingerspelled word.

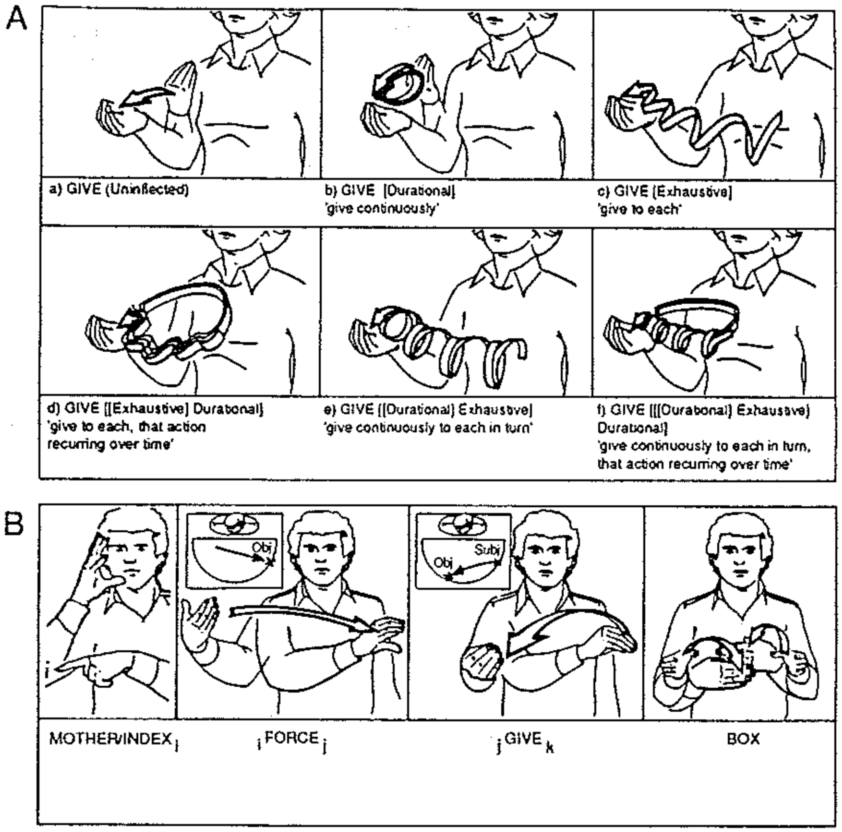


FIG. 1. (A and B) Recursive morphological processes and spatially organized syntax in American Sign Language.

logical process and nested spatially in a pattern created by the same or a different morphological process.

*Spatially organized syntax.* All spoken languages have grammatical elements and structure relating items to one another in sentences, providing the underlying scaffolding on which to build sentential meaning. Languages have different ways of marking grammatical relations among their lexical items. In English, it is primarily the order of the lexical items that marks the basic relations among verbs and their related nouns. ASL, by contrast, specifies relations among signs primarily through the manipulation of sign forms in space. In sign language, space itself bears linguistic meaning. The most striking and distinctive use of space in ASL is in syntax and discourse. Noun phrases introduced into ASL sentences may be associated with specific points in a plane of signing space: pointing again to a specific locus clearly "refers back" to a previously mentioned noun, even with many other signs intervening. This mechanism serves an equivalent function to what has been termed pronominal reference in spoken language. Moreover, verb signs move between abstract loci in signing space, specifying subject and object of the verb, as shown in Fig. 1B. The system of spatial reference affords a great deal of complexity, permitting the signer to refer, in a global manner, to a previously established clause, whose local constituents are themselves spatially distinct. Thus ASL may also use hierarchically organized subspaces to express complex syntactic relations.

ASL has developed as a fully autonomous language, with complex organizational properties not derived from spoken languages, thus illuminating the biological determinants of language. ASL exhibits formal structuring at the same levels as spoken language and principles similar to those of spoken language. Yet, the surface form of phonological and grammatical processes in a visuospatial language is rooted in the modality in which the language developed (Bellugi, 1980). Despite these differences there is now overwhelming evidence that signed languages, as well as spoken languages, exhibit dense *compositionality* at all levels of linguistic structure. In the simplest sense, a system is compositional when it is built up, in a systematic way, out of regular parts drawn from a certain determinant set (van Gelder, 1990). Another distinguishing characteristic of compositionality as it applies to natural language is the tendency for the organization of meaningful units to exploit hierarchical patterning. Thus at every level of linguistic structure, we find basic meaningful units; features, segments, morphemes, syntactic constituents organized and bounded into hierarchically organized systems. One operational formalism which captures this tendency for hierarchical organization of natural language may be found in the theory of prosodic phonology which argues that all phonological units must be prosodically licensed, that is, must belong to higher prosodic structures such as syllables, metrical (or stress) feet, phonological words, and the phonological phrase. These units are assumed to be in a dominance hierarchy, with a terminal projection governing the segment (Selkirk, 1982). Signed languages like spoken languages consist of basic meaningful units constructed from a small set of recurring elements whose hierarchical combinations are constrained in systematic ways.

*Comparison of sign and pantomime.* There are major differences between sign languages and communicative pantomimic gesture. In systematic studies exploring the difference between sign and pantomine, several factors can be identified, even when both share a common theme. An example is shown in Fig. 2, from a study comparing nonsigners' pantomimic renditions of words with corresponding ASL signs (Klima & Bellugi, 1979). The pantomime for conveying "egg" required a number of different

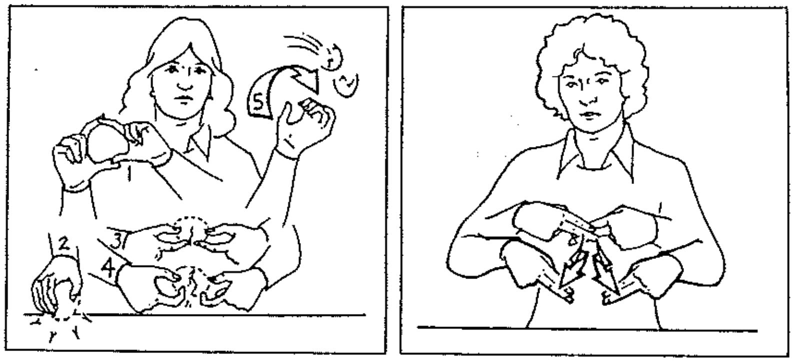

FIG. 2. Comparison to pantomimic rendition of "egg" (left) and the ASL sign EGG (right).

steps, and details of individual renditions were entirely different. Typically in pantomime, movements are continuous, there are no well-defined transitions between particular action sequences (e.g., picking up the egg versus cracking an egg). In addition, pantomime will often include movements of the head and the body in the depiction of some action. Naturally there is great variability in the particular actions that will be depicted and further variability in specific configurations of body "articulations" that are used. For example in the depiction of "egg" one finds little consistency in the configuration of the handshapes used to grasp the "egg." In great contrast, the ASL sign EGG is recognizably the same across different signers and, moreover, shares specific components (handshape, location, movement, orientation) with other ASL signs, drawn from a restricted inventory. In an ASL sign, movement of the hands is organized into a linguistic system; there are clear temporal boundaries to sign movement during which a set of discrete articulatory configurations are enacted and then relaxed. Both the inventory of articulatory gestures used and the spatial domain of execution are discrete and limited. ASL signs are constructed from a small set of discrete elements of handshape, location, movement, and orientation. Language-specific and language-independent constraints and regularities govern the way these elements are combined and recombined to create the lexical items of the language: a compositionally dense system (Bellugi, 1980).

The sign-specific linguistic breakdown in the present case of a left-lesioned signer lays bare the differences between a true linguistic gestural system and a nonlinguistic pantomimic gesture and helps elucidate the compositional organization of sign language. The separation in brain systems for signs and for gestures is revealing, since both of these functions involve symbolic gesturing of the hands in space.

## CASE HISTORY OF LEFT-LESIONED DEAF SIGNER, W.L.

W.L. is a 76-year-old congenitally deaf right-handed male, born to normally hearing parents. W.L. has two deaf signing brothers and one hearing sister. He grew up signing, became an integral member of the deaf community, and has relied on sign language for his primary means of communication with a deaf spouse, friends, and community throughout most of his life. He communicates primarily through writing and mouthing simple English with people outside the deaf community. Prior to his stroke, W.L. worked as a craftsman in a local hospital making orthopedic devices. W.L. is an important member of many deaf fraternal organizations. W.L. has been married twice, both times to a deaf signing spouse.

We have been extremely fortunate to obtain a 2-hr videotaped interview of W.L. that was recorded 10 months *prior* to his stroke. It is through this sign history that we are able to evaluate W.L.'s prestroke signing use. Importantly, the tape reveals that prior to his stroke, W.L. was a fluent signer of ASL. He correctly used a full range of grammatical devices of ASL, including the spatialized syntax and the derivational and inflectional morphology. Moreover there was no evidence of pantomimic gesturing during this interview.

W.L. has a history of coronary artery disease, prior myocardial infarction and coronary bypass graft, and carotid endarterectomy. Seven months prior to testing, he experienced the acute onset of right-sided weakness. On admission to the hospital he was noted to have right facial weakness and right hemiparesis, which rapidly resolved. W.L.'s wife and the hospital sign language interpreter noted that the patient no longer understood most signs and made numerous errors in signing. Moreover the deaf wife was puzzled as he had begun to use gestures with her, and this was a change noted following the brain injury.

CAT scan analysis was performed utilizing a neuroanatomical atlas (Damasio & Damasio, 1989). The CAT scan revealed a large frontotemporoparietal lesion in the left hemisphere. The lesion was mapped onto templates representing horizontal sections at 0° relative to the orbitomedial line. A lateral projection was mapped as well (see Fig. 3). Brodman's areas 44 and 45 (Broca's area) and the subsequent white matter tracts, including arcuate fasciculus, were damaged. Most of middle and posterior area 22 (Wernicke's area) was not involved in the lesion. The inferior parietal lobule was almost entirely spared except for a small portion of area 40 (supramarginal gyrus). However, there was considerable damage to the white matter deep to the inferior parietal lobule.

## SIGN LANGUAGE DIAGNOSTIC PROFILE OF W.L.

As part of our general program of studies at the Laboratory for Language and Cognitive Studies, the subject was given our Sign Language

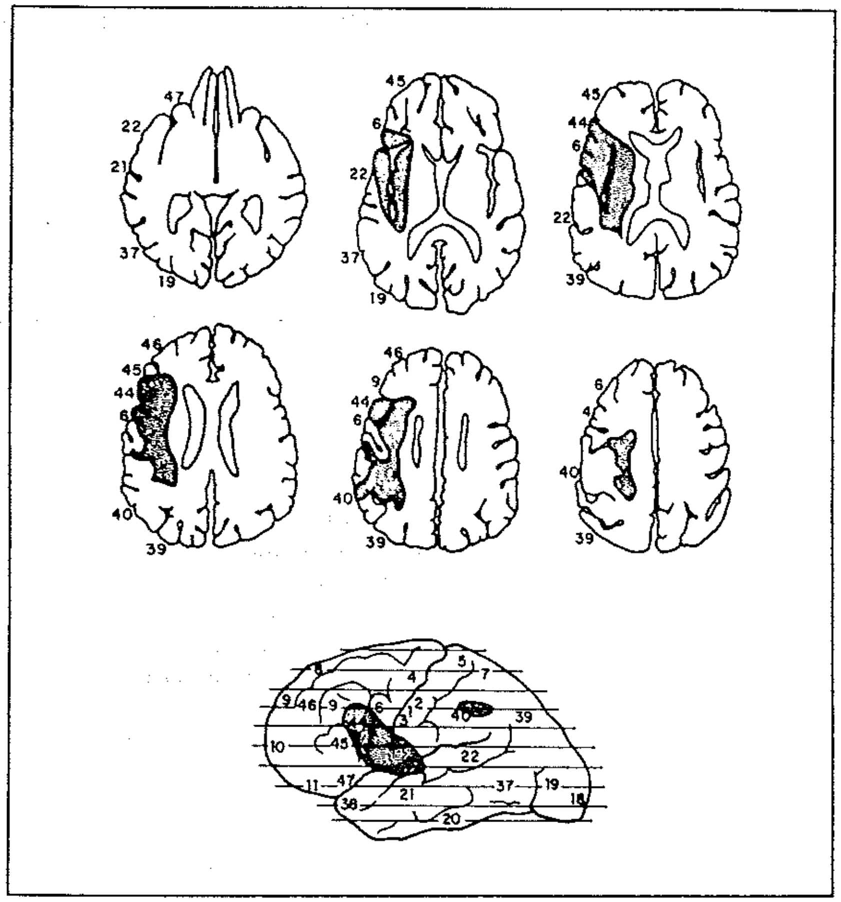

FIG. 3. Mapping of brain lesion from left-hemisphere-damaged deaf signer, W.L.

Aphasia Battery, which includes formal tests for processing specific levels of ASL structure (Bellugi, 1988) as well as the Salk Aphasia Examination (an ASL version of the Boston Diagnostic Aphasia Examination, based on Goodglass & Kaplan, 1983). In addition we presented our battery of nonlanguage visuospatial tests, apraxia tests, as well as tests for comprehension of pantomime. All tests were administered by a native deaf signer using ASL. W.L.'s left-hemisphere lesion produced a marked sign language aphasia disrupting both comprehension and production of sign language. Figure 4 presents W.L.'s sign language profile as assessed by his performance on the Salk Aphasia Examination compared with controls. Test results demonstrated that W.L. tends to be motorically fluent in his signing with good intonational contour, having somewhat depressed phrase length, but good articulatory agility. W.L. used his right hand as his

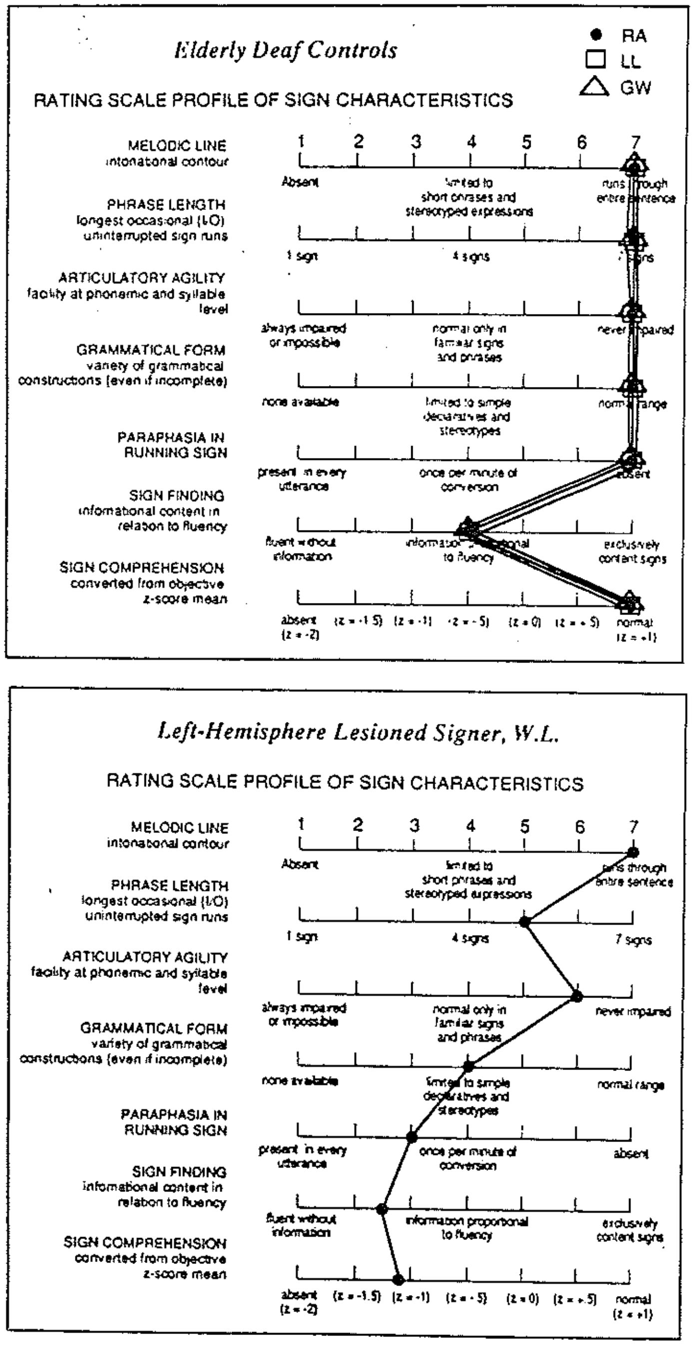


FIG. 4. Rating scale profiles of sign characteristics from the Salk Aphasia Examination, an ASL version of the Boston Diagnostic Aphasia Examination. Comparison of elderly deaf controls (top) and left-lesioned signer W.L. (bottom) reveals marked sign aphasia in W.L.

dominant hand in signing. His grammatical form is compromised, consisting of largely uninflected verbs, fewer nouns, and virtually no pronouns. His signing output had many neologisms and paraphasias. In cases where W.L. chose a two-handed sign variant (e.g., FINE[emphatic]), paraphasic errors were evidenced on *both* right and left hands. This evidence argues against a motor-weakness explanation for these sign paraphasic errors. He was very poor at repetition and showed sign finding difficulties. His overall comprehension of sign language was poor. This language profile has aspects of Wernicke's type aphasia, although his reduction in grammatical forms suggests a more global deficit. In testing of visual spatial abilities, W.L. like other left-hemisphere-damaged signers previously reported, showed no deficits (Poizner, Bellugi, & Klima, 1989). We briefly discuss the finding from these visual spatial tests below. We then turn to the main focus of this paper, the comparison between linguistic and nonlinguistic gestural abilities.

## PRESERVED NONLANGUAGE SPATIAL COGNITION

Nonlanguage visuospatial functioning was assessed by a range of tasks, including the Parietal Lobe Battery of the Boston Diagnostic Aphasia Examination (Goodglass & Kaplan, 1983), the Benton Test of Facial Recognition (Benton, Van Allen, deS Hamsher, & Levine, 1978), the Benton Test of Judgement of Line Orientation (Benton, Varney, & deS Hamsher, 1977), and the WAIS-R Block Design Test. These tests are ones on which hearing patients with right-hemisphere damage often show specific visuospatial impairments. When appropriate, we compare W.L.'s score to that of S.M., a right-hemisphere-damaged signer reported extensively in Poizner et al. (1989). S.M. has a large lesion involving much of the territory of the right middle cerebral artery. Had this lesion been in the left hemisphere, it would have likely produced a global aphasia.

W.L. scored well within normal limits on the facial recognition task, getting 43/54 correct, an excellent score. Moreover, on the judgement of line orientation task, W.L. scored perfectly: 30 responses out of 30 items correct. An example item from the test is shown in Fig. 5. Benton, deS Hamsher, Varney, and Spreen (1983) provide normative data on control and on brain-damaged patients and provide corrections for age and educational level. W.L.'s scores on both of these tests are excellent, showing remarkably good and completely unimpaired visuospatial capacities, as well as excellent attentional capacities for the tasks. Indeed, his performance on one of the two was perfect, above the score for any of the brain-damaged patients examined to date in The Salk Institute program.

On a spatial construction task, the WAIS-R Block Design Test, the subject is asked to assemble four or nine three-dimensional blocks with red, white, or half-red and half-white surfaces to match a two-dimensional model of the top surface. W.L.'s performance on the block design task

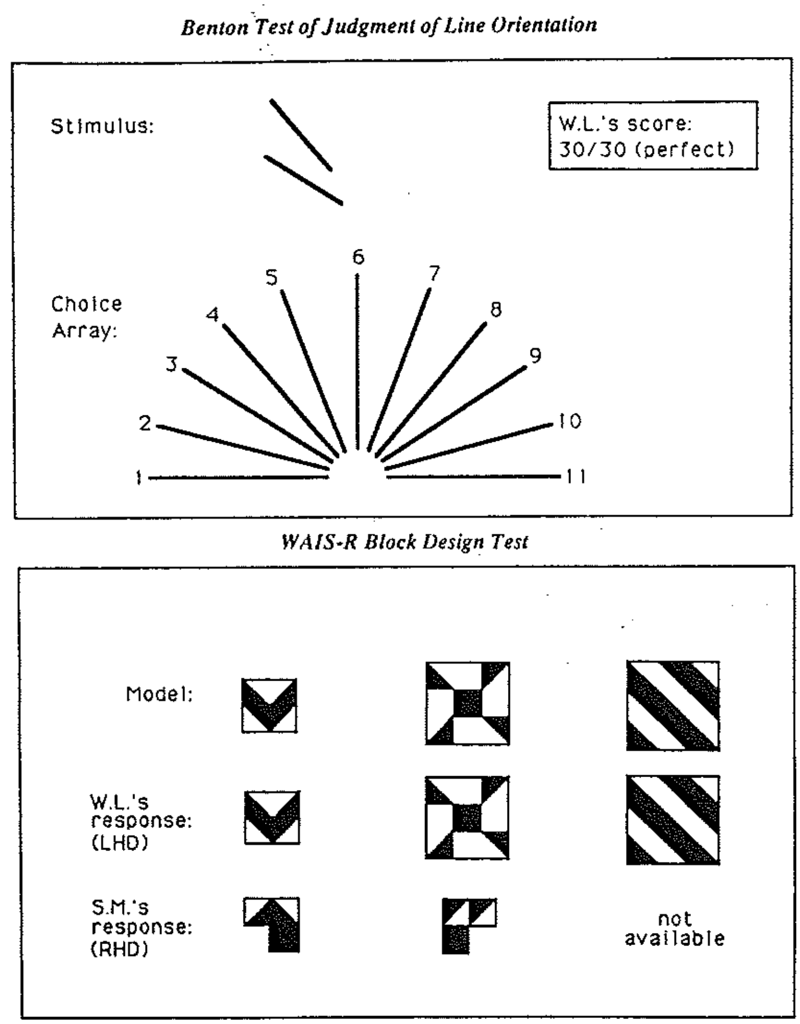


FIG. 5. Visuospatial tests illustrating preservation of nonlanguage visuospatial abilities in left-lesioned signer W.L. in contrast with the impaired performance of right-lesioned S.M.

was excellent, showing remarkable nonlanguage spatial abilities, in contrast to that of our right-hemisphere-lesioned patients. The contrast between spared ability in W.L. and deficient performance in his right-lesioned counterpart, S.M., is shown in the bottom of Fig. 5.

Another spatial cognitive task which typically differentiates right- from left-lesioned subjects is drawing, either from a model or to command. S.M., the right-lesioned patient, was an artist before her stroke. After

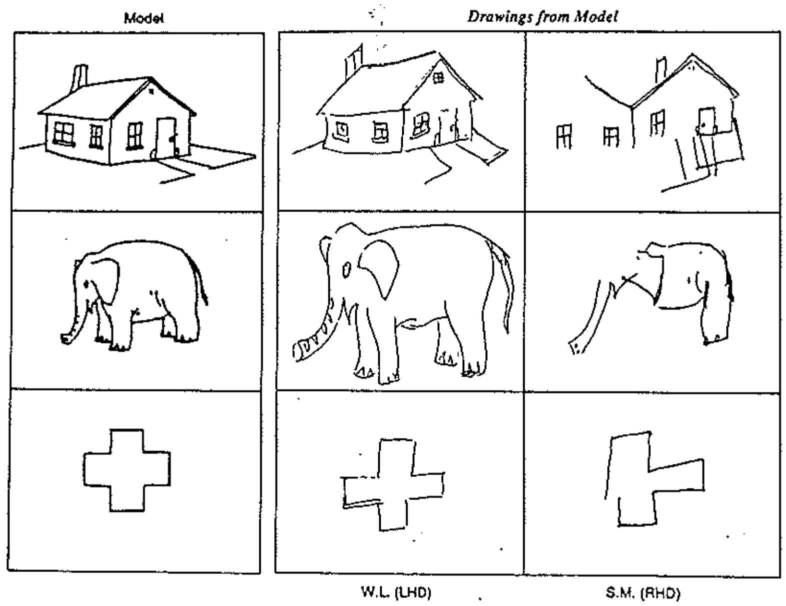


FIG. 6. Comparisons of drawings from model of left-lesioned W.L. and right-lesioned S.M., showing preservation of nonlanguage abilities in the left- as opposed to the right-lesioned signer.

her stroke, her drawings were impaired, showing a lack of three-dimensional perspective, severe neglect of the left side of space, and evident distortions. W.L.'s drawings, in great contrast, show good overall configuration, dimensionality, complete use of space, and excellent capacity. Figure 6 compares W.L.'s copies from a model of an elephant and a house with those of S.M. Note the marked preservation of visuospatial abilities in W.L. in contrast to the impairment of S.M.

This profile of spared visuospatial abilities in W.L. following left-hemisphere damage is consistent with previous reports of spared spatial cognition in left-lesioned signers and points to the right hemisphere's mediation of nonlanguage visuospatial processing in deaf signers as well as in hearing speakers. W.L.'s marked and specific sign language aphasia, discussed in detail below, highlights the separation between language and spatial nonlanguage functions in deaf signers, even when the language itself relies heavily on spatial processing. We turn now to discussion of W.L.'s performance on selected tests of language and gesture production and comprehension.

## SEVERELY IMPAIRED SIGN LANGUAGE PRODUCTION

*Naming/sign fluency.* To test fluency in sign naming, the subject was asked to name as many animals as possible in 60 sec. Non-brain-damaged signers, on the average, produce 25 animal names and have always provided responses consisting of lexical signs or fingerspelled names for specific animals. W.L.'s performance on this test was poor; he generated only three correct responses. Interestingly, his responses were not exclusively signs, as is typical of deaf signers on this test, but included a pantomimic intrusion. (Words written in capital letters refer to glosses for ASL signs, bold lowercase words refer to actions which are mimed, and square brackets are used to indicate paraphasic responses.)

1. CAT
2. HORSE
3. [neologism]
4. BIRD + **(W.L. flaps his arms)**
5. UNDER-WATER VARIOUS (circumlocution for fish)

It is interesting that despite W.L.'s correctly signed response for "bird" he adds a pantomimic descriptor of "flapping his arms" as if to further clarify his response. This is a highly unusual pattern which has not been seen in deaf control subjects nor in other deaf signers with brain damage. In some sense this error would be similar to a normally hearing person substituting "arf arf" when trying to produce the word "dog," a highly marked response.

*Sign repetition.* W.L. performed poorly at reciting automatic sequences (e.g., days of the week, months of the year), although he was slightly better at counting than reciting the alphabet. In sign repetition, single signs were adequately repeated. However, repetition of more complex sign sequences (e.g., the number 1776 and CALIFORNIA GOVERNMENT) was much worse. Repetition of phrases was very poor. W.L. often repeated only a single word or two from the entire phrase (e.g., Target: NOW BEAUTIFUL DAY, Produced: BEAUTIFUL DAY). Most often his repetitions were off-target or not understandable due to the frequency of neologistic intrusions.

*Narrative description.* W.L.'s description of the BDAE Cookie Theft Picture is particularly revealing. It demonstrates W.L.'s tendency to mix sign and mime in his language output. This intermixing of sign language and gesture, characteristic of W.L.'s output, is quite remarkable and certainly deviates from normal sign language production. We present a portion of this description below:

> CHAIR **(W.L. teeters his body to indicate the chair was teetering)** STAND **(tips his body rightward as if he is falling, hand outward as if to brace for a fall)** WATER FLOW-DOWN **(moves body to the right, following the flow of the water).**

Clearly this is an impoverished description. With additional cueing, W.L. was able to provide more detail. What is more interesting than the brevity of the description is W.L.'s consistent interjection of mime. For example, following the correct sign for "chair," W.L. added a pantomimic descriptor indicating that the chair was "tipping." This was followed by the correct sign for "stand" and then again a pantomimic description indicating that someone was "falling." Finally, W.L. correctly described the fact that water was overflowing from the sink but added a body movement which emphasized the direction of the water's flow. This mixture of signs and mimes is very unusual, but characteristic of W.L.'s output. We will discuss the implications of this unusual pattern below.

*Story reproductions.* To elicit aspects of ASL sentence structure, we asked W.L. to retell a picture book story without words, used across our subjects. In the picture book, a boy is walking down a street. He sees a man selling balloons and asks him for one. The balloon escapes his grip and flies away, and the boy cries. W.L.'s retelling of the picture story required much prompting by the examiner, even though the book was present. An approximate English rendition is presented below:

> Walking. Working. He gave him [phonological paraphasia in ASL] (analogous to "malloon" for target "balloon"). Just one. He gave one, then holding and walking. Held, and let go and flew away. (Boy) [phonological paraphasia in ASL] (analogous to "bybing" for target "crying"). Lost.

As can be inferred from this translation, W.L. has the grasp of the story but fails to correctly produce the ASL signs for the boy or the objects involved. Instead, he primarily uses verbs to describe the events and, in addition, phonological paraphasias replace target ASL nouns. He does, however, make use of some spatial verb agreement in the sign "GIVE," correctly indexed for subject and object of the verb, respectively.

*Semantic blends of signs.* W.L. showed occasional semantic blends of signs that were often quite elaborate and complex. In identifying a picture of a tree, W.L. signed the location and hand arrangement of the sign "TREE" but with the handshape and movement of the sign "GREEN"; in identifying a picture of a book, W.L. made the movement and location of the sign "TURN-PAGES" but with a handshape appropriate to the sign "SEE." These unusual semantic blends suggest that in W.L.'s mental lexicon semantically related items were often coactivated at some stage in production prior to the actual phonetic programming.

*Phonemic paraphasias in a sign language.* Highly characteristic of W.L.'s sign language output is the abundance of neologistic and paraphasic errors in signing. To understand the nature of these errors, we refer back to the phonological structure of ASL. Research on the structure of lexical signs in ASL has shown that signs are decomposed into sublexical elements just as are the words of spoken languages. It is well established that this level of linguistic structure in ASL is functionally analogous to the phonological level of spoken languages. Recent linguistic analyses focus on the segmental structure of signed languages, suggesting a sequential structure analogous to the phonemes and syllables of spoken language (Liddell & Johnson, 1989; Perlmutter, 1989). Based on evidence from minimal pairs in ASL, there are four major parameters of sign formation: handshape, location, orientation, and movement (Stokoe et al., 1965; Klima & Bellugi, 1979; Battison, 1978). These parameters are formally analogous to the analyses of sound along parameters of place, manner, etc. Each parameter encompasses only a limited number of specifications (e.g., just as for the parameter of place, we identify labial, labiodental, alveolar, etc.), which can be recombined in systematic ways to form the lexical items of the specific language. This structural systematicity reflects the underlying compositionality of linguistic systems.

In spoken language aphasias, phonemic paraphasias consist of substitutions of sublexical elements, for example /dei/→/tei/ (Blumstein, 1973). In ASL, sublexical structural errors have been occasionally noted in left-lesioned signers. For example, Poizner et al. (1987) report a handshape paraphasia in a left-hemisphere-damaged signer, K.L. This paraphasia occurred in the sign "CAREFUL," which in its correct form is signed with a "K" handshape. The left-hemisphere-damaged signer, however, substituted the "W" handshape. Another paraphasic error produced by K.L. indicated a substitution of the parameter movement. K.L. produced the sign "ENJOY" with the correct handshape, but with an up and down movement rather than the circular movement correct for the sign.

We analyzed a corpus of 17 paraphasic errors of W.L. obtained from free conversation and from a responsive naming task in which the target sign is derivable either from the produced sign's similarity to the intended sign target or from signing context. This analysis showed that W.L.'s frequently occurring paraphasic errors were predominantly at the *phonological* level, rather than at any other linguistic level of ASL structure. We examined the form of these errors in the context of the major formational parameters of ASL: handshape, location, orientation, and movement. The results indicate 17 handshape errors, 3 movement errors, but no errors in the other parameters of location and orientation. Some of these handshape errors are illustrated in Fig. 7. We note that even when a movement error occurred, it also involved a handshape error. Importantly, these paraphasic errors were not limited to only the right hand, but are observed on both hands in instances of two-handed signs. Thus these errors cannot be discounted as an effect of motoric weakness. This impairment of a single phonological parameter, handshape, following brain damage is striking. Such a particular fractionation of sign language following brain damage has never been reported before and is quite re-

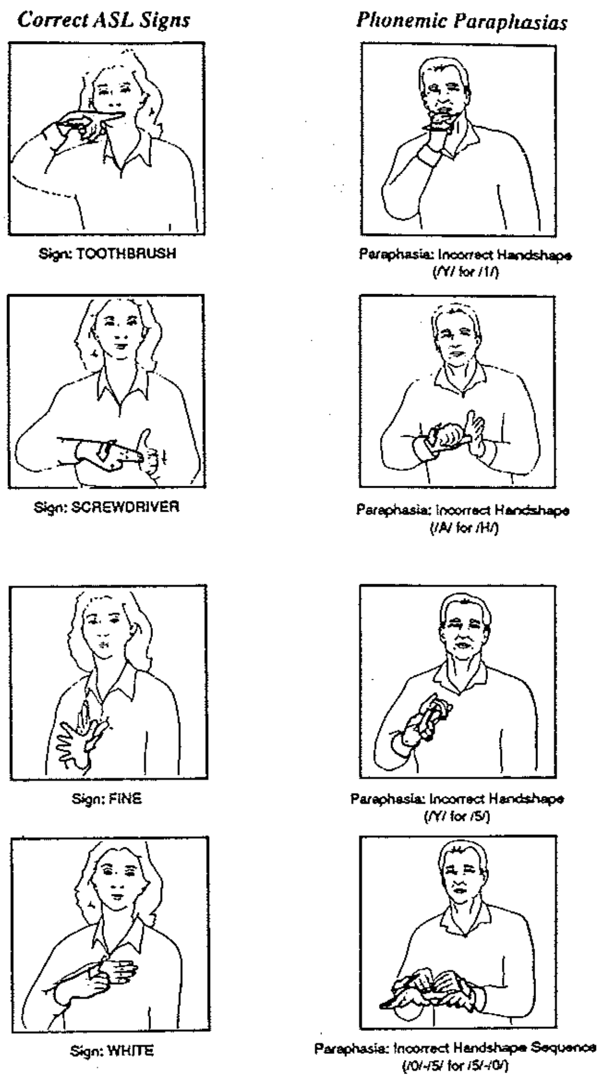


FIG. 7. Phonological paraphasias from left-hemisphere-damaged signer W.L. implicate impairment of a specific phonological tier: handshape.

vealing. The paraphasias are highly selective in terms of only one parameter in the formational composition of signs: handshape. The vulnerability of this one phonological parameter is consistent with hierarchical models of ASL phonology which treat handshape as a phonological tier separate from location, orientation, and movement (Sandler, 1989; Liddell & Johnson, 1989). We argue that such a pattern of sign language breakdown,

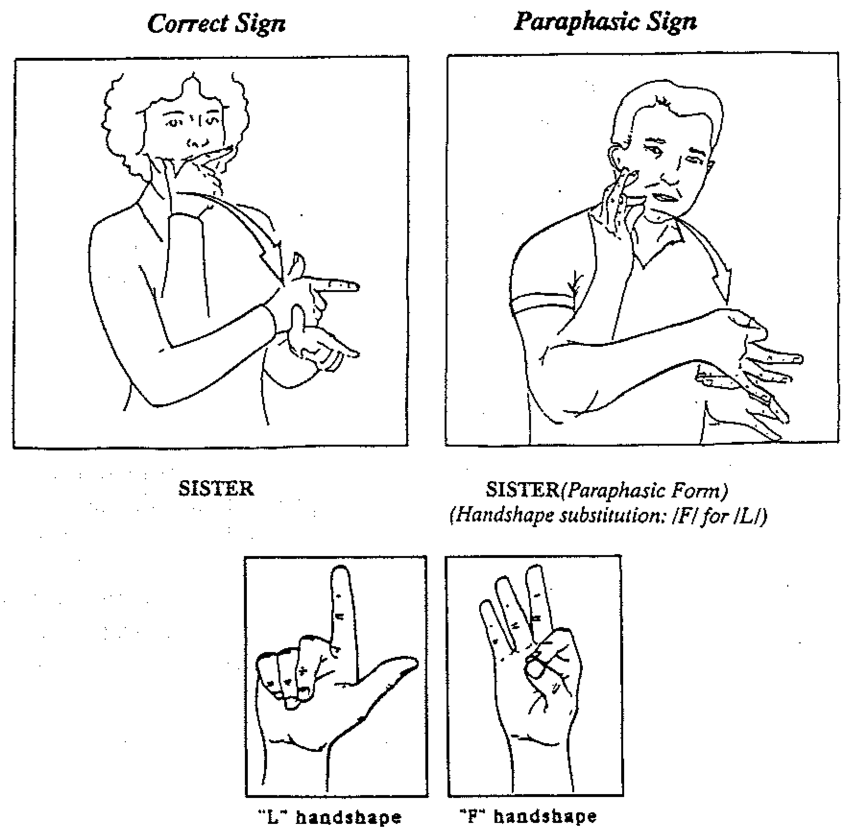


FIG. 8. The sign SISTER (correct) and paraphasic form. In the paraphasic form, an F handshape is substituted for the intended L handshape. On the surface these handshapes are quite dissimilar, but phonological underspecification theory reveals a great deal of similarity. These facts argue for a phonemic rather than phonetic level of impairment (Corina, 1991).

following brain damage, provides support for an autosegmental model of ASL phonology and for the structural coherence of phonology in ASL and its dissolution.

In a separate paper, Corina (1991) provides a detailed linguistic analysis of these paraphasic errors couched in current linguistic theory. While the details of the analysis are beyond the scope of the present paper, the data speak in favor of a phonemic rather than a phonetic impairment. Specifically the analysis reveals that comparisons of *surface* handshape substitutions are largely dissimilar and unmotivated. For example in one characteristic paraphasic error W.L. substitutes an F handshape for an L handshape as seen in the sign SISTER (Fig. 8, top). On the surface these handshapes bear little similarity to one another (Fig. 8, bottom). However, viewed in light of an independently motivated phonological underspecification analysis (Corina, 1990; Corina & Sagey, 1989), the handshapes L and F are highly similar. In this phonological analysis, these two handshapes share a specified thumb and index finger and differ only in the configuration values for these specified fingers. Under this analysis the L and F handshapes differ by only two distinctive features. The phonemic specifications for the remaining fingers (middle, ring, and pinky) are predictable and thus unspecified at this level of representation. Thus the analysis of underlying forms reveals a striking degree of regularity of handshape substitution which is unavailable from an analysis of phonetic level features. The selective impairment to a sublexical component of grammar provides striking evidence that W.L.'s aphasia stems from a linguistic disturbance. The finding that sign languages, like spoken languages, cleave along linguistically relevant boundaries following left-hemisphere damage provides evidence for a left-hemisphere capacity for language that is independent of transmission modality.

W.L.'s sign language production indicates a severe production impairment. Phrase length was limited, composed mostly of verbs, yet executed in a motorically fluent fashion. W.L.'s lack of referents in his signing places the burden of interpretation on the addressee. Furthermore, his signing shows marked paraphasias as well as neologisms. The forms of these paraphasias are particularly interesting and implicate primarily phonemic level impairment.

## REMARKABLY PRESERVED PANTOMIMIC GESTURE PRODUCTION

We have presented evidence that W.L., like other left-hemisphere-damaged deaf signers studied in The Salk Institute program (Bellugi et al., 1989), had a severe sign aphasia. However, unlike the other left-hemisphere-damaged signers, W.L. showed a highly unusual pattern, frequently reverting to pantomime instead of sign. Indeed, we were struck by the extent to which W.L. would interject pantomimic forms for lexical signs in stretches of ASL discourse. As noted, his deaf wife remarked how this intrusion of pantomime into sign communication differed significantly from his prestroke signing. These pantomimic forms accompany signs and sometimes appear to embellish the meaning of signs. At other times they serve to substitute for signs. This pattern of substitution, in the context of aphasic breakdown, has important theoretical significance: it indicates a separability of nonlinguistic pantomime and a linguistically based sign system such as ASL. This is particularly striking since both pantomime and signs are expressed through hand movements.

*Substitution of mime for sign.* Table 1 presents clear cases in which W.L. used pantomimes spontaneously as substitutes for signs or as embellishments for signs. Signs are represented in capital letters, whereas descriptions of mimed actions are in lowercase and bold. The right-hand

TABLE 1
PANTOMIME INTRUSIONS FOR SIGNS

| | Intended sign target |
|---|---|
| Shape mimes | |
| 1. Uses his hands palms down moving back and forth to indicate a flat surface | TABLE (n) |
| 2. Cups his hands to form a small cup | DRINK (v) |
| 3. Uses a complex sequence of mimes to form a stem, petals, and blossom of a flower | FLOWER (n) |
| 4. Traces out the shape of a book | BOOK (n) |
| Function mimes | |
| 5. Swings an imaginary bat | BASEBALL (n) |
| 6. Dribbles an imaginary ball | BASKETBALL (n) |
| 7. Holds an imaginary cup by the handle and raises it to his mouth | DRINK (v) |
| 8. Holds his fist out clenched | HAND (n) |
| 9. Demonstrates use of imaginary scissors | SCISSORS (n) |
| 10. Acts as if he is turning on a stove, POUR, pouring a drink from a tea pot | TEAPOT (n) |
| 11. Demonstrates how to smell a flower | FLOWER (n) |
| 12. Demonstrates how one takes a bite from an apple | APPLE (n) |
| 13. Mimes the raising of a window | WINDOW (n) |
| 14. Arms out-stretched body leans forward | AIRPLANE (n) |
| 15. Demonstrates tripping, places his arms out as if to brace himself from a fall | FALL (v) |
| 16. CLOSET, arms folded near his sides fists clenched "shiver," motions to raise a window | WINDOW (n) |
| 17. Open hands and palms facing W.L., head moves back and forth as if reading | BOOK (n) |
| 18. Clenched fists rotate on cheeks, grimaces as if crying | CRY (v) |
| 19. BED, closes his eyes | SLEEP (v) |
| 20. Puffs cheeks and blows out imaginary smoke | SMOKE-CIGARETTE (v) |

column indicates the intended target and the grammatical class of the target (e.g., (n)oun or (v)erb). These examples were taken from free conversational passages and a responsive naming task. We examine the form of these pantomimes and note an interesting pattern of their use. We then move to formal tests which demonstrate W.L.'s preservation of gestural abilities.

The systematic pattern of substitution of manual pantomimic gestures for signs is quite striking and unlike any pattern of aphasic signing reported in the literature or witnessed in our extensive sign aphasia program. What makes this performance all the more interesting is that, as indicated in the right-hand column of Table 1, each of the gestural substitutions replaces a common, conventionalized, manual sign of ASL. The pantomimic substitutions differ markedly from ASL signs. The mimes extend far be-

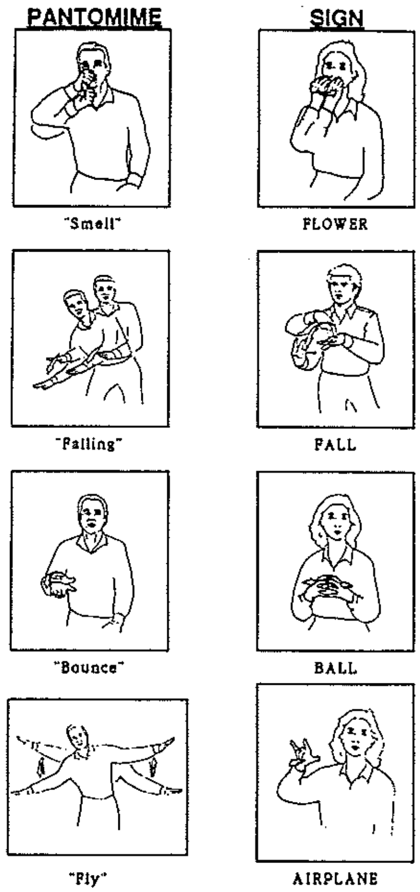


FIG. 9. Spontaneously substituted pantomime forms for ASL signs.

yond the boundaries of the limited set of components that make up ASL signs and may involve complex sequences, arm and body movements, and gestures far removed from ASL signs. For example, instead of signing "AIRPLANE," W.L. stretched his arms out beyond the boundaries of signing space and moved his head and torso from side to side. Similarly, instead of signing "FALL," he mimed a body action of falling. Instead of signing "FLOWER" and "BALL," he mimed an action of smelling and an action of bouncing a ball. These instances, in which W.L. is producing nonsign pantomimes rather than ASL signs, are illustrated in Fig. 9.

The substitution of pantomime for sign is all the more surprising given the apparent iconicity afforded by sign language. For example, in response to a picture of a pair of scissors, W.L. opened and closed his fist while miming the act of "cutting" along an imaginary line, instead of making the ASL sign "SCISSORS." This pantomimic substitution is surprising since the ASL sign for scissors uses the index and middle finger to represent the opening and closing blades of the scissors. In fact, the ASL sign for scissors is analogous to "body part as object" errors commonly seen in hearing apraxic patients when asked "Show me how you use scissors?" (Heilman, 1979), and yet W.L. produces a pantomimic response.

Quite often W.L.'s production of pantomime gestures was more sequentially complex than the surface form of the corresponding ASL sign. For example in another instance of miming "flower," W.L. produced a sequence of mime descriptors for the stem, the petals, and the blossom of a flower. In contrast, the ASL sign "FLOWER" appears quite simple. It consists of a hand closed at the finger tips which touches twice beneath the nose, but is nevertheless structurally compositional. The components of this sign are drawn from a limited set of ASL phonological components which reoccur in other ASL signs.

## DIFFERENTIAL BREAKDOWN OF PANTOMIME AND ASL SIGN

It is of interest to note that W.L.'s use of pantomime is unencumbered and fluent. We do not find evidence for groping errors in his production of pantomime, although these do sometimes occur in the production of ASL signs. Moreover, we do not find examples of what may be termed articulatorily distorted pantomimes (e.g., showing how to bounce a ball with a closed rather than open fist). This fluent pantomime stands in contrast to his sign production in which we often find paraphasic errors, which nonetheless use permissible components of ASL signs. The differential *breakdown* observed within these gestural systems serves to illustrate the difference between a compositional linguistic system and nonlinguistic pantomime. However, the pattern of *usage* of sign and pantomime by W.L. suggests similarities rather than differences at a communicative level.

As Table 1 illustrates, most of the pantomimes are substitutions for nouns. Recall that W.L.'s signing is composed largely of verbs and adjectives, with relatively few nouns or pronouns. Thus, it appears that W.L.'s pantomime intrusions may stem from his difficulty with noun signs and may be an attempt to compensate nonlinguistically for his linguistic deficit. Furthermore, we see that the majority of pantomimes are descriptions of actions rather than objects. This interplay between linguistic and nonlinguistic gestural systems at a communicative level is intriguing. Research on spoken language development has provided evidence that early in the acquisition process gestural ability and spoken naming coevolve in hearing children. Thus, ontologically at some communicative level gesture and language may be functionally homologous (Bates et al., 1988). The emergence of W.L.'s compensatory strategy following the dissolution of language may be a reflection of a functional homology between language and gesture. Nevertheless, the difference in the production and breakdown of sign language, relative to pantomimic gesture, places limits on the degree to which these systems can be argued to arise from a common source.

## STANDARD TESTS OF NONLINGUISTIC GESTURE

In addition to the rich corpus of spontaneously generated pantomimes analyzed, two standard tests of gestural ability were administered. These tests demonstrate that W.L.'s ability to produce mime outstrips his ability to communicate in a linguistic gestural system, ASL. We used the slightly abbreviated form of Kimura and Archibald's (1974) Movement Copying Test described in Kimura (1982). The task is to imitate multicomponent movements of the hands and arms in unfamiliar and meaningless sequences. The subject sees three movements to be imitated, each involving only one hand and arm. The first movement has an open hand with all the fingers spread, positioned perpendicular to the body in front of the opposite arm. The hand is swept across the body, and the extended fingers move from spaced apart to touching each other. This movement is scored for initial hand posture, initial hand orientation, lateral and straight movement, and proper hand closing. In the second movement, the extended fingers and thumb are in contact, the back of the hand slaps the other forearm, rotates, and then the palm slaps the forearm. This movement is scored for hand posture, forearm rotation, and front and back slaps. The final movement in the series starts fingertips and thumb together in a ring, all touching the forehead, rotating and opening as it moves out. This movement is scored for starting posture, forward and linear movement, forearm rotation, and hand opening. Two trials are given for each sequence. Each component of each sequence is given a score of two if performed correctly on the first trial, a score of one if performed correctly on the second trial, and a score of zero if not performed correctly on either trial. Each of the three possible sequences has four components that can be scored, so the maximum score is 24 points. Kimura (1982) reports data from 118 hearing patients with unilateral brain damage: 72 patients with left hemisphere damage and 46 patients with right-hemisphere damage. Because many patients have one hand or arm paralyzed, Kimura scores the hand on the same side as the lesion, where there is no peripheral motor deficit; for W.L. this is the left hand. The mean score of Kimura's (1982) hearing patients with left-hemisphere damage was 59% correct, whereas the mean score of the hearing patients with right-hemisphere damage was 78% correct, significantly higher. Kimura indicates that scores falling below a level of 90% of the mean score of the patients with right-hemisphere damage (80.2%) should be considered impaired. W.L.'s left hand score was 86% correct and is clearly in the

TABLE 2
W.L.'s Performance on Test of Ideomotor Apraxia

| Instruction<br>Show me how you . . . | Command | Imitation | Falls | Comments |
|---|---|---|---|---|
| Buccofacial | | | | |
| Cough | √ | | | |
| Sneeze | √ | | | |
| Kiss | √ | | | |
| Chew | | | × | No response elicited |
| Moves eyes up | | | × | Paraphasic sign response |
| Limb | | | | |
| Wave-goodbye | | √ | | |
| Signal-stop | | | × | Repeated examiner's instruction |
| Call a dog | | √ | | |
| Transitive limb | | | | |
| Throw a ball | | | × | Mimed "swing a bat" instead |
| Clean a bowl | √ | | | |
| Write name | | √ | | |
| Start a car | √ | | | |
| Cut meat | √ | | | |

*Note.* √, correct response; ×, incorrect response.

unimpaired range. Thus W.L.'s ability to produce meaningless gesture sequences was unimpaired.

A test of ideomotor apraxia was administered in which the subject was asked to perform several representational gestures. This test included buccofacial commands ("Show me how you sneeze"), intransitive limb movements ("Show me how you wave good-bye"), and transitive limb movements ("Show me how you throw a ball").[2] If the subject was unable to carry out a movement from command, the examiner then modeled the correct gesture for copying. W.L.'s responses are shown in Table 2. Of 13 possible gestures, W.L. produced 9 correct gestures, 3 to imitation. Importantly the items failed on this test were not due to the production of apraxic-like errors, rather the unsuccessful elicitations were off-target responses which appear reflective of comprehension problems. For example, W.L. mimed the "swinging of a bat" in response to the examiners's gesture "throw a ball," which he was to copy. W.L.'s performance on this formal test of ideomotor apraxia, while not perfect, certainly illustrates a capacity for gestural ability. Interestingly, we note that W.L. substituted a sign only once in response to this gesture elicitation task, and this in fact resulted in a paraphasic form. In contrast, during sign elicitation

[2] Cases where the sign instruction would inadvertently give a clue to the gesture, a fingerspelled item is used, (e.g., SHOW-ME HOW #W-A-V-E-G-O-O-D-B-Y-E).

tasks, we find a much greater frequency of pantomime substitution. For example on a subtest of the BDAE, of 12 items to be named in sign, W.L. provided 5 mime responses, 4 sign responses, and 3 paraphasic responses. Taken together these data suggest that W.L.'s pantomime production is better preserved than his sign production.

A hint with respect to differential comprehension of ASL signs and pantomime in W.L. emerged from consideration of the examiner's difficulty in conveying instructions for this test in ASL. When W.L. appeared not to grasp a particular signed instruction, the examiner sometime resorted to mime in order to prompt a response. In each case that this occurred, W.L. did respond with the correct gesture. For example, after signing several times to W.L. the ASL equivalent of "How do you cut meat?", the examiner pretended to pick up an imaginary steak and tear a bite out of it and queried W.L. as to whether that was the correct way to cut meat. He immediately shook his head "no," proceeded to produce the sign for "KNIFE," and then produced the *gesture* for holding a fork and knife and "cutting" the piece of meat. This suggests that W.L.'s predilection for mime production might extend to comprehension as well. Below we systematically examine this hypothesis. First, however, we present data from sign comprehension measures which demonstrate that W.L. shows severe sign comprehension problems.

## IMPAIRED SIGN LANGUAGE COMPREHENSION

Sign comprehension as assessed by our Sign Language Aphasia Battery, including our formal tests of processing linguistic levels of ASL and the Salk Aphasia Examination, demonstrated a severe comprehension deficit. Comprehension of both single signs and multipart commands was impaired.

*Sign comprehension.* In a test of comprehension, the signer is asked to point to a picture which corresponds to the sign provided by the examiner. While comprehension of many classes of single signs was largely intact, W.L. showed marked deficits in comprehension of certain classes of single signs (e.g., signs for colors) which are not uncommonly found in aphasics with marked comprehension deficits.

*Multipart commands.* As an indication of his difficulty in the comprehension of signing, W.L. was unable to follow simple two-part commands (e.g., Point to the door and then point to the ceiling). Furthermore, performance on complex ideational material (e.g., Will a brick float on water?) also showed marked deficits. Figure 10 shows a comparison of W.L.'s performance on sign comprehension tasks relative to that of a nonaphasic signer, S.M., who had a comparable lesion in the right hemisphere. As Fig. 10 indicates, the right-lesioned signer, S.M., is relatively free of impairment across the three comprehension tasks, whereas left-

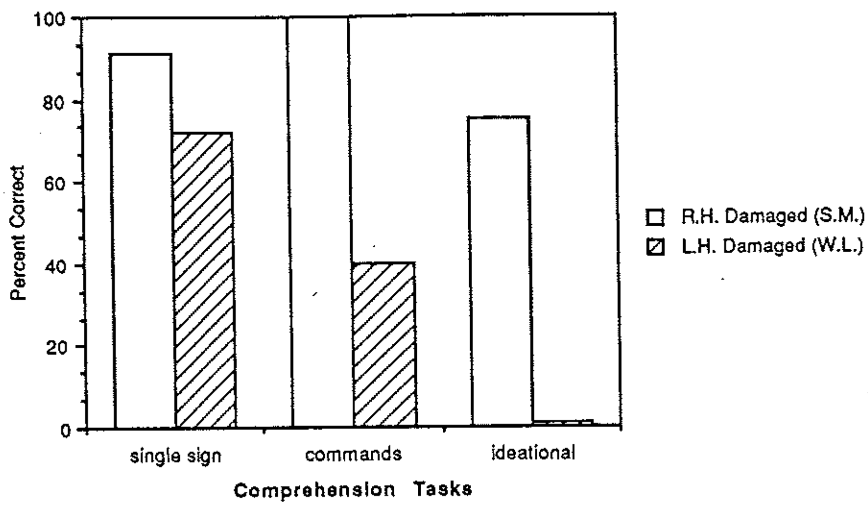


FIG. 10. Comprehension scores illustrating sign language deficits of left-lesioned signer W.L. in contrast with the excellent performance of right-lesioned S.M.

lesioned W.L.'s scores reflect significant impairment across tasks, showing a severe deficit in comprehension of signing.

*Processing spatially organized syntax.* Although ASL uses spatial contrasts at all linguistic levels, the most distinctive use of space is in syntax and discourse. As indicated above, sentence structure in ASL is primarily specified by the way in which verbs, nominals, and pronominal indices are related to one another in signing space. Nominals can be associated with points in a plane of signing space, and pronominal signs directed toward these points refer back to nominals, even after many intervening signs. Verb signs move between such points in signing space, thus specifying subject and object relations. To examine W.L.'s comprehension of ASL syntax, we administered two tests that are part of the Salk Sign Language Battery: the Nominal Establishment Test and the Verb Agreement (Fixed Framework) Test (Bellugi, 1988). The Nominal Establishment Test probes perception and memory for spatial loci associated with specific nominals in signing space. This test assesses necessary underpinnings for understanding nominal and pronominal spatialized reference in sign language. W.L.'s performance on this measure was markedly impaired in comparison to that of right-hemisphere-lesioned deaf signers and controls.

W.L.'s performance was also impaired on another test of spatially organized syntax, the Verb Agreement Test. This test assesses processing of nominals and their associated spatial loci as well as the direction of movement of the verb between spatial loci, crucial aspects of the syntax of ASL. The experimenter signs a sentence describing an event with two participants, either of which semantically could be the subject or the object of the verb. The subject must select the appropriate picture from an array of pictures. W.L. showed marked impairment, performing at chance level on this test of ASL spatialized syntax, attesting to his severe linguistic impairment.

W.L. has a marked sign comprehension deficit, having somewhat impaired single-sign comprehension and chance performance for comprehension of multipart commands and spatialized syntactic relations. Naeser, Helm-Estabrooks, and Haas (1987) have shown that the severity of auditory comprehension disturbances in Wernicke's aphasia correlated with the degree of damage within the posterior two-thirds of the superior temporal gyrus (Wernicke's area) but not with the total temporoparietal size of the lesion. Additional damage to the middle temporal gyrus was also associated with poor outcome. Wernicke's area and the middle temporal gyrus were largely spared in W.L., suggesting that the Wernicke-like sign comprehension disturbances in W.L. were not caused by damage to the classical Wernicke's area. There was also a sparing of most of the inferior parietal lobule, but extensive involvement of the white matter deep to the inferior parietal lobule, which could have disconnected areas 40 and 39 (supramarginal and angular gyri) from anterior language regions. These data suggest that the location of Wernicke's area in a deaf signer may be more caudal to the traditional Wernicke's area and may involve regions more intimately connected with primary visual input, motor praxis, or both.

## PRESERVED PANTOMIME COMPREHENSION

In formal testing of W.L.'s gestural abilities, we discussed anecdotal evidence for preserved comprehension of pantomimic gesture. This is particularly striking in light of W.L.'s very poor performance on measures of sign comprehension. To further assess this possibility, we administered the Varney and Benton (1978) Pantomime Comprehension Test in which the subject is shown a videotape of an actor producing a pantomime for an object (e.g., a man eating an apple). The subject must point to a picture of the correct object pantomimed from a four-choice display including the correct object (apple), a semantically related object (banana), a common object (sink), and an odd object (elephant). W.L.'s performance on this test was well within the normal range. We then presented a version of this test in which the correct *sign* for the target stimulus was presented rather than the pantomime. W.L.'s performance on the sign version was impaired relative to that of our deaf elderly controls, who routinely score near 100% on this test. Thus, we find a sparing of W.L.'s comprehension of pantomime which parallels his production of nonlinguistic gesture (see Fig. 11). This interesting pattern stands in marked

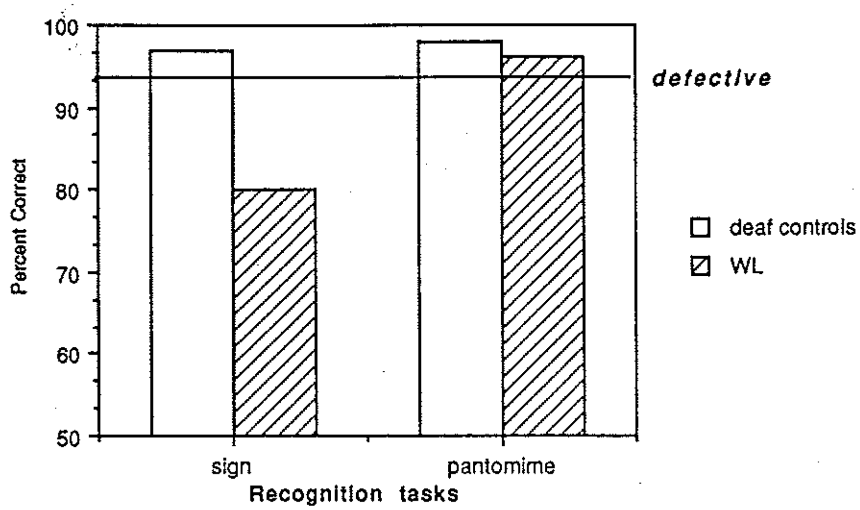


FIG. 11. Impaired sign recognition with intact pantomime recognition in left-lesioned W.L.

contrast to his severe deficits in the comprehension and production of ASL signs.

## DIFFERENTIAL DISRUPTION OF SIGN AND MIME

As is evident from the Sign Diagnostic profile, the formal tests of ASL processing, linguistic analysis of signing, and performance on nonlanguage visuospatial tests, W.L. has a severe sign aphasia with spared visuospatial abilities. W.L.'s performance on a range of linguistic tests of ASL processing reveals severe deficits for both comprehension and production of sign language, as well as for repetition of signs. W.L.'s sign output may be characterized as fluent, with reduced phrase length but good articulatory agility. We note that in his spontaneous signing, as well as in his responses to formal testing, there were widespread paraphasias and neologisms and a conspicuous lack of explicit referents. Despite the marked aphasia for sign language, W.L. shows excellent capacity in visuospatial cognitive tasks.

Two facets of W.L.'s language performance deserve particular attention. First, there are a wide range of sign paraphasias which appear to be almost exclusively phonological in nature. These paraphasias provide evidence for breakdown of linguistically relevant categories in this sign aphasic. Second, W.L. shows extensive use of effective and well-articulated pantomime in many contexts where ASL signs and signing were called for, requested, and appropriate.

## DISCUSSION AND SUMMARY

This case illustrates a striking dissociability of nonlinguistic gestural abilities from the use of a highly evolved linguistic gestural system, American Sign Language. This differential disruption of linguistic (sign) and nonlinguistic gestures (mime) thus poses a challenge to theories which assume an undifferentiated motoric basis for both language and gesture. Below, we discuss implications this case holds for our understanding of the neural organization underlying language and gesture.

The study of the fractionation of sign language abilities in deaf subjects who have incurred localized lesions to the brain provides new insight into brain function for language. The present case of a left-lesioned signer adds to the recent, but growing, body of data indicating that anatomic structures within the left cerebral hemisphere mediate the processing of visuomanual, as well as auditory–vocal languages. This left-lesioned signer, with an intact right hemisphere, was severely aphasic for both the expression and the comprehension of sign language. His sign expression, while motorically fluent, showed a conspicuous lack of referents, and numerous phonological sign paraphasias, and neologisms. The compositions of the sign paraphasias were particularly interesting and implicate a tier-specific phonological impairment. Moreover, he showed marked sign comprehension deficits. In contrast to his severe linguistic deficits, the subject's nonlanguage visuospatial capabilities were remarkably intact. Clearly, auditory experience and speech are not necessary prerequisites for the development of hemispheric specialization in man.

A remarkable feature of this case is the preservation of the comprehension and production of pantomime in the face of his severe sign language aphasia. W.L. performed normally on a test of pantomime comprehension but showed defective performance on the same test of comprehension for ASL signs. Moreover, W.L. showed a preserved ability to produce pantomimic gestures and often substituted nonsign pantomimes for ASL signs. Importantly, it must be acknowledged that this dissociation between the production of linguistic gesture (ASL) and that of nonlinguistic gesture (pantomime) cannot be attributed to differences in control of articulatory movement. Recall that W.L.'s performance in a task copying nonrepresentational movement sequences was normal. Furthermore, W.L.'s spontaneous nonlinguistic gestures were often multicomponent movement sequences which served as replacements for conventionalized, outwardly simple signs. It is clear that no simple notion of motoric complexity, such as sheer number of sequential produced movements, can account for the production differences found in the present case.

The selective sparing of production and comprehension of gestural abilities in the face of a severe sign language aphasia, as evidenced in W.L., has important theoretical implications for our understanding of the neurological basis of language and gesture. Since the early 1900s, researchers have theorized about the close association between disturbances of gesture and disturbances of language following left-hemisphere damage. Theories attempting to account for the close association between language and gesture typically posit either a shared conceptual or motoric basis as the common denominator (Finkelburg, 1870; Dejerine, 1906; & Kimura, 1977, 1982). While explanations based upon shared conceptual structure are discounted by the fact that the severity of aphasia does not correlate with the degree of gestural impairment (Goodglass & Kaplan 1963), evidence for motor-based accounts are more compelling (Kimura, 1982; Kimura & Watson, 1989). However, the very rare case of a hereditary deaf signer reported here, who shows a remarkable separation between linguistic and gestural function, places limits on the degree to which impairments in language and gesture can be viewed as emanating from a common undifferentiated motoric base. This is made particularly clear in the present case as the transmission of both linguistic signal and gestural pantomime utilizes the same manual articulators. This finding is important not only within the realm of sign language research but also extends to disturbances underlying spoken language aphasia as well. A careful analysis of this case suggests principles which may help to understand the neural separation of linguistic gesture (ASL) from nonlinguistic pantomimic gesture.

The differential disruption of linguistic and nonlinguistic gestures is not attributable to *surface* level complexity (indeed pantomimic forms are often composed of more complex action sequences than corresponding sign forms) but the *internal* organization underlying these movement systems. The critical difference between nonlinguistic and linguistic gestures is the degree of *compositionality* which underlies these movement systems. Compositionality in natural languages refers an organizational principle in which basic meaningful units (phonemes, morphemes, etc.) are constructed from a small set of recurring elements. Importantly, the combination of these units exploits hierarchical patterning at all levels of linguistic structure. While this is a descriptive formalism, compositionality permits a systematic distinction between true linguistic gestural systems (e.g., ASL) and communicative pantomimes, which as demonstrated in the present case may be differentially disrupted. The present case suggests that motor system which embody hierarchical compositionality will be differentiable from motor systems which lack this kind of or degree of organization. The compositionality hypothesis receives support from the existence of paraphasic errors evident in W.L.'s signing. Recall that these errors implicate a phonemic level language impairment and indicate the dissolution of sublexical level language structure. In contrast, nonlinguistic gestural abilities in W.L. are unencumbered and motorically fluent. This systematic difference in structural integrity serves to illustrate the qualitative differences in the internal structure of language versus pantomime.

Sign language, as spoken language, is compositionally dense, while pantomime appears to lack the same degree of organization. The analysis of language and gesture breakdown, cast in light of compositionality, may begin to provide a better account of the interrelationships and differences between language and gestural systems. Ultimately, understanding the neural basis of encoding for compositional motoric systems may lead to a principled anatomical account of the neural separability of language and gesture. Although at some level there must be convergence of the neural systems mediating sign language and manual gesture, this case shows that the neural systems underlying sign and pantomime may be separable.

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