Chapter 1

Preliminaries: Language in a Visual Modality

In all known societies of hearing people, language takes the form of speech. In the course of human evolution, the vocal tract, the breathing organs and muscles, and the brain have all developed in conjunction with spoken language. Until recently, nearly everything learned about the human capacity for language came from the study of spoken languages. It has been assumed that the organizational properties of language are inseparably connected with the sounds of speech. The fact that, normally, language is spoken and heard presumably determined in part the basic structural principles of grammar. There is good evidence that the structures involved in breathing, chewing, and the ingestion of food have evolved into a versatile and more efficient system for producing sound. Studies of brain organization for language indicate that the left cerebral hemisphere is specialized for linguistic material in the vocal-auditory mode and that the major language-mediating areas of the brain are intimately connected with the vocal-auditory channel. It has even been argued by some that hearing and speech are necessary prerequisites to the development of cerebral specialization for language in the individual (McKeever et al. 1976). Thus the link between biology and linguistic behavior has been identified with the auditory modality, the particular modality in which language has naturally developed.

Language, however, is not limited to the vocal tract and ears. There also exist systems of symbolic communication, passed down from one generation of deaf people to the next, that have become forged into autonomous languages not derived from spoken languages. These visual-gestural languages of the deaf, with deep roots in the visual modality, provide a testing ground for competing explanations of how the brain is organized for language, how the brain came to be so organized, and how modifiable that organization is.

One direct window into brain organization for language is language breakdown under conditions of brain damage. A century of investigating deficits in the spoken language of brain-damaged patients has revealed that the neural substrate for language is primarily in the left cerebral hemisphere. Moreover, localized damage to the left hemisphere produces differentiated patterns of language impairment, depending on the site of the lesion. Unlike spoken languages, however, sign languages make use of visuospatial distinctions. Although the left hemisphere has the dominant role in processing spoken languages it is the right hemisphere that is dominant for processing visuospatial relations. This specialization of the right hemisphere is particularly important because in sign language many grammatical processes crucially involve spatial relations and the manipulation of space by the signer.

Over the past years we have enjoyed a rare opportunity to delve into the biological foundations of language. The focus of our study has been the analysis of the breakdown of sign language following localized brain damage in deaf signers. The implications of brain organization for sign language reach far beyond issues in sign language processing per se. Indeed, the study of sign language breakdown promises to uncover the basic principles underlying both the specialization of the two cerebral hemispheres and their functional modifiability.

Let us begin with the nature of American Sign Language (ASL) itself. ASL is the visual-gestural language of the deaf community in the United States. Like other sign languages, ASL has developed its own linguistic mechanisms, independent of the spoken language of the surrounding community, American English. As we show, ASL is a fully developed natural language with a highly complex grammar; it serves everyday conversation, intellectual argumentation, wit, and poetry. Research on ASL allows us to raise some fundamental questions about the determinants of language form: What is language like when produced with the hands and perceived by the eyes? How is it different from simple gestural communication? So long as our knowledge of language structure is based solely on studies of language in a single modality, we cannot know whether that structure is merely the product of the transmission modality or of some more basic cognitive requirements, or both. Our findings about ASL—about the structure and organization of a language in a modality entirely different from that of speech—provide some fascinating clues to the resolution of this issue.

1.1 *Modality and Language Form*

The fact that signed languages use as articulators the hands, face, and body rather than the vocal tract suggests that spoken and signed languages might be vastly different from one another and that signed languages might lack some of the properties shared by grammars of spoken languages. It has long been thought that there is a highly privileged speech-language connection (Liberman 1982). However, despite the differences in resources provided by the two forms of communication, signed languages have been demonstrated to be highly constrained, following general restrictions on structure and organization comparable to those proposed for spoken languages. Research on ASL shows that this visual-gestural system exhibits formal structuring at the same two levels as spoken languages: a sublexical level of structure internal to the sign (the phonological level in spoken languages) and a level of structure that specifies the ways in which signs are bound together into sentences (the grammatical level). ASL does share principles of organization with spoken languages, but the realization of those principles occurs in formal devices arising from the different possibilities afforded by a language in three-dimensional space.

1.1.1 Sublexical Structure in the Hands

There is a sublexical structure to signs of ASL. Signs are composed of representatives of classes of sublexical components. The parameters within which sublexical contrasts in ASL signs occur are Hand Configuration, Place of Articulation, and Movement (Klima and Bellugi 1979; Stokoe, Casterline, and Croneberg 1965). These are roughly comparable to parameters of spoken language that provide for, for example, consonant/vowel distinction and, in languages such as Chinese, lexical tone. The number of configurations that the hand can physically assume, the number of possible places of articulation, and the number of possible different kinds of movements are large indeed. Yet ASL uses only a limited set of these sublexical components. Each parameter has a limited number of representatives, or values, which serve to differentiate lexical signs (figure 1.1). The sign forms that we gloss as CANDY, APPLE, and JEALOUS, for example, differ only in hand configuration (in the appendix we give the notation conventions used in this book); the signs SUMMER, UGLY, and DRY differ only in place of articulation (the forehead, nose, and chin, respectively); and the signs TAPE, CHAIR, and TRAIN differ only in movement. Like spoken languages, sign languages have a highly restricted inventory of elements and systematic restrictions on the ways in which sublexical components can combine. Although the values of the different parameters are arrayed concurrently with respect to one another in a layered fashion, there is sequentiality in the sublexical structure when more than one representative of a parame-

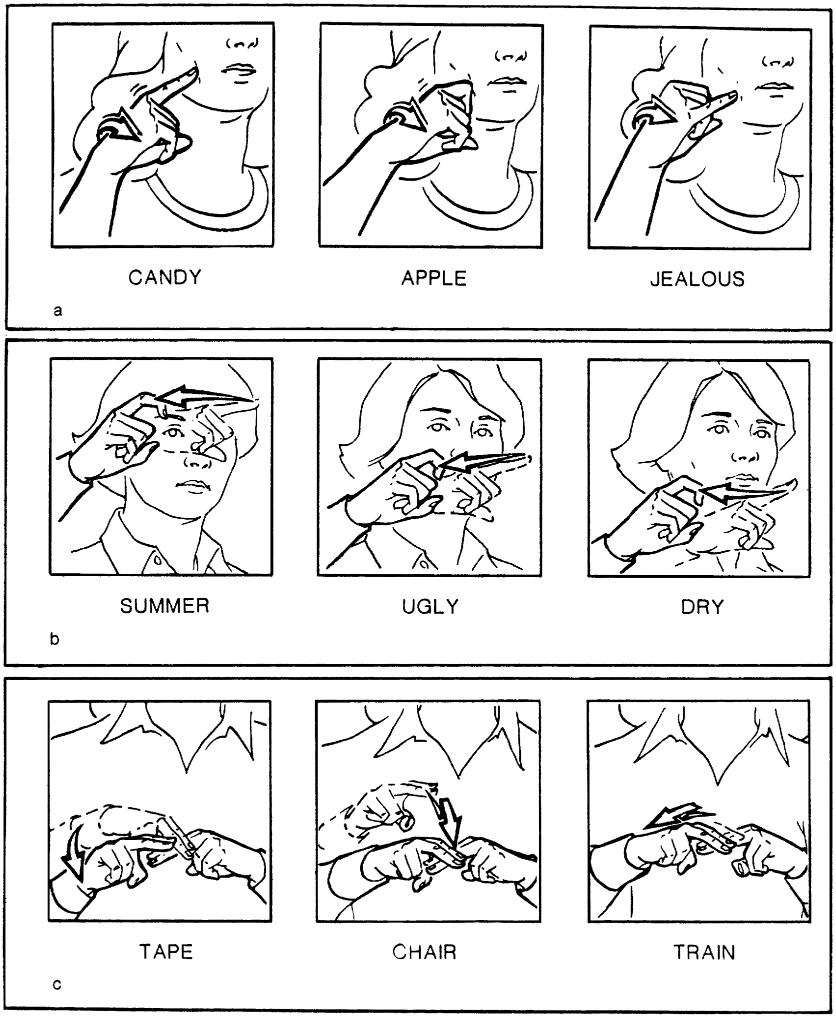


Figure 1.1
Minimal contrasts illustrating major formal parameters of ASL sign: (a) Hand Configuration, (b) Place of Articulation, (c) Movement.

ter occurs in a single sign: two Hand Configurations, for example, or two Movements (Liddell 1984; Liddell and Johnson 1985; Wilbur, Klima, and Bellugi 1983; Padden, in press; Supalla 1982, 1985).

Moreover, despite the vast differences in the transmission modalities of sign and speech, both language systems reflect the same underlying principles, principles that determine the internal organization of their basic lexical units. Clearly, these principles do not originate in the constraints of a particular transmission system. This sameness of principles suggests that the constraints determining linguistic structure arise at a more central level (Bellugi and Studdert-Kennedy 1980; Studdert-Kennedy and Lane 1980). In what follows we offer some evidence for the sublexical structure of sign and for the parallels between the structure of ASL and that of speech.

Studies of historical change in signs over the past century show that the direction of change in particular signs has uniformly been away from the more iconic and representational to the more arbitrary and constrained, hence toward conformity to a tighter linguistic system (Frishberg 1975). A classic example of this historical change is shown in the ASL sign HOME, originally a merged compound of the highly representative signs EAT and SLEEP (figure 1.2). In EAT an /0/ handshape moves as if bringing food to the mouth; SLEEP is an open palm laid on the cheek. Today, owing to processes of compounding and historical change, HOME is a unitary sign with a single handshape, touching two places on the cheek. The iconicity of the original two signs has been completely lost; HOME is one of the more abstract signs of ASL. Historical changes such as this one suggest that there are systematic pressures within ASL that constrain its lexical elements in regular, formationally based ways, resulting in more abstract, arbitrary forms.

Observational evidence for the sublexical structure of a sign language such as ASL comes from slips of the hands, which, like slips of the tongue (Fromkin 1973), yield valuable information about the organization of the language (Klima and Bellugi 1979, chapter 5; Newkirk et al. 1980). A subject intending to sign SICK, BORED (meaning 'I am sick and tired'), for instance, inadvertently switched the hand shapes of the two signs, keeping all other parameters the same (see figure 1.3a). This slip results in two possible but nonexistent sign forms. The figure also shows transpositions of Place of Articulation and of Movement parameters in slips of the hand from ASL signers. In such slips of the hand, the typical errors are not actual ASL signs but rather *possible* signs constructed from the restricted set of available Hand Configurations, Movements, and Places of Articulation making up the signs of ASL. They are never arbitrary errors, never movements or handshapes that do not occur in the language. The signer

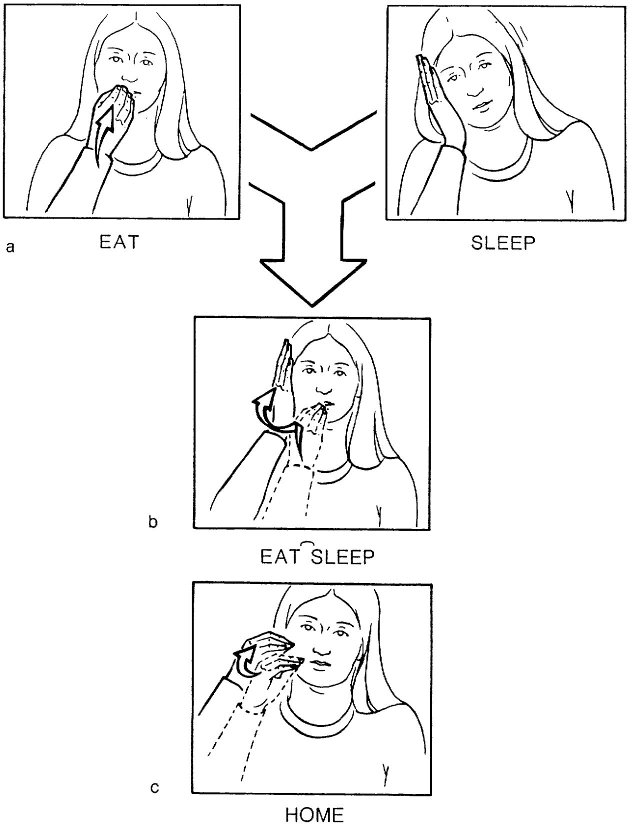


Figure 1.2
The suppression of iconicity through historical change in compounds. (a) Mimetic signs EAT and SLEEP. (b) The formal compound EAT and SLEEP meaning 'home.' (c) The modern opaque merged sign HOME.

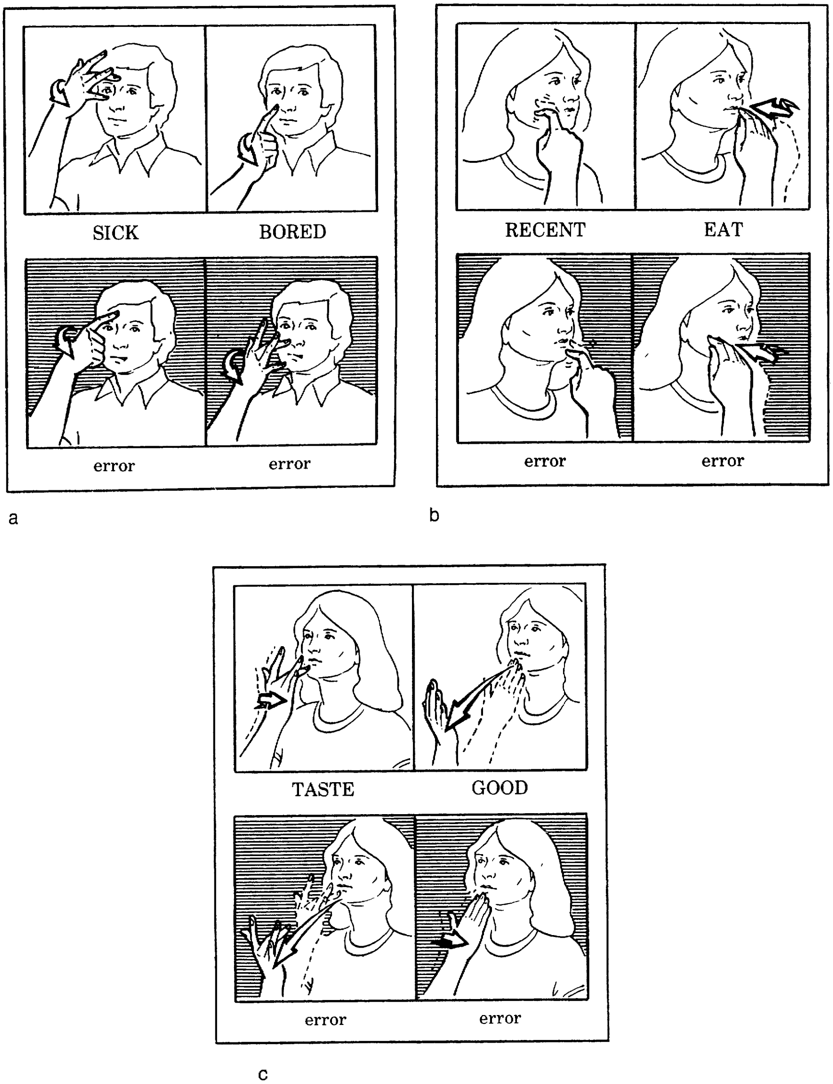


Figure 1.3
Transpositions of formal parameters in unintended slips of the hand, showing the independence of components in ASL signs: transpositions of (a) Hand Configuration, (b) Place of Articulation, and (c) Movement.

makes the erroneous form consistent with the systematically constrained combination of parameter values in ASL. Moreover, these are errors of combination rather than errors of selection; that is, they reflect a "reshuffling" of what was intended rather than an erroneous selection of a possible sign form. Slips of the hand thus provide impressive evidence that the sublexical components postulated have psychological reality as independent units at a level of programming prior to the actual articulation of a string.

A variety of experimental evidence also confirms the sublexical structure in sign. For example, deaf signers uniformly code ASL signs in short-term memory experiments on the basis of the component elements of signs. Intrusion errors in the immediate short-term recall of lists of signs share formational rather than semantic or iconic properties with the presented signs (Bellugi, Klima, and Siple 1975; Bellugi and Siple 1974). Commonly, the sign presented and the error differ by only one formational parameter. Moreover, just as phonological similarity among words causes interference in the short-term recall of lists of words, formational (but not semantic) similarity of signs interferes with the short-term recall of lists of ASL signs (Poizner, Bellugi, and Tweney 1981). These experimental studies indicate that the formational parameters of signs have significance in processing as well as structured significance linguistically.

Comparison of two different sign languages with independent histories, ASL and Chinese Sign Language (CSL), also shows parallelism with sublexical structure in spoken languages. Among spoken languages there are two kinds of systematic differences: differences in the elements that comprise morphemes and differences in the ways in which these elements can be combined. A sound or a sound combination that occurs in one language may be impossible in another. Figure 1.4a shows the different signs for FATHER and SUSPECT in ASL and CSL. Even the inventories of components (Hand Configurations, Places of Articulation, and Movements) differ in ASL and CSL, and, moreover, even when the two sign languages use the same elements, there are systematic differences in the ways in which the elements can combine. Figure 1.4b shows the same handshape and its differing uses in the two sign languages. In ASL the common contacting region for this handshape with another hand is with thumb and index finger, illustrated in the ASL signs COUNT, INTERPRET, VOTE, and JOIN. By contrast, in CSL the same handshape can make contact on or with the three extended fingers, as shown in figure 1.4b, in NAME, ENROLL, SUMMARY, and TOPIC. This contact region, perfectly acceptable and common in CSL, is not an allowed form in ASL. Thus we see that, even when the same component is used in the two

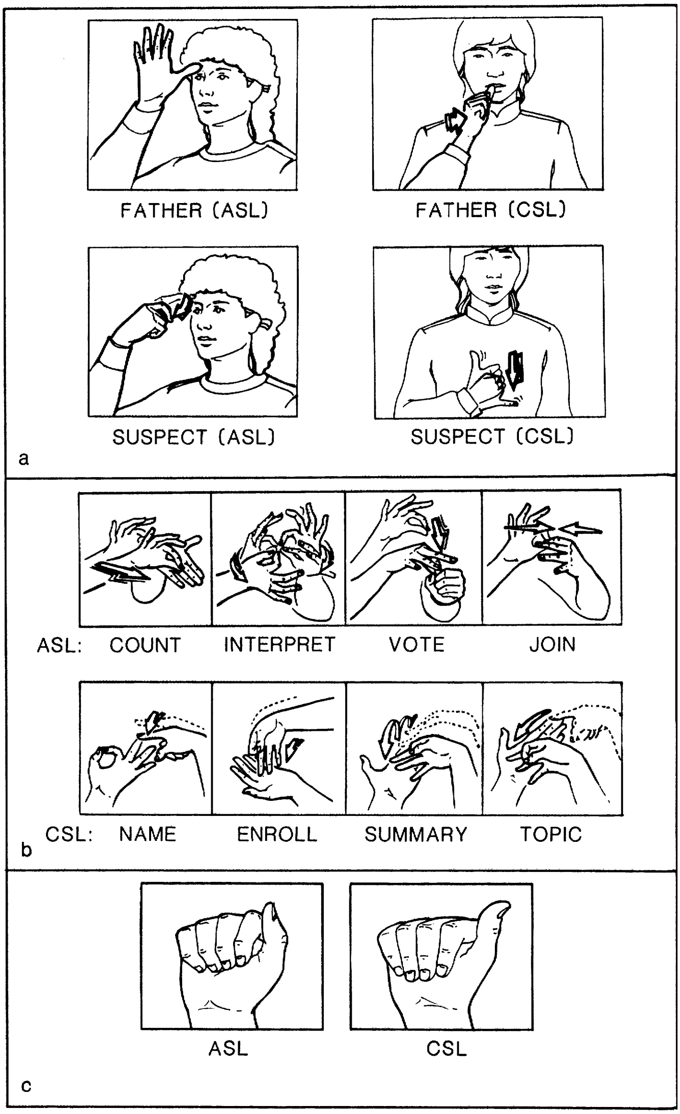


Figure 1.4
Contrast between two different sign languages: Chinese and American Sign Languages. (a) Differing ASL and CSL signs. (b) Differing morpheme structure constraints in the use of the pinching handshape in ASL and CSL. (c) "Phonetic" differences between ASL and CSL Hand Configurations.

sign languages, there may be differing morpheme structure constraints. Furthermore, we have identified fine-level "phonetic" differences that occur systematically between the two sign languages, just as there are phonetic differences between spoken languages (as in the difference between American and French /n/ sounds). Even something as simple as hand closure differs systematically between CSL and ASL. Both signed languages use a closed fist handshape, which occurs in many signs, as shown in the Chinese sign for FATHER. However, there are characteristic differences in hand closure and thumb placement, as illustrated in figure 1.4c. The ASL handshape has a more relaxed closure with the thumb resting on the fist; the CSL handshape characteristically has a more tensed closure of the fingers into the palm, with the thumb stretched outward. These fine phonetic level differences lead to something like a foreign accent when native users of one sign language learn the other (Klima and Bellugi 1979; Fok, Bellugi, and Lillo-Martin 1986).

Finally, native signers reveal an awareness of the internal structure of signs in their creation of poetic sign forms and plays on signs (Klima and Bellugi 1978). The creative use of language regularly and deliberately manipulates sublexical sign components. In poetic sign, for example, one handshape may recur throughout a passage, forming a kind of alliteration or a play on signs. One value of a parameter may be deliberately substituted for another, producing wit. This deliberate manipulation of elements of a linguistic system clearly reflects signers' intuitive awareness of this aspect of linguistic form (Klima and Bellugi 1979).

There can be no doubt that both types of language system—sign and speech—reflect similar underlying principles. It is important to note, however, that signs and words do not have the same internal structure in all respects. Their sublexical units combine differently in the formation of morphemes. The elements that distinguish English words from one another appear in contrasting linear order; the elements that distinguish ASL signs are preferentially arrayed concurrently in a layered structure. The predominance of concurrent layering, however, is most evident in the morphological processes found in ASL.

1.1.2 *Three-dimensional Morphology*

It had long been thought that sign languages lacked grammar, but recent research has shown that ASL and other sign languages have highly articulated grammars that are as complex and expressive as those of spoken languages. It turns out, however, that the grammatical processes of ASL are conditioned in important ways by the modality. In particular, many grammatical mechanisms elaborately exploit the spatial medium and the possibilities of multilayered structure.

Like spoken languages, ASL has developed grammatical markers that serve as inflectional and derivational morphemes; there are regular changes in form associated with systematic changes in meaning across syntactic classes of lexical items. Some morphologically marked distinctions in ASL happen not to be marked by grammatical inflections in English—another indication of the autonomy of ASL—although they are so marked in other spoken languages. Morphological processes in ASL typically involve changes in features of movement of sign forms. Figure 1.5 shows a variety of these derivational processes; note that members of pairs or of triplets share the same root (Hand Configuration, Place of Articulation, Movement Shape) and yet differ from one another by features of movement, such as manner, speed, tension, and number and type of repetition. Figure 1.5 illustrates examples of some of the various derivational processes we have found in ASL, including the derivation of deverbal nouns from verbs (a form meaning 'comparison' related to a form meaning the sign COMPARE), nominalizations from verbs ('the activity of measuring' related to a form meaning MEASURE), derivation of predicates from nouns ('proper' related to a form meaning BUSINESS), sentence adverbials from signs ('unexpectedly' related to a form meaning WRONG), characteristic predicates from adjectival signs ('vain' related to a form meaning PRETTY), and derivations for extended or figurative meaning (a form meaning 'acquiesce' related to QUIET). Frequently, these devices result in whole families of signs that are related in form and meaning (Bellugi and Newkirk 1980). An example is shown in figure 1.5g: the sign CHURCH has a derivationally related predicate meaning 'pious' and a related idiomatic derivative meaning 'narrow-minded.'

We have described derivational processes in ASL that typically change grammatical category (for example, verb to noun). ASL verb and noun signs also undergo a wide variety of inflectional processes, again characteristically affecting patterns of movement and spatial contour co-occuring with root forms. As shown in figure 1.6, verb signs in ASL undergo inflections for specifying their arguments (subject and object), for reciprocity ('to each other,' for example), for distinction of grammatical number ('to both,' 'to many'), for distinction of distributional aspect ('to each,' 'to any,' 'to certain ones at different times'), for distinction of temporal aspect ('for a long time,' 'over and over again,' 'uninterruptedly,' 'regularly'), for distinction of

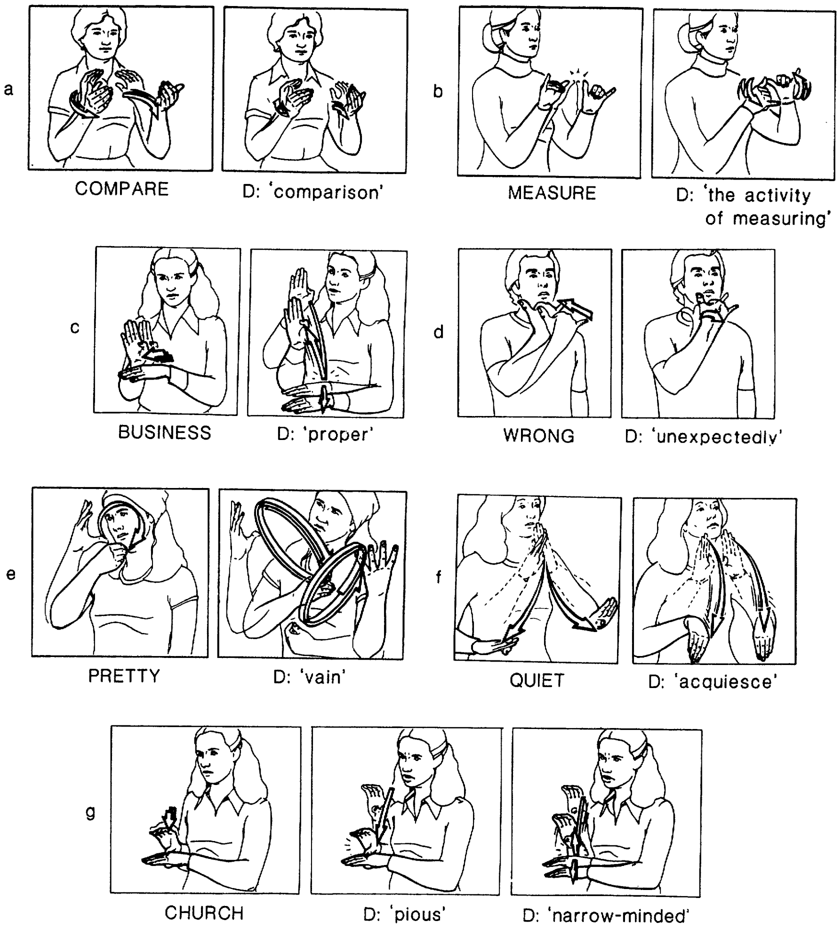


Figure 1.5
Derivationally related sets of forms in ASL. (a) The formation of deverbal nouns. (b) Nominalizations from verbs. (c) Derivation of predicates from nouns. (d) Sentence adverbials from basic signs. (e) Characteristic predicates from basic signs. (f) Derivations for extended or figurative meaning. (g) Predicate form of the sign CHURCH meaning 'pious' and a related idiomatic derivative meaning 'narrow-minded.'

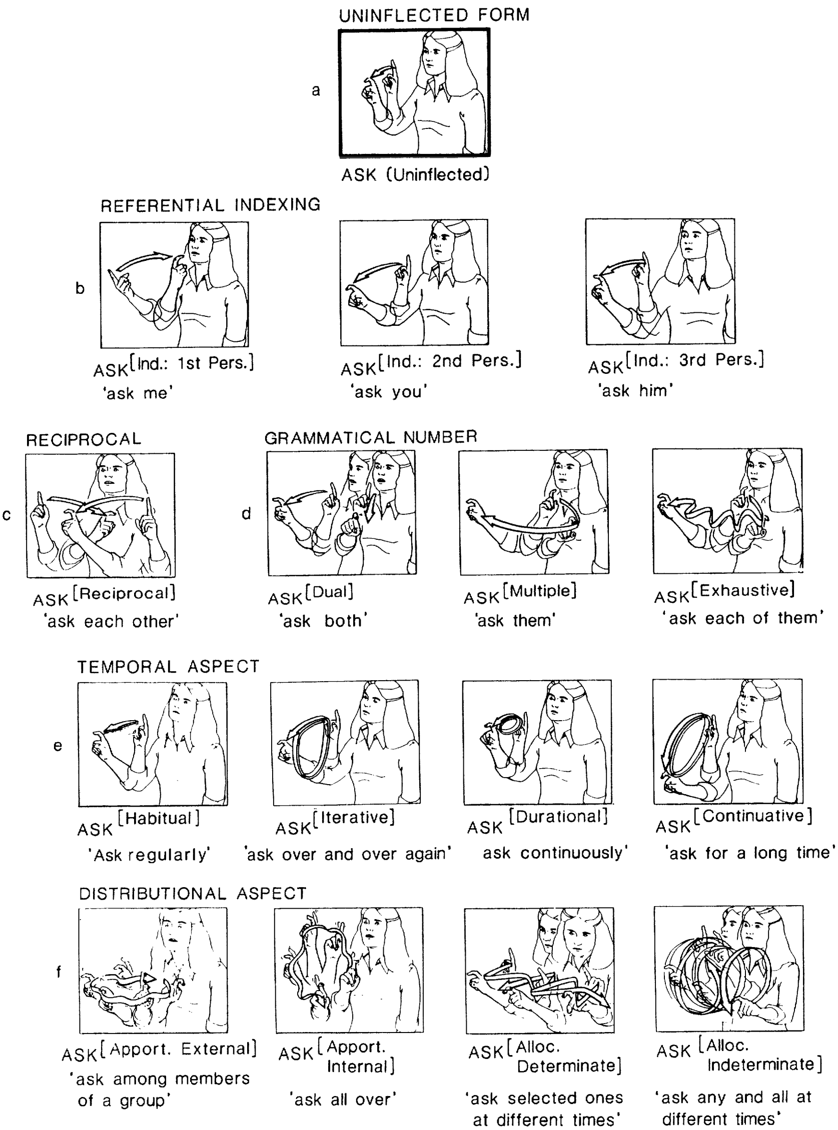


Figure 1.6
Layered inflectional processes in different grammatical categories stemming from a single root. (a) The uninflected sign ASK. (b) Distinctions of referential indexing. (c) A reciprocal form. (d) Marking for grammatical number. (e) Marking for temporal aspect. (f) Marking for distributional aspect.

temporal focus ('starting to,' 'increasingly,' 'resulting in'), and for distinction of manner ('with ease,' 'readily'), among others.

In ASL, which is rich in morphology, families of sign forms are related by an underlying root: The forms in figure 1.6 share a handshape /G/, a location (plane in front of body), and a local movement shape (closing of the index finger). Inflectional and derivational processes represent the interaction of the root with other features of movement in space (dynamics of movement, manner of movement, directions of movement); these, along with spatial array, doubling of the hands, and reduplication, are all layered, as it were, on the sign root. Thus a single root form—such as the one underlying ASK—has a wide variety of manifestations (see figure 1.6).

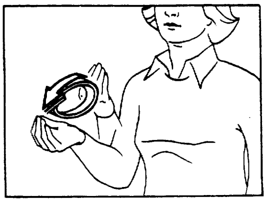
In the *kinds* of distinctions that are morphologically marked, ASL is similar to many spoken languages. In the *degree* to which morphological marking is a favored form of patterning in the language, ASL is again similar to some spoken languages. In the *form* by which lexical items are systematically modified, however, ASL may have aspects that are unique. What appears striking in ASL morphology is that the stem, derivational patterns, and inflectional patterns can co-occur as layered in the final surface form; these forms can be spatially (as well as temporally) nested within one another.

The numerous morphological processes in ASL are conveyed by combinations of a limited number of formal components; these components, which consist of the structured use of space and movement, are peculiar to the visual-gestural mode. Spatial components, such as geometric arrays (circles, lines, arcs), planar locus (vertical, horizontal), and direction of movement (upward, downward, sideways), primarily involve the manipulation of forms in space, and they figure significantly in the structure of inflections for indexing, reciprocity, grammatical number, and distributional aspect. Movement qualities, such as end manner (continuous versus hold), tension (tense versus lax), and rate (fast versus slow), figure significantly in the structure of inflections for temporal aspect, focus, manner, and degree. Two components—cyclicity (single cycle versus reduplicated) and hand use (one hand or two hands)—interact with other components to form inflections in several grammatical categories.

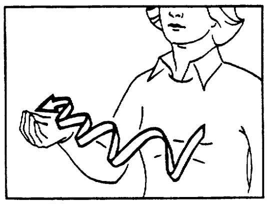
1.1.3 Recursive Rules: Nesting of Morphological Forms

In ASL inflectional processes can combine with root signs, creating different levels of form and meaning. In these combinations the output of one inflectional process can serve as the input for another (can be recursive), and there can also be alternative orderings, which produce different levels of semantic structure. Figure 1.7 shows the unin-

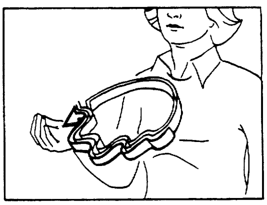
a GIVE (uninflected)



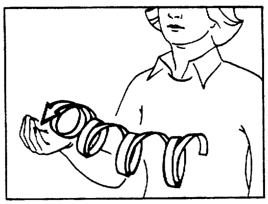
b $\text{GIVE}^{[\text{Durational}]}$
'give continuously'



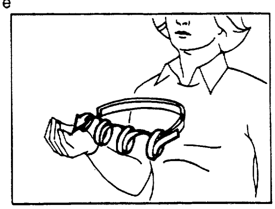
c $\text{GIVE}^{[\text{Exhaustive}]}$
'give to each'



d $\text{GIVE}^{[[\text{Exhaustive}]\ \text{Durational}]}$
'give to each, that action recurring over time'



e $\text{GIVE}^{[[\text{Durational}]\ \text{Exhaustive}]}$
'give continuously to each in turn'



f $\text{GIVE}^{[[[\text{Durational}]\ \text{Exhaustive}]\ \text{Durational}]}$
'give continuously to each in turn, that action recurring over time'

Figure 1.7
Recursive nesting of morphological processes in ASL. (a) The uninflected sign GIVE. (b, c) GIVE under single inflections. (d) One combination of inflections (Exhaustive in Durational). (e) Another combination of inflections (Durational in Exhaustive). (f) Recursive applications of rules (Durational in Exhaustive in Durational).

flected sign GIVE (figure 1.7a), the sign under the durational inflection meaning 'give continuously' (figure 1.7b), and, alternatively, the sign under the exhaustive inflection meaning 'give to each' (figure 1.7c). The exhaustive form of GIVE can itself undergo the durational inflection (figure 1.7d). The resulting form means 'to give to each that action recurring over time.' Conversely, the durational form of GIVE can also undergo the exhaustive inflection (figure 1.7e), the resulting form meaning 'to give continuously to each in turn.' And the output in figure 1.7e can once again undergo the durational inflection: The durational of the exhaustive of the durational of GIVE means something like 'to give continuously to each in turn that action recurring over time.' This creation of complex expressions through the recursive application of hierarchically organized rules is also characteristic of the structure of spoken languages. The form such complex expressions take in this visual-gestural language, however, is certainly unique: the sign stem embedded in the pattern created by a morphological process with that pattern itself nested spatially in a pattern created by the same or a different morphological process. The proliferation of co-occurring components throughout the language makes it obvious that ASL tends toward conflation, toward the systematic packaging of a great deal of information in co-occurring layers of structure.

1.2 *Spatially Organized Syntax and Discourse*

We now turn to a domain in which the nature of the apparatus used in ASL may have its most striking effect: the means by which relations among signs are stipulated in sentences and in discourse. The requirements of a spatially organized syntax may be especially revealing for the neurological substrate of language. The most distinctive use of space in ASL is in its role in syntax and discourse, especially in pronominal reference, verb agreement, anaphoric reference, and the referential spatial framework for discourse. Languages have different ways of marking grammatical relations among their lexical items. In English it is primarily order that marks the basic grammatical relations among verbs and their arguments; in other spoken languages it is the morphology of case marking or verb agreement that signals these relations. By contrast, ASL specifies relations among signs primarily through the manipulation of sign forms in space. A horizontal plane in front of the signer's torso plays an important role in the structure of the language and not just as an articulatory space accommodating hand and arm movements as the mouth accommodates the tongue. In this language space itself carries linguistic meaning.

Grammatical relations in ASL, such as subject and object of the verb, are specified in several distinct ways. One of these mechanisms involves the relative order of the signs in the clause. In clauses with transitive verbs in ASL, the subject noun phrase occurs directly before the verb. As a formal syntactic mechanism, this is equivalent to the determination of grammatical relations through word order. This is a mechanism also found in English. A second mechanism that identifies subject and object of the verb in ASL is essentially spatial in nature, and it is this device that we describe in more detail. The class of inflecting verbs in ASL is a large one; inflecting verbs are verbs whose paths are mutable with respect to points in signing space. In this way the subject and/or object of the verb is expressed. For many of these verbs, such as GIVE, the subject of the verb is defined by the initial point and the object is defined by the final point; however, there are ASL verbs for which the role relations with respect to the loci are reversed, as in WELCOME. Thus inflecting verb signs move between abstract loci in signing space to indicate the grammatical function (subject, object) of their arguments.

A nominal introduced into ASL discourse can be associated with an arbitrary locus in a horizontal plane of signing space, provided that another nominal in the discourse frame has not already been associated with that locus. Subsequent reference to that locus (by verb agreement or by pointing) is the equivalent of pronominal reference in ASL. In signed discourse pointing again to a specific assigned locus clearly "refers back" to a previously mentioned nominal, even with many other signs intervening. This spatial indexing allows explicit coreference and may even reduce ambiguity. In English the intended reference of lexical pronouns is often unclear. The sentence "He said he hit him and then he fell down" fails to specify which pronouns refer to the same noun, that is, which are coreferential. The spatial mechanisms used in ASL, by contrast, require that the identities of the referents be maintained across arbitrary points in space. In ASL the failure to maintain such identities results in strings that are ill-formed, rather than in strings that are simply unclear. Among the special facts about ASL pronouns to be borne in mind are (1) there is potentially an indefinite number of formal pronominal distinctions (because any arbitrary point in the appropriate plane of signing space can serve as a referential locus); (2) the referents are unambiguous, at least within the confines of a given discourse frame; and (3) linguistic reference, under a variety of circumstances, can shift (Lillo-Martin and Klima 1986).

We illustrate aspects of the use of spatial loci for referential indexing, coreference, verb agreement, and the use of spaces embedded within spaces (figure 1.8). Figure 1.8a presents a sample sentence with an embedded clause, in which the subjects of the main clause and of the embedded clause differ. The same signs in the same order but with a change in the direction of the spatial endpoints of the verb would indicate a different grammatical relation. Figure 1.8b illustrates the spatial arrangement of the multiclausal sentence meaning John encouraged him to urge her to permit each of them to take up the class. Because verb agreement may be given spatially, sentences whose signs are made in different temporal orders can still convey the same meaning. Spatial indexing thus permits a certain freedom of word order (in simple sentences, at any rate) while providing clear specification of grammatical relations by spatial means. Different spaces may be used to contrast events, to indicate reference to time preceding the utterance, and to express hypotheticals and counterfactuals. It is also possible to embed one subspace within another subspace, as in embedding a past-time context within conditional subspace, as illustrated in figure 1.8c.

Overall, then, the ASL system of spatialized syntax is similar in *function* to grammatical devices found in the spoken languages of the world (Bellugi and Klima 1982b). However, in its *form*—marking connections among spatial points—spatially organized syntax in ASL bears the clear imprint of the mode in which the language evolved (Padden 1983, in press; Lillo-Martin and Klima 1986; Lillo-Martin 1986).

This spatial referential framework for syntax and discourse is further complicated by interacting mechanisms. Although the referential system described is a *fixed* system in which nominals remain associated with specific points in space until specifically "erased," the spatial referential framework sometimes *shifts;* for example, third-person referents may be assigned to the locus in front of the signer's torso, which otherwise denotes self-reference. When this shift occurs, the whole spatial plane rotates, and previously established nominals are now associated with new points, as illustrated in figure 1.9.

The different systems mentioned here (pronominal reference, verb agreement, coreferentiality, and spatial contexts) make complex and dynamic use of space. In each subsystem there is mediation between the visuospatial mode and the overlaid grammatical constraints in the language. Because the syntax of ASL relies so heavily on the manipulation of abstract points in space and on spatial representation, the processing of linguistic structures involves the processing of visuospatial relations. Obviously, no such processing is required in spoken

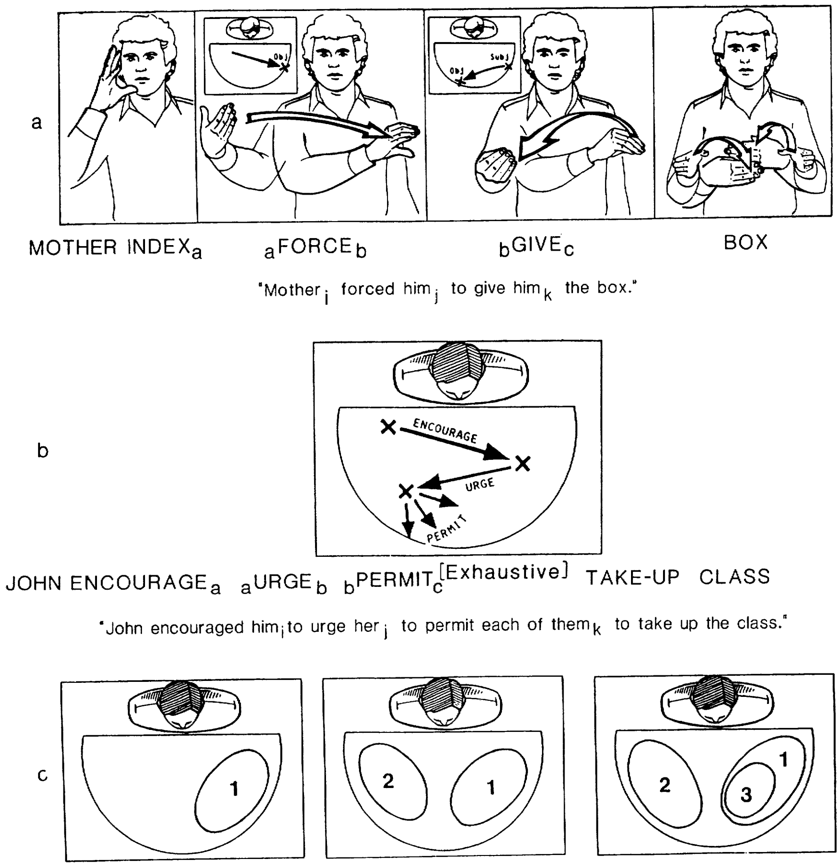


Figure 1.8
Syntactic spatial mechanisms in ASL. (a) A spatially organized sentence in ASL showing nominal establishment and verb agreement. (b) Spatial reference diagram for multiclausal sentence. (c) Embedded spatial references, one subspace within another.

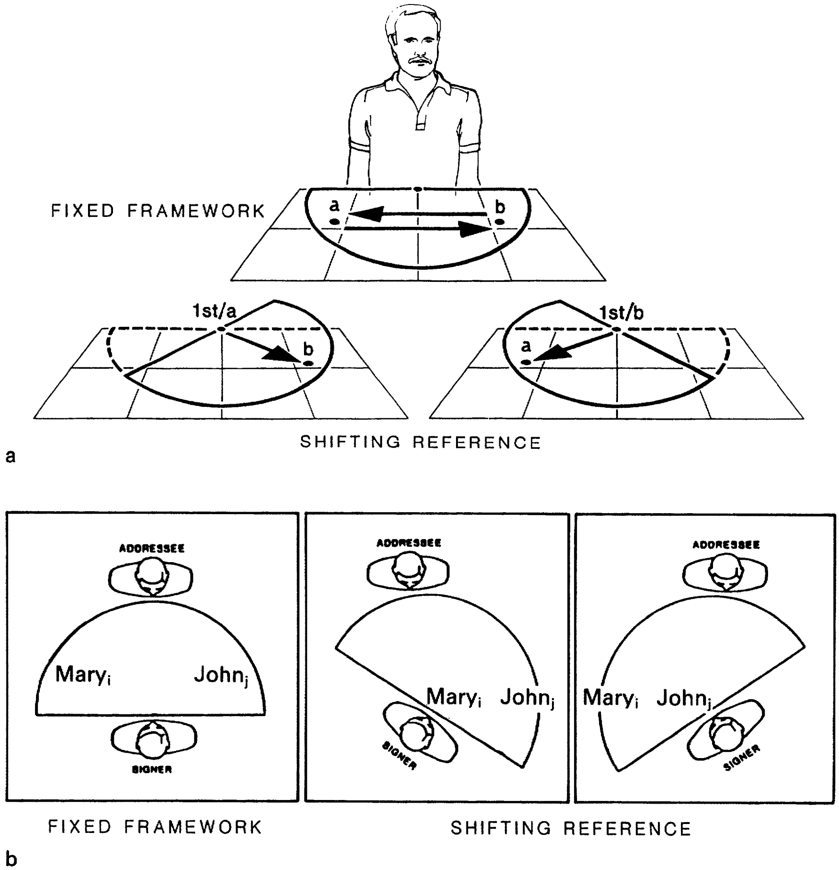


Figure 1.9
Fixed and shifting frames of reference in ASL syntax, as illustrated by (a) verb agreement, and (b) nominal establishment. The arrows in (a) represent different directions of movement of the verbs, reflecting alternative ways of indicating 'a verbed b' and 'b verbed a.' The diagrams in (b) illustrate the assignment of noun phrases to arbitrary loci in signing space. In the fixed framework the third-person loci remain constant. In the shifting framework the whole spatial plane rotates, and previously established nouns are reassigned to new spatial loci.

languages. This difference between the surface form of syntactic mechanisms in spoken and signed languages may have important consequences for the way in which a visuospatial language is represented in the brain. We discuss some of these implications throughout the chapters that follow.

Despite the important differences in form, signed and spoken languages clearly share underlying structural principles. Like spoken language, sign language exhibits formal structuring at the lexical and grammatical levels, similar kind and degree of morphological patterning, and a complex, highly rule-governed grammatical and syntactic patterning. The implications of representation of a visuospatial language can be brought out by investigating the additional two perspectives that close this chapter: sign language acquisition and sign language perception and processing.

1.3 *Acquiring a Visual-gestural Language*

Studies of children's acquisition of spoken language have illuminated both the nature of linguistic systems and the child's natural propensity for linguistic analysis. Children who are learning a language analyze underlying grammatical rules, and their course of development can be revealing of the linguistic structure. Because visual-gestural language is unlike spoken language in the ways we have described, one might expect to find that sign language is acquired in radically different ways from spoken languages. In fact, the similarity in the acquisition of signed and spoken language is remarkable. The differences that do appear reflect the spatial nature of sign language organization. In what follows we discuss some developments in the acquisition of the spatial mechanisms of ASL by deaf children of deaf parents, including pronominal reference, the morphological inflections associated with verb agreement, and the syntactic system of referential spatial indexing (Bellugi and Klima 1982a, 1982b; Boyes-Braem 1981; Hoffmeister and Wilbur 1980; Lillo-Martin 1986; Loew 1982; Maxwell 1980; Newport and Meier, in press; Newport and Supalla 1980; Petitto 1983; Pettito and Bellugi, in press; Supalla 1982).

1.3.1 *Pronominal Signs: The Transition from Gesture to Symbol*

Deixis in spoken languages is considered a verbal surrogate for pointing; in ASL, however, it *is* pointing. The pronominal signs in ASL meaning 'I' and 'you' are, in fact, the same pointing gestures used by hearing people to give their words a nonverbal supplement. Thus we would expect the acquisition in ASL of pronominal reference to self and addressee to be easy, early, and error free, even though in the development of spoken languages pronoun reversal errors are found in young children. Instead, despite the identity of ASL pronouns with nonlinguistic gestures, the course of their acquisition is startlingly similar to that in spoken languages. Deaf infants between 9 and 11 months of age point freely for investigating and indicating and for drawing attention to themselves and others, as do hearing children. During the second year, however, something dramatic happens. The deaf children stop pointing to themselves or their addressee; in fact, they seem to avoid such pointing. During this period their language development evinces a steady growth in sign vocabulary, which they use stably in a variety of contexts and in multisign sentences. The next period sees the reemergence of pointing to self and addressee but now as part of a linguistic system. At this stage surprising errors of reversal appear in the children's pronominal signing; children sign (YOU) when intending self, patently ignoring the transparency of the pointing gesture. These pronoun reversals are also found in hearing children of the same age. By around the age of 2½ years, such reversal errors are completely resolved, just as they are in hearing children of the same age. Because the form of the pronominal sign is the same as the pointing gesture, these errors and their resolution provide evidence for a *discontinuity* in the transition from prelinguistic gesture to a formal linguistic system (Petitto 1983, in press).

1.3.2 Inflections: Verb Agreement

The ASL system of verb agreement functions is similar to that of spoken languages, but the form of verb agreement in ASL requires that the signer mark connections between spatial points. Around the age of 2 years, deaf children begin using uninflected signs, even in imitating their mothers' inflected signs and even in cases in which the adult grammar requires marking for person and number (Newport and Ashbrook 1977). So, even though the children are perceiving complexly inflected forms, they begin, like hearing children do, by selecting the uninflected stems. By the age of 3 years, deaf children have learned the basic aspects of verb morphology in ASL (inflections for person, temporal aspect, and number; see Meier 1981, 1982). At this age they make overgeneralizations to noninflecting verbs, analogous to overgeneralizations such as *eated* in the speech of hearing children. Such errors reveal the child's analysis of forms across the system (Bellugi and Klima 1982b; Meier 1981, 1982). So, despite the difference in the form of spatial marking, the development and the age of mastery of the spatial inflection for verb agreement is the same in ASL as for comparable processes in spoken languages.

1.3.3 Referential Indexing: Syntax and Discourse

The integration of the spatial verb agreement system in the sentences and discourse of ASL is highly complex. When deaf children first attempt to index verbs to arbitrary locus points in space, they index all verbs for all referents to a single locus. In telling the story of Rapunzel, for example, a child of 3½ years (evidently using her early hypothesis about syntactic rules) indexed three verbs in space—SEE, ASK, and PUSH (each of which has distinct referents)—but she indexed all three verbs at the same locus (figure 1.10a). In effect, she "stacked up" the three referents (father, witch, Rapunzel) at a single locus point (Loew 1982). In later developments the loci for distinct referents are differentiated, although occasional discourse problems still interfere with the establishment and maintenance of the one-to-one mapping between referent and locus (Loew 1983; Lillo-Martin 1986). Figure 1.10b gives a particularly complex example in which a deaf child is recounting an imaginary story in which she (Jane) has ten children, and another woman arrives to claim them as her own. Jane (in the role of the other woman) signed, "(I) WANT MY . . . YOUR . . . JANE'S CHILDREN." One can understand why in this situation she finally resorted to the use of her own name sign to clarify the reference! By the age of 5 years, however, children give the appropriate spatial index to nearly every nominal and pronoun that requires one, and almost all verbs show the appropriate agreement.

Deaf children, like their hearing counterparts, extract discrete components of the system presented to them. Furthermore, the evidence suggests that, even when the modality and the language offer possibilities that seem intuitively obvious or transparent (pointing for pronominal reference, for example), deaf children ignore this directness and analyze the language input as part of a formal linguistic system. Young deaf children are faced with the dual task in sign language of spatial perception, memory, and spatial transformations on the one hand and processing grammatical structure on the other, all in one and the same visual event (Stiles-Davis, Kritchevsky, and Bellugi, in press). Studies of the acquisition process have found that deaf and hearing children show a strikingly similar course of development if exposed to a natural language at the critical time. These data thus dramatically underscore the biological substrate of the human capacity for creating linguistic systems. These findings show powerfully how language, independent of its transmission mechanisms,

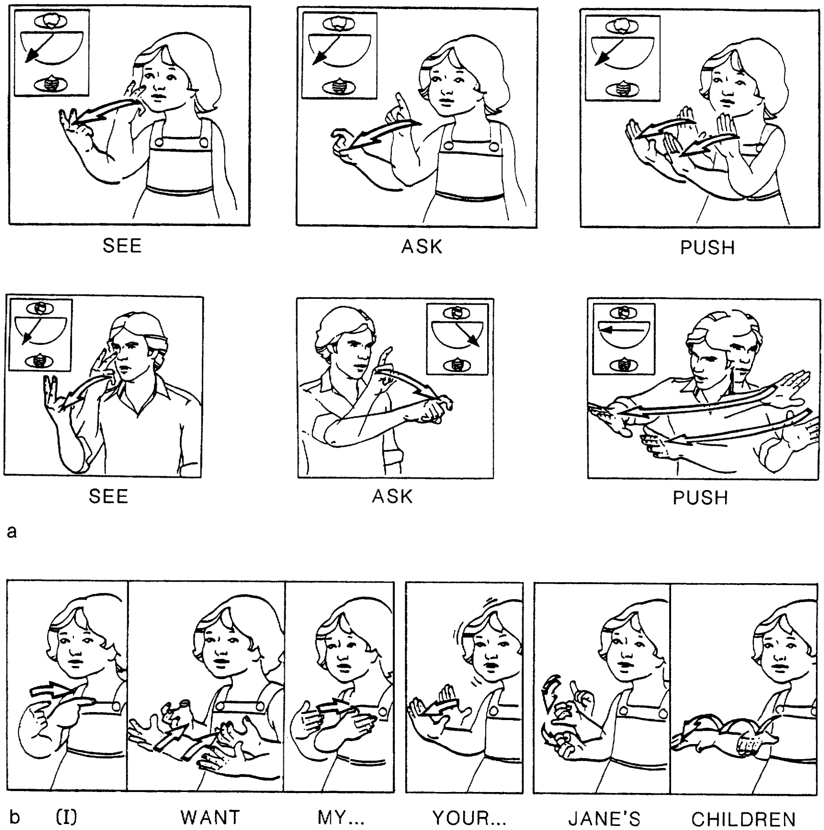


Figure 1.10
The acquisition of spatialized syntax in deaf children. (a) Deaf child's incorrect "stacking" of referents (note that child has indexed verbs referring to three different referents at the same locus point) and adult's correct spatial reference for context. (b) Child's complex pronominal spatial reference meaning 'The old woman said to Jane, "I want my . . . your . . . Jane's children." '

emerges in children in a rapid, patterned, and, above all, linguistically driven manner.

1.4 *Perception and Production of a Visual-gestural Language*

1.4.1 *Extracting Movement from Sign Form*

The visual system is organized more for the analysis of changing events than for the analysis of static ones (Johansson 1973). As we have seen, in ASL superimposed patterns of movement and spatial contouring convey grammatical information. To study directly the complicated movement patterns within the linguistic system of ASL, we need to extract movement from sign forms. We adapted a technique introduced by Johansson (1973) for studying the perception of biological motion, by first placing nine small incandescent bulbs at the major joints of the arms and hands (shoulders, elbows, wrists, and index fingertips). We then recorded signing in a darkened room so that on the videotape only the pattern of moving points of light appeared against a black background. We found that, even with such greatly reduced information, deaf signers could quite accurately recognize and identify the inflections presented in these point-light displays, demonstrating that these grammatical patterns of movement form a distinct and isolable (but co-occurring) layer of structure in ASL. By removing various pairs of points, we found that movement of the fingertips, but not of any other pair of points, is necessary for sign identification. This study showed that the dynamic point-light displays accurately transmit linguistic information; they capture the subtleties of contrasts in movement that mark grammatical distinctions in the language and demonstrate the isolability of this co-occurring layer of grammatical structure in ASL (see Poizner, Bellugi, and Lutes-Driscoll 1981; Bellugi 1980).

1.4.2 *The Interplay between Perceptual and Linguistic Processes*

We have been using point-light displays to study the interplay between basic perceptual processes and higher-order linguistic ones. To pursue this, we have shown sign movements to both native deaf signers and hearing nonsigners in order to see what differences might exist in their perception of movement. Triads of basic and of inflected ASL signs were presented as point-light displays for judgments of movement similarity. Multidimensional scaling and hierarchical clustering of judgments for both deaf and hearing subjects revealed, first, that lexical and inflectional movements are perceived in terms of a limited number of underlying dimensions. Second, the perceived dimensions for the lexical level are generally different from those for the inflectional level. These results, with perceptual data, support our previous linguistic conclusion, namely, that the linguistic fabric of the two levels of structure in ASL is woven from different formational material. Furthermore, deaf and hearing subjects have different psychological representations of movement type within each level; the perception of movement form is tied to linguistically relevant dimensions for deaf but not for hearing subjects. Thus the data suggest that the acquisition of a visual-gestural language can modify the natural perceptual categories into which these movement forms fall (Poizner 1981, 1983, in press).

These experiments extend previous studies of the perception of other formational categories of ASL, that is, configuration of the hands (Lane, Boyes-Braem, and Bellugi 1976; Stungis 1981) and location of the hands (Poizner and Lane 1978). In these previous studies, however, the patterns of results for deaf signers and for hearing nonsigners were the same; no modification of perception resulting from linguistic experience was found for static sign attributes. The perception of ASL movement (and perhaps movement in general as a category) may be crucially different from the perception of static parameters, such as Handshape and Place of Articulation. It is important that the modification of perception of movement following sign language acquisition parallels processes found for spoken language. Experience with spoken language likewise can affect the perception of speech sounds. For example, the distinction between /r/ and /l/ serves to contrast words in English but not in Japanese, and, unlike infants and English-speaking adults, Japanese-speaking adults fail to discriminate these acoustic differences (Miyawaki et al. 1975). Thus modification of natural perceptual categories following language acquisition appears to be a general consequence of acquiring a formal linguistic system, be it spoken or signed.

1.4.3 *Three-dimensional Computer Graphics and Linguistic Analysis*

The modality of language interacts deeply with biological mechanisms for perceptual processing and movement control. In many ways the transmission system of sign language (visual-gestural) is radically different from that of speech and offers remarkably different possibilities and constraints. The study of sign language offers an opportunity for investigating language production because movements of the articulators are directly observable. By measuring sign language articulations, we can directly compare the physical structure of the signed and spoken signals. Nonetheless, it has been difficult to analyze and measure the subtle movements of the hands and arms in three dimensions. We have recently devised new techniques for such an analysis, and these techniques enable us to quantify the movement signal and thus help us to uncover the structure of movement organized into a linguistic system.

We currently analyze three-dimensional movement using a modified Op-Eye system (figure 1.11), a monitoring apparatus permitting rapid high-resolution digitization of hand and arm movement (Poizner, Wooten, and Salot 1986). Two optoelectronic cameras track the positions of light-emitting diodes (LEDs) attached to the hands and arms and provide a digital output directly to a computer, which calculates three-dimensional trajectories. From the position measurements the movements are reconstructed in three dimensions on an Evans and Sutherland Picture System. This system allows dynamic display and interactive control over the three-dimensional movement trajectories, so that various trajectory and dynamic characteristics can be calculated for any portion of the movement (Loomis et al. 1983; Jennings and Poizner 1986).

Figure 1.12 illustrates aspects of the measurement and analysis process, presenting the reconstructed movement of the hand and the associated velocity and acceleration profiles for two grammatically inflected signs, $\text{LOOK}^{[\text{Continuative}]}$ and $\text{LOOK}^{[\text{Durational}]}$. Although ASL relies heavily on spatial contrasts, temporal contrasts are also used. The Continuative and Durational inflections, for example, are minimally contrasted by their temporal qualities and serve to elucidate a difference in timing between signed and spoken language. The Continuative inflection, meaning 'action for a long time,' is made with a tense, rapid outward movement with an elliptical slow return to the starting point. The Durational inflection, meaning 'continuous action,' is made with a smooth, circular, even movement that is repeated. The panels of figure 1.12b present for each inflection the reconstructed movement of the hand along with the associated velocity and acceleration profiles. The panels of figure 1.12c present characteristics of a single movement cycle. We find that the temporal contrasts underlying these inflections, as well as those for ASL in general, are typically stretched over much longer intervals than those found in speech. Sign language simply does not use the extremely rapid 40–50-msec temporal intervals found in spoken languages to contrast forms (Poizner 1985). Rather, temporal variation in sign language occurs over much longer intervals, and sign language heavily uses spatial contrasts.

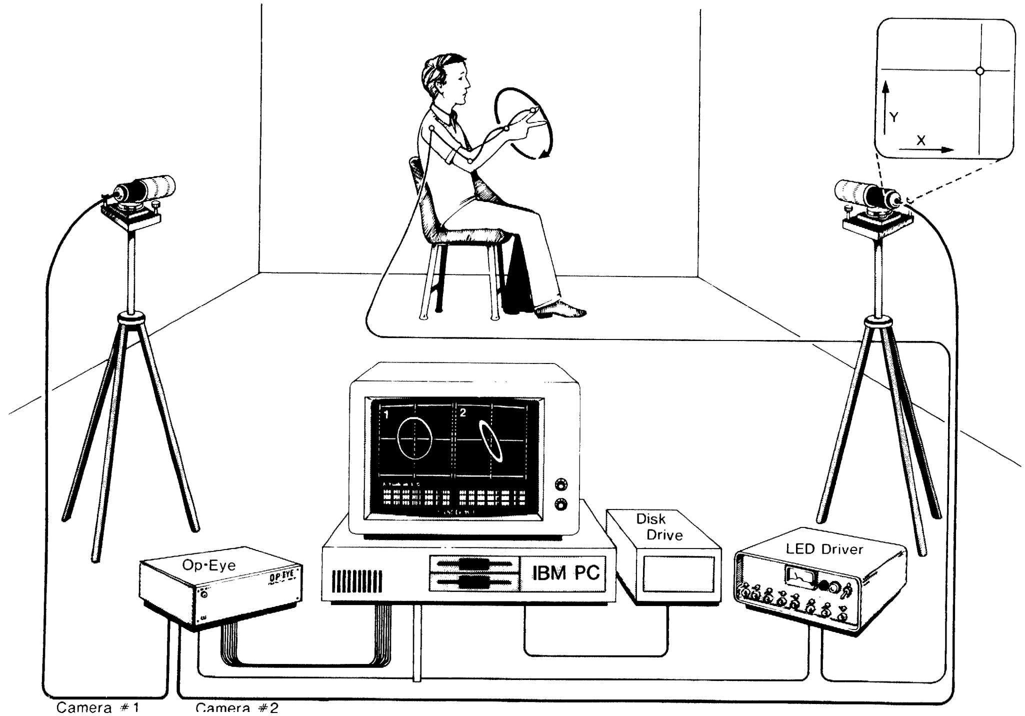


Figure 1.11
Three-dimensional movement monitoring system showing the main hardware components and the position of infrared emitting diodes on a subject.

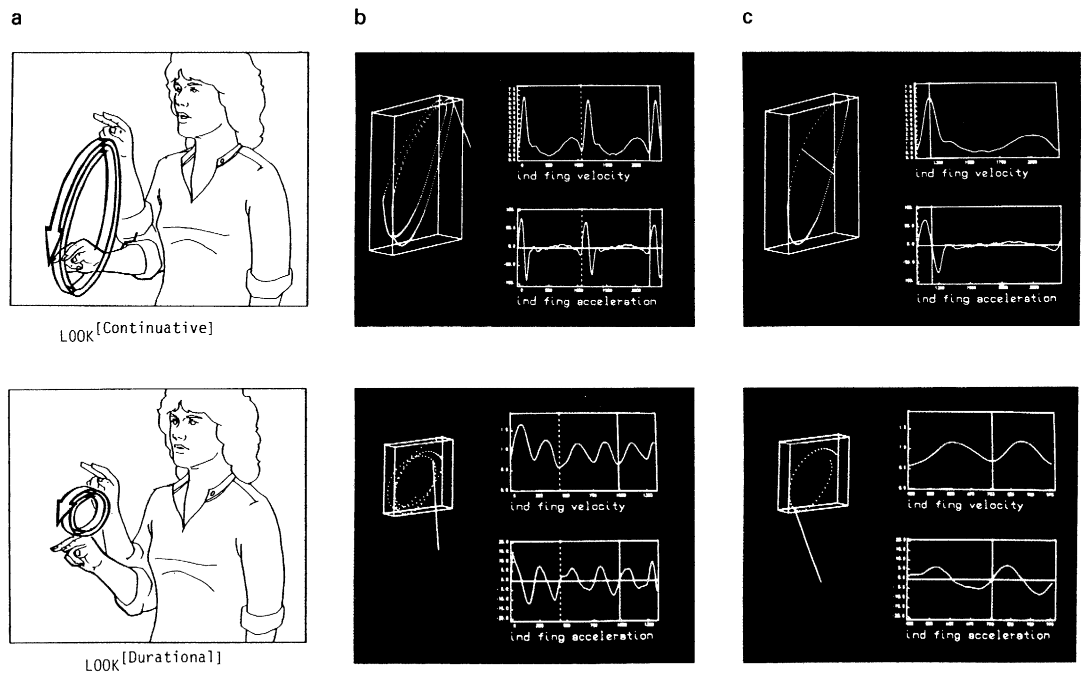


Figure 1.12
Three-dimensional reconstructions of two ASL inflections. (a) Line drawings. (b) The entire reconstructed movement of the hands with time pointers "windowing" one movement cycle. (c) Characteristics of one movement cycle. Tangential velocity is given in meters per second and acceleration in meters per second^2.

This difference in temporal structure between signed and spoken languages has important implications for our understanding of the basis of the specialization of the left hemisphere for language. The left hemisphere is specialized not only for language but also for the rapid temporal analysis that speech strongly requires. It has been proposed that the specialization of the left hemisphere for language is actually a secondary consequence of its more primary specialization for rapid temporal analysis. Theories basing the specialization of the left hemisphere for language on superior capacities for auditory processing and rapid temporal analysis would not predict left-hemisphere specialization for sign language. ASL pits linguistic function against stimulus form in a strong way because in large part it conveys grammatical relations through spatial relations. As we will show, ASL provides a special window into the nature of brain organization for language.

These studies lead to the following conclusions. ASL has developed as a fully autonomous language with a complex organization not derived from spoken languages, providing a new perspective on human language and the determinants of its organization. ASL exhibits its formal structuring at the same two levels as spoken language (the internal structure of lexical units and the grammatical scaffolding underlying sentences) and similar kinds of organizational principles (constrained systems of features, rules based on underlying forms, recursive grammatical processes). The forms assumed by this manual language reflect its modality. The inflectional devices of ASL make structured use of space and movement, nesting the basic sign stem in spatial patterns and complex dynamic contours. In the basic lexical items, morphological processes, and sentences of ASL, the multilayering of linguistic elements is a pervasive structural principle. Spatial-locational contrasts and the manipulations of space have a crucial syntactic function in ASL. Rather than relying primarily on the order of items and fine temporal processing, sign language is organized in co-occurring layers and requires the processing of spatial relations. Sign language thus incorporates functions for which each of the cerebral hemispheres shows a different predominant specialization. How, then, is language organized in the brain when the language is inherently spatial? To answer this question, the following chapters report on our studies of six deaf signers with unilateral brain damage. We analyze the capacities of these patients to process nonlanguage visuospatial relations, to produce nonsign gestures, and to communicate in sign language. In the next chapter we turn to the issues involved, to previous studies performed, and to our methods of analysis.