# Language Structure and Language Organization in the Brain: Evidence from the Study of Human Sign Languages [1]

***

**Laura A. Petitto**
Department of Psychology
McGill University
Stewart Biological Sciences Building
1205 Dr. Penfield Ave.
Montréal, Québec
Canada H3A-1B1

***

In press, RSSI

# Language Structure and Language Organization in the Brain: Evidence from the Study of Human Sign Languages[1]

**Laura A. Petitto**
Department of Psychology
McGill University

Until recently, nearly all that was known about human language had come from the study of spoken languages. The research discussed in this paper provides both challenges to our conception of human language and important insights into central issues in modern-day cognitive science.

Sign language structure. Intensive research on the sign languages of deaf people over the past 20 years has disproven three common myths about them: (1) that they are a crude mix of pantomine and concrete gestures, (2) that there is a single, universal sign language used by all deaf people, and (3) that they lack the grammatical organization characteristic of spoken languages. As a result of studies by Stokoe (1960), Klima and Bellugi (1979), Petitto (1981), and others, the basic organizational structure and grammatical components of ASL, a naturally-evolved language that is used by most deaf people in the United States and in parts of Canada, have been identified. Analyses of ASL have revealed that it exhibits formal organization at the same levels found in spoken languages, including a sublexical level of structuring internal to the sign (analogous to the phoneme level; Battison, 1978, Bellugi, 1980; Bellugi & Klima, 1982; Klima & Bellugi, 1979; Stokoe, 1960), and a level that specifies the precise ways that signs must be bound to form signs and signs to form sentences (analogous to the morphological and syntactic levels; Bahan & Petitto, 1980; Kegl, 1979; Klima & Bellugi, 1979; Padden, 1979, 1981, 1983; Petitto, 1981; Supalla, 1982).

ASL "words" (signs) are built from a highly restricted set of four formational components: hand configurations, movements, places of articulation, and palm orientations. A change in any one of these four components changes a sign's meaning, in the same way that a change in voicing distinquishes the phonemes /p/ from /b/ in spoken English (see Figure 1) [2].

**--Figure 1 about here--**

Despite the fact that each of these dimensions could take on a potentially infinite number of values,

ASL uses only a limited set of formational elements, similar in number to the phonemes in spoken languages (Klima & Bellugi, 1979). Because communication occurs primarily in front of the signer's body, both space and movement have a complex formal role in the language's grammar. In particular, the systematic use of space is central to the pronominal and anaphoric referencing systems in ASL, where nominals are "established" at arbitrary points infront of the signer's body and subsequent referencing (anaphora) is accomplished by re-indexing the previously established referent in space (Bellugi & Klima, 1982; Petitto, 1981; 1981; see Figure 2). Subtle changes of movement mark a variety of grammatical functions, including aspect, noun-verb distinctions, and verb agreement (see especially papers in Klima & Bellugi, 1979). As with spoken languages, the combination of these elements into sentences in discourse is rule-governed (Marmor & Petitto, 1979; Wilbur & Petitto, 1981; 1983).

**--Figure 2 about here--**

Evidence from observational, historical, and experimental studies support this analysis of signs and suggest that the four components are "psychologically real" units of language representation for deaf signers. For example, "slips of the hand" (inadvertent ordering of articulatory elements, analogous to slips of the tongue) involve substitution of component elements only (Klima & Bellugi, 1979). The four components restrict the form that new signs can assume and account for the loss of a sign's global iconic (pictorial) features over time (Frishberg, 1975). Further, experimental studies of short-term-memory in deaf signers have demonstrated that their memory errors are wholly in terms of a sign's formational components (Bellugi & Siple, 1974). Thus, despite the modality difference, both spoken and signed languages reflect the same underlying linguistic principles and internal organization; these do not appear to derived from particular transmission systems, suggesting more central, modality-free constraints on linguistic form (Bellugi, 1980; Wilbur & Petitto, 1983).

Sign Language and Cognitive Science. The importance of current research on ASL is that it yields the surprising conclusion that human languages are not restricted to the speech channel. The existence of signed languages presents a natural experiment providing data relevant to several essential problems

in the study of human cognition, the fundamental one being how modality influences the knowledge and use of language. Until recently, the human linguistic capacity was studied exclusively with respect to spoken languages. Language evolved in the speech channel, and some researchers have argued that the structural properties of spoken languages reflect constraints imposed by the perceptual, cognitive and motoric capacities that subserve speech and hearing (e.g. Bellugi and Studdert-Kennedy, 1980). For example, the linear, sequential ordering of phonemes universally observed in spoken languages may be a consequence of biological constraints on the production and perception of sound. However, a different set of constraints are relevant to languages in the visual-gestural modality. On the one hand, it would seem that signed and spoken languages should differ in fundamental ways: they involve different types of signals (visual-gestural vs. auditory), they are differentially adapted to conveying various kinds of information (e.g., imagistic, analogic), perceived through different sensory systems, remembered using different memory structures, and may be subserved by different neural structures. On the other hand, both spoken and signed languages convey identical kinds of linguistic information and are used to perform the same communicative functions. Because of the linguistic status of sign language, researchers can now address several fundamental questions involving the manner in which modality influences the structure of language, and how differences in the way information is represented in the two modalities affect the acquisition, processing, and neural representation of language. In particular:

• Are the universal properties of language hypothesized by Chomsky (1965, 1975) "modality-independent"? Specifically, do these properties require an aural-oral basis or can they be expressed in gesture and space?

• Which properties of languages are incidental consequences of the modality of transmission, and which are essential and modality-free?

• Do the differences in how information is represented in the two modalities affect how the languages are structured and processed? The visual-gestural channel affords greater potential for the perception and production of multiple, simultaneous sources of information; perception and production

in the speech channel may make greater use of linear and temporal contrasts between discrete sources of information.

• Is the course of the acquisition process similar for languages in the two modalities or does acquisition differ because of modality-specific properties (e.g., the potential for iconic or indexical structures in a signed language)?

• Does the pattern of cerebral specialization for language differ depending on modality? Is the pattern of cerebral specialization for language speech dependent, or is it neurologically modifiable depending on the mode of language transmission? Are the cerebral areas implicated in language processing "language" areas or "speech" areas?

In sum, the basic similarities between signed and spoken languages having been established, it is now possible to use sign language research to address deeper questions concerning human cognitive and linguistic capacities. In the remaining section of this paper I will discuss two areas of sign language research that promise to be especially revealing with regard to the representation of language in the brain: in particular, studies of sign language acquisition (language build-up), and studies of sign language aphasia (language breakdown).

Sign Language and Language Acquisition. While signed and spoken languages share fundamental properties, they also differ in important respects. First, space and movement (including facial expressions) are the means for conveying morphological and syntactic information in signed languages, but not in spoken languages. The continuous, analogue properties of space and movement are used in ASL in systematic, rule-governed ways. These abstract spatial and movement units are analogous in function to discrete morphemes found in spoken language. The greater potential for non-arbitrary form-meaning correspondences afforded by the visual-gestural modality is exploited in sign languages. In particular, indexical signs point to their referents while the forms of iconic signs physically resemble aspects of their referents.

These modality differences allow us to address important issues in language acquisition. In particular, studies of ASL provide a way to resolve a major theoretical controversy concerning the role

of pre-linguistic gestures in the acquisition of linguistic symbols. Both deaf and hearing children rely upon gestural communication prior to language. For the hearing child the transition from pre-linguistic communication to spoken language involves a change in modality while for the deaf child, the transition to signed language does not. That is, for the deaf child gestures and symbols reside in the same modality. In evaluating the importance of pre-linguistic gestures in early language acquisition, sign languages provide a unique methodological advantage, since, given a single modality, and external articulators, certain developmental processes in language can be directly observed over time. In spoken language, of course, this is not the case; there appears to be an abrupt transition from the use of pre-linguistic manual gestures to linguistic (spoken) communication: However, this could be an artifactual consequence of the shift in modality, rather than reflecting a deeper discontinuity between pre-linguistic and linguistic knowledge. The basic question, then, is whether the acquisition of linguistic forms will (a) be facilitated by, (b) be continuous with, or (c) share important symbolic properties with deaf children's knowledge of their extra-linguistic communicative functions. In sum, this research provides a unique way to examine whether language derives from general cognitive capacities to think and learn, or whether it involves a domain-specific type of knowledge or faculty.

Recent studies have revealed that the acquisition of sign languages in deaf children is strikingly similar to hearing children's acquisition of spoken languages, despite the radical differences in modality. As with hearing children, deaf children produce prelinguistic gestures beginning around 6 to 12 months of age. These prelinguistic gestures are surprisingly similar in form, function and use to those observed in hearing children.

Interestingly, deaf children do not sign earlier than hearing children use their first words. Powerful evidence for this claim was provided in a recent study by Petitto (1983 a,b). In her study of profoundly deaf children (ages 10 through 27 months), a dramatic discontinuity was observed between the children's use of prelinguistic communicative pointing and their linguistic expression of YOU and ME pronouns in ASL (both pronouns are formed by pointing to the addressee or speaker, respectively). That is, although the deaf infants were able, for example, to point to mother's necklace to indicate it

beginning around 9 months, they did not use the pointing form to indicate mother as in YOU until around 16 to 22 months, the precise age-range when hearing children first begin acquiring spoken pronouns. In addition, as is the case in hearing children acquiring pronouns, deaf children also demonstrated unstable use of pronouns, with one child engaging in systematic pronoun reversal errors. Specifically the deaf child signed YOU to intend ME in the same way that some hearing children initially say you to refer to themselves; see Figure 3). This error was especially striking in sign language because the child had to ignore the truly indexical nature of the indexical point and treat it as a frozen lexical sign. In doing so, the child apparently conceptualized the sign in a manner that increased the abstractness of the mapping between form and its meaning.

**--Figure 3 about here--**

Another interesting aspect of the deaf child's development is the onset of linguistically relevant sign babbling around the ages 7 through 12 months (Petitto, in press; Petitto & Roberge, in preparation); these babbling forms are fundamentally distinct from the deaf child's prelinguistic gestures.

Finally, detailed accounts now exist of the deaf child's acquisition of "phonology" (i.e., states of manual articulation; e.g., Petitto, 1979; McIntire, 1977), acquisition of complex verb morphology (Fischer & Gough, 1973; Meier, 1982; Petitto, 1981; Supalla, 1982), development of gramatical and semantic categories (Launer, 1982; Newport & Ashbrook, 1977), and studies of later acquisition of pronominal and anaphoric referencing (Bellugi and Klima, 1980; Hoffmeister, 1978; and Loew, 1983). These important studies have firmly established that despite the differences in modality, deaf children acquire ASL as a first language in ways that are very similar to those of hearing children acquiring spoken language.

Sign Language and Sign Language Aphasia. The study of the breakdown of sign language in brain-injured deaf people offers a direct window into the organization of language in the brain. Language and visual-spatial information have been thought to have distinct neuroanatomical realizations, with the right hemisphere of the brain said to be dominant for processing visual-spatial information, and the left for language. Because human language has evolved in conjunction with

sound, the sound-language relationship has been regarded as the critical determinant for the development of this pattern of hemispheric specialization (Lieberman, 1975). The intriguing question with respect to deaf signers is, what is the pattern of cerebral organization for a language that has evolved in the absence of sound? Because signed languages are visual and spatial, they might be expected to be represented primarily in the right hemisphere. Becasue they are languages, however, they might be represented on the left.

The surprising finding from initial studies of brain damaged deaf signers was that their language functions were lateralized on the left side of the brain, even though ASL's linguistic units are visual-spatial in nature; Bellugi, Poizner & Klima, in press). Other important findings include the observation that brain-injured deaf signers exhibit selective loss of linguistic functions depending on the exact location and nature of the lesion (Bellugi, Poizner, & Zurif, 1982). Remarkably, patterns of sign "aphasia" have been uncovered that closely resemble those observed in hearing persons with left hemisphere brain damage. Left hemisphere brain-damaged deaf people have been found with sign deficits corresponding to the two classical aphasias: (1) articulatory impairments in the production of signs, although semantically appropriate with generally unimpaired sign comprehension (analogous to Brocca's aphasia), and (2) phonologically intact, but semantically anomolous utterances with impaired comprehension (analogous to Wernicke's aphasia; Bellugi, Poizner, & Zurif, 1982).

The above findings raise important questions about the causes of cerebral specialization and neurological plasticity. Sign langauges offer a powerful way to explore the links among language, perception and gestural-mortoric activity, and their effects on brain organization. Comparative study of aphasias among signing and speaking persons provides a way to determine whether it is the type of information which is relevant to cerebral organization (visual-spatial vs. oral-aural). Evidence concerning the selective impairments following brain injury also provides further information concerning the structure of the sign code, its mental representation, and its relation to non-linguistic knowledge.

## Summary and Future Research

The study of signed languages is an exciting area of research that provides a novel scientific way to address basic issues in human cognition. We can learn more about the nature of language and gestural symbols, the effects of modality on language structure, and the relationship between language and the brain. Additionally, research on the linguistic and psycholinguistic properties of signed languages addresses a major question in Cognitive Science. Specifically, is knowledge organized along distinct domain-specific faculties or "modules" (e.g., language, space), or are there general cognitive capacities that serve multiple functions? On the latter view, one's ability to use language or perceive spatial relationships is thought to be governed by general cognitive processes (e.g., memory, learning) implicated in all types of knowledge, rather than domain-specific types of knowledge. Signed languages provide a way to address this issue because linguistic and non-linguistic information are of the same visual-gestural form. Differentiation between linguistic and non-linguistic use of visual-gestural information in language acquisition and breakdown would provide behavioral evidence for the existence of domain-specific types of knowledge including a distinct language faculty that exists irrespective of the mode of language transmission. Further, comparative studies of the structure and processing of signed languages provide important information about the modality-free versus channel-specific constraints on the human language faculty.

## FOOTNOTES

1. This research was funded both by a fellowship from the John D. and Catherine MacArthur Foundation's "San Diego Node" (Dr. Elizabeth Bates, Director), and by a grant from the Natural Sciences and Engineering Research Council of Canada.

2. The illustrations in this paper were drawn by the sign artist, Frank Paul, and are the exclusive, copyrighted property of Dr. Ursula Bellugi, Director, Neurolinguistic Laboratory, The Salk Institute for Biological Sciences, P.O. Box 85800, San Diego, California, 92138, U.S.A.; these illustrations may not be used without the written permission of Dr. Bellugi.

## REFERENCES

Bahan, B., and Petitto, L.A. Aspects of rules for character establishing and reference in American Sign Language storytelling. Working Paper. The Salk Institute for Biological Studies, La Jolla, California, 1980.

Battison, R. Lexical borrowing in American Sign Language. Silver Spring: Linstok Press, 1978.

Bellugi, U. The structuring of language: clues from the similarities between signed and spoken language. In U. Bellugi and M. Studdert-Kennedy (Eds.), Signed and spoken language. Biological constraints on linguistic form. Dahlem Konferenzen. Weinheim/Deerfield, Fla.: Verlag chemie, 1980, 115-140.

Bellugi, U., and Klima E. The acquisition of three morphological systems in American Sign Language. In Papers and Reports on child language development. Stanford, CA.: Stanford University, 1982, 21, 1-35.

Bellugi, U., Poizner, H., and Klima, E. What the hands reveal about the brain. MIT Press, in press.

Bellugi, U., Poizner, H., and Zurif, E. Prospects for the study of aphasia in a visual-gestural language. In M.A. Arbib et al. (Eds.), Neural Models of Language Processes. NY :Academic Press, 1982, 271-292.

Bellugi, U., and Siple, P. Remembering with and without words. In F. Bresson (Ed.), Current Problems in Psycholinguistics. Paris: Centre National de la Recherche Scientifique, 1974, 214-236.

Bellugi, U., and Studdert-Kennedy, M. (Eds.), Signed and spoken language: Biological constraints on linguistic form. Dahlem konferenzen. Weinheim/Deerfield Beach, Fla.: Verlag Chemie, 1980.

Chomsky, N. Aspects of the theory of syntax. Cambridge, Mass.: M.I.T. Press, 1965.

Chomsky, N. The logical structure of linguistic theory. New York: Plenum Press, 1975.

Fischer, S. and Gough, B. Verbs in American Sign Language. Sign Language Studies, 1973, 18, 17-48.

Frishberg, N., Arbitrariness and Iconicity: Historical change in ASL. Language, 1975, 51, 696-719.

Hoffmeister, R.J. The acquisition of American Sign Language by deaf children of deaf parents: the development of demonstrative pronouns, locatives, and personal pronouns. Unpublished doctoral dissertation. University of Minnesota, 1978

Kegl, J. Pronominalization in American Sign Language. Unpublished manuscript. Cambridge, Mass.: M.I.T. Department of Linguistics, 1979.

Klima, E., and Bellugi, U. The signs of language. Cambridge, Mass.: Harvard University Press, 1979.

Launer, P. "A plane" is not "to fly": Acquiring the distinction between nouns and verbs in American Sign Language. Unpublished doctoral dissertation. City University of New York, 1982.

Lieberman, P. On the origins of language. New York: Macmillan, 1975.

Loew, R. Roles and reference in American Sign Language: A developmental perspecitve. Unpublished doctoral dissertation. University of Minnesota, 1983.

Marmor, G.S., and Petitto, L.A. Simultaneous communication in the classroom: How well is English grammar represented? Sign Language Studies, 1979, 3, 99-136.

McIntire, M. The acquisition of American Sign Language hand configurations. Sign Language Studies, 1977, 16.

Meier, R. Icons, analogues and morphemes: The acquisition of verb agreement in American Sign Language. Unpublished doctoral dissertation. University of California, San Diego, 1982.

Newport, E., and Ashbrook, E. The emergence of semantic relations in American Sign Language. Papers and Reports on Child Language Development, 1977, 13, 16-21.

Padden, C. Verbs in American Sign Language. Working Paper. The Salk Institute for Biological Studies, Laboratory for Language and Cognitive Studies, LaJolla, California, 1979.

Padden, C. Some arguments for syntactic patterning in ASL. Sign Language Studies, 1981, 32, 239-259.

Padden, C. Interaction of morphology and syntax in American Sign Language. Unpublished doctoral dissertation. University of California, San Diego, 1983.

Petitto, L.A. The acquistion of phonology in deaf children learning American Sign Language. Paper presented at the

NATO Advanced Study Institutes Programme: Conference on Sign Language Studies, Copenhagen, Denmark, August, 1979.

Petitto, L.A. On the acquisition of anaphoric reference in American Sign Language. The Salk Institute for Biological Studies, La Jolla, California, 1981.

Petitto, L.A. From gesture to symbol: The relationship between form and meaning in the acquisition of personal pronouns in American Sign Language. Unpublished doctoral dissertation. Harvard University, 1983 (a).

Petitto, L.A. From gesture to symbol: The relationship between form and meaning in the acquisition of personal pronouns in American Sign Langauge. Papers and Reports on Child Language Development, 1983, 22, 100-107, (b).

Petitto, L.A. "Language" in the Pre-linguistic Child. In F. Kessel (Ed.) The development of language and language researchers. Hillsdale, New Jersey: Lawrence Erlbaum Associates, in press.

Petitto, L.A. and Roberge, M. Sign babbling in deaf infants. Department of Psychology, McGill University, in preparation.

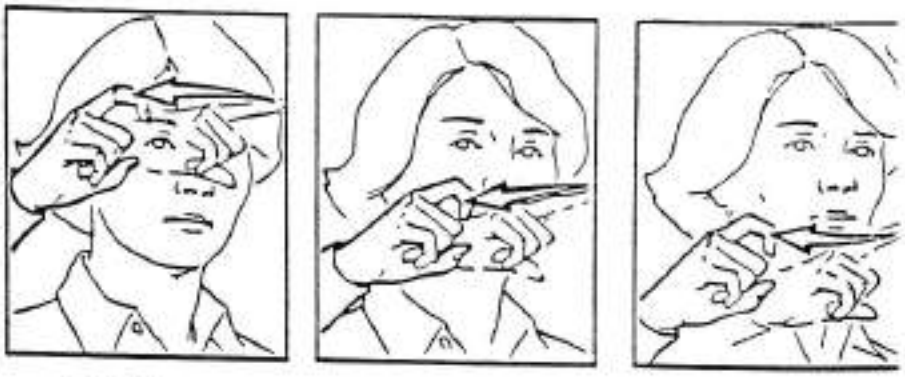
Stokoe, W. Sign language structure: An outline of the visual communication systems of the American Deaf. Studies in Linguistics, Occasional Papers, University of Buffalo, 1960.

Supalla, T. Acquisition of morphology of American Sign Language verbs of motion and location. Unpublished doctoral dissertation. University of California, San Diego, 1982.

Wilbur, R. B., and Petitto, L. A. How to know a conversation when you see one: Discourse structure in American Sign Language conversations. Journal of the National Student Speech Language Hearing Association, 1981, 91,66-81.

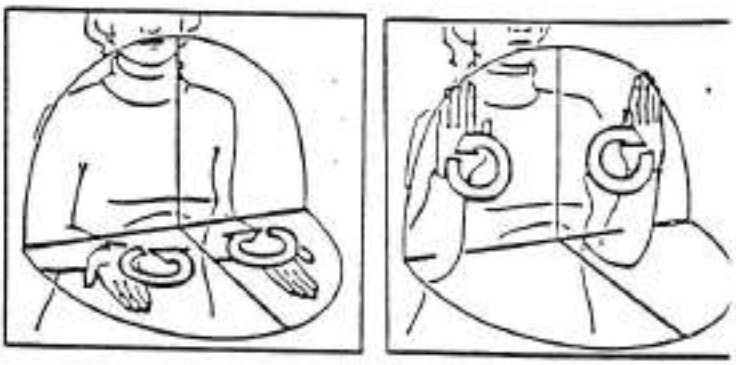
Wilbur, R.B., and Petitto, L.A. Discourse structure of American Sign Language conversations. Discourse Processes, 1983, 6:3, 225-241.

Places of Articulation



SUMMER UGLY DRY

BIRD NEWSPAPER



HERE SUNDAY

Figure 1: Places of articulation important for lexical contrasts

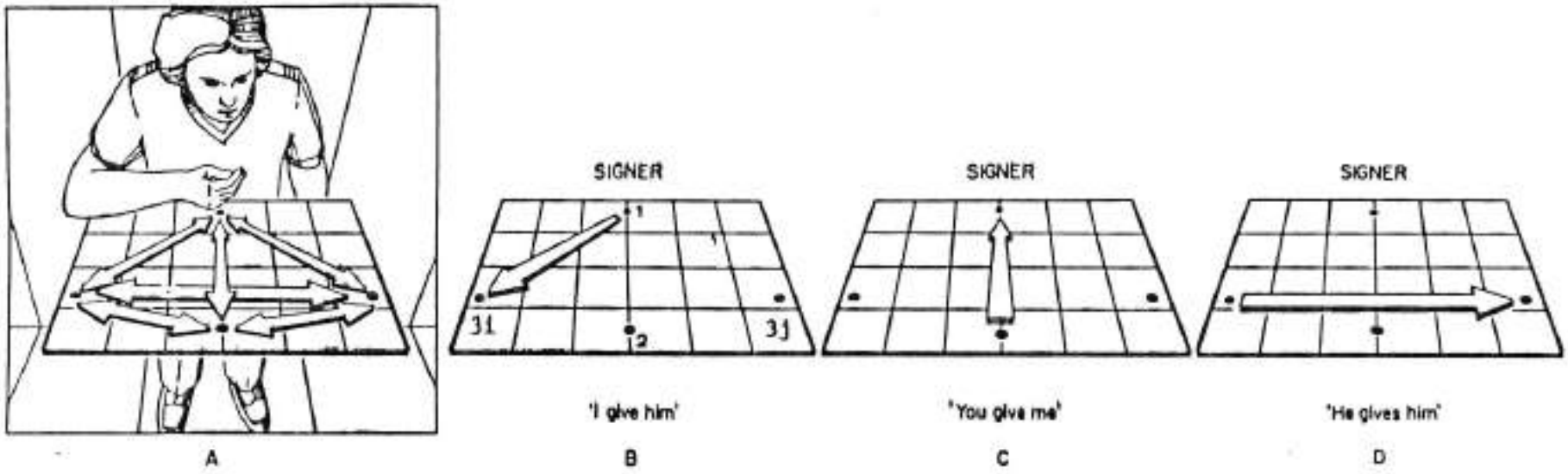



Figure 2: Signs are established within an indexic plane in front of the signer's body. A large class of verbs move along this spatial plane to form the verb agreement and anaphoric referencing systems in ASL. For example, the verb GIVE (a) can be moved along the signing plane to indicate «I give him» (b), «You give me» (c), and «He gives him» (d).

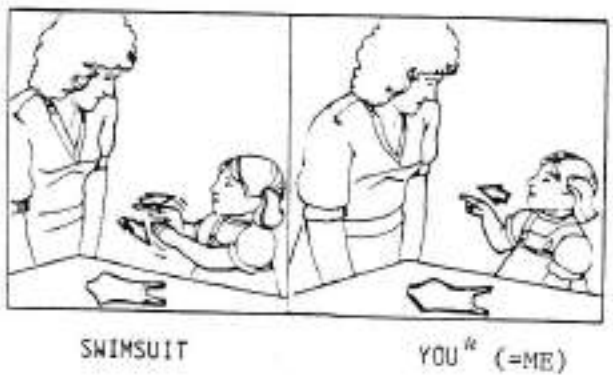



Figure 3: Child's pronoun reversing error (age 1;11).

# Language Structure and Language Organization in the Brain: Evidence from the Study of Human Sign Languages [1]

***

**Laura A. Petitto**
Department of Psychology
McGill University
Stewart Biological Sciences Building
1205 Dr. Penfield Ave.
Montréal, Québec
Canada H3A-1B1

***

In press, RSSI

# Language Structure and Language Organization in the Brain: Evidence from the Study of Human Sign Languages[1]

**Laura A. Petitto**
Department of Psychology
McGill University

Until recently, nearly all that was known about human language had come from the study of spoken languages. The research discussed in this paper provides both challenges to our conception of human language and important insights into central issues in modern-day cognitive science.

Sign language structure. Intensive research on the sign languages of deaf people over the past 20 years has disproven three common myths about them: (1) that they are a crude mix of pantomine and concrete gestures, (2) that there is a single, universal sign language used by all deaf people, and (3) that they lack the grammatical organization characteristic of spoken languages. As a result of studies by Stokoe (1960), Klima and Bellugi (1979), Petitto (1981), and others, the basic organizational structure and grammatical components of ASL, a naturally-evolved language that is used by most deaf people in the United States and in parts of Canada, have been identified. Analyses of ASL have revealed that it exhibits formal organization at the same levels found in spoken languages, including a sublexical level of structuring internal to the sign (analogous to the phoneme level; Battison, 1978, Bellugi, 1980; Bellugi & Klima, 1982; Klima & Bellugi, 1979; Stokoe, 1960), and a level that specifies the precise ways that signs must be bound to form signs and signs to form sentences (analogous to the morphological and syntactic levels; Bahan & Petitto, 1980; Kegl, 1979; Klima & Bellugi, 1979; Padden, 1979, 1981, 1983; Petitto, 1981; Supalla, 1982).

ASL "words" (signs) are built from a highly restricted set of four formational components: hand configurations, movements, places of articulation, and palm orientations. A change in any one of these four components changes a sign's meaning, in the same way that a change in voicing distinquishes the phonemes /p/ from /b/ in spoken English (see Figure 1) [2].

**--Figure 1 about here--**

Despite the fact that each of these dimensions could take on a potentially infinite number of values,

ASL uses only a limited set of formational elements, similar in number to the phonemes in spoken languages (Klima & Bellugi, 1979). Because communication occurs primarily in front of the signer's body, both space and movement have a complex formal role in the language's grammar. In particular, the systematic use of space is central to the pronominal and anaphoric referencing systems in ASL, where nominals are "established" at arbitrary points infront of the signer's body and subsequent referencing (anaphora) is accomplished by re-indexing the previously established referent in space (Bellugi & Klima, 1982; Petitto, 1981; 1981; see Figure 2). Subtle changes of movement mark a variety of grammatical functions, including aspect, noun-verb distinctions, and verb agreement (see especially papers in Klima & Bellugi, 1979). As with spoken languages, the combination of these elements into sentences in discourse is rule-governed (Marmor & Petitto, 1979; Wilbur & Petitto, 1981; 1983).

**--Figure 2 about here--**

Evidence from observational, historical, and experimental studies support this analysis of signs and suggest that the four components are "psychologically real" units of language representation for deaf signers. For example, "slips of the hand" (inadvertent ordering of articulatory elements, analogous to slips of the tongue) involve substitution of component elements only (Klima & Bellugi, 1979). The four components restrict the form that new signs can assume and account for the loss of a sign's global iconic (pictorial) features over time (Frishberg, 1975). Further, experimental studies of short-term-memory in deaf signers have demonstrated that their memory errors are wholly in terms of a sign's formational components (Bellugi & Siple, 1974). Thus, despite the modality difference, both spoken and signed languages reflect the same underlying linguistic principles and internal organization; these do not appear to derived from particular transmission systems, suggesting more central, modality-free constraints on linguistic form (Bellugi, 1980; Wilbur & Petitto, 1983).

Sign Language and Cognitive Science. The importance of current research on ASL is that it yields the surprising conclusion that human languages are not restricted to the speech channel. The existence of signed languages presents a natural experiment providing data relevant to several essential problems

in the study of human cognition, the fundamental one being how modality influences the knowledge and use of language. Until recently, the human linguistic capacity was studied exclusively with respect to spoken languages. Language evolved in the speech channel, and some researchers have argued that the structural properties of spoken languages reflect constraints imposed by the perceptual, cognitive and motoric capacities that subserve speech and hearing (e.g. Bellugi and Studdert-Kennedy, 1980). For example, the linear, sequential ordering of phonemes universally observed in spoken languages may be a consequence of biological constraints on the production and perception of sound. However, a different set of constraints are relevant to languages in the visual-gestural modality. On the one hand, it would seem that signed and spoken languages should differ in fundamental ways: they involve different types of signals (visual-gestural vs. auditory), they are differentially adapted to conveying various kinds of information (e.g., imagistic, analogic), perceived through different sensory systems, remembered using different memory structures, and may be subserved by different neural structures. On the other hand, both spoken and signed languages convey identical kinds of linguistic information and are used to perform the same communicative functions. Because of the linguistic status of sign language, researchers can now address several fundamental questions involving the manner in which modality influences the structure of language, and how differences in the way information is represented in the two modalities affect the acquisition, processing, and neural representation of language. In particular:

• Are the universal properties of language hypothesized by Chomsky (1965, 1975) "modality-independent"? Specifically, do these properties require an aural-oral basis or can they be expressed in gesture and space?

• Which properties of languages are incidental consequences of the modality of transmission, and which are essential and modality-free?

• Do the differences in how information is represented in the two modalities affect how the languages are structured and processed? The visual-gestural channel affords greater potential for the perception and production of multiple, simultaneous sources of information; perception and production

in the speech channel may make greater use of linear and temporal contrasts between discrete sources of information.

• Is the course of the acquisition process similar for languages in the two modalities or does acquisition differ because of modality-specific properties (e.g., the potential for iconic or indexical structures in a signed language)?

• Does the pattern of cerebral specialization for language differ depending on modality? Is the pattern of cerebral specialization for language speech dependent, or is it neurologically modifiable depending on the mode of language transmission? Are the cerebral areas implicated in language processing "language" areas or "speech" areas?

In sum, the basic similarities between signed and spoken languages having been established, it is now possible to use sign language research to address deeper questions concerning human cognitive and linguistic capacities. In the remaining section of this paper I will discuss two areas of sign language research that promise to be especially revealing with regard to the representation of language in the brain: in particular, studies of sign language acquisition (language build-up), and studies of sign language aphasia (language breakdown).

Sign Language and Language Acquisition. While signed and spoken languages share fundamental properties, they also differ in important respects. First, space and movement (including facial expressions) are the means for conveying morphological and syntactic information in signed languages, but not in spoken languages. The continuous, analogue properties of space and movement are used in ASL in systematic, rule-governed ways. These abstract spatial and movement units are analogous in function to discrete morphemes found in spoken language. The greater potential for non-arbitrary form-meaning correspondences afforded by the visual-gestural modality is exploited in sign languages. In particular, indexical signs point to their referents while the forms of iconic signs physically resemble aspects of their referents.

These modality differences allow us to address important issues in language acquisition. In particular, studies of ASL provide a way to resolve a major theoretical controversy concerning the role

of pre-linguistic gestures in the acquisition of linguistic symbols. Both deaf and hearing children rely upon gestural communication prior to language. For the hearing child the transition from pre-linguistic communication to spoken language involves a change in modality while for the deaf child, the transition to signed language does not. That is, for the deaf child gestures and symbols reside in the same modality. In evaluating the importance of pre-linguistic gestures in early language acquisition, sign languages provide a unique methodological advantage, since, given a single modality, and external articulators, certain developmental processes in language can be directly observed over time. In spoken language, of course, this is not the case; there appears to be an abrupt transition from the use of pre-linguistic manual gestures to linguistic (spoken) communication: However, this could be an artifactual consequence of the shift in modality, rather than reflecting a deeper discontinuity between pre-linguistic and linguistic knowledge. The basic question, then, is whether the acquisition of linguistic forms will (a) be facilitated by, (b) be continuous with, or (c) share important symbolic properties with deaf children's knowledge of their extra-linguistic communicative functions. In sum, this research provides a unique way to examine whether language derives from general cognitive capacities to think and learn, or whether it involves a domain-specific type of knowledge or faculty.

Recent studies have revealed that the acquisition of sign languages in deaf children is strikingly similar to hearing children's acquisition of spoken languages, despite the radical differences in modality. As with hearing children, deaf children produce prelinguistic gestures beginning around 6 to 12 months of age. These prelinguistic gestures are surprisingly similar in form, function and use to those observed in hearing children.

Interestingly, deaf children do not sign earlier than hearing children use their first words. Powerful evidence for this claim was provided in a recent study by Petitto (1983 a,b). In her study of profoundly deaf children (ages 10 through 27 months), a dramatic discontinuity was observed between the children's use of prelinguistic communicative pointing and their linguistic expression of YOU and ME pronouns in ASL (both pronouns are formed by pointing to the addressee or speaker, respectively). That is, although the deaf infants were able, for example, to point to mother's necklace to indicate it

beginning around 9 months, they did not use the pointing form to indicate mother as in YOU until around 16 to 22 months, the precise age-range when hearing children first begin acquiring spoken pronouns. In addition, as is the case in hearing children acquiring pronouns, deaf children also demonstrated unstable use of pronouns, with one child engaging in systematic pronoun reversal errors. Specifically the deaf child signed YOU to intend ME in the same way that some hearing children initially say you to refer to themselves; see Figure 3). This error was especially striking in sign language because the child had to ignore the truly indexical nature of the indexical point and treat it as a frozen lexical sign. In doing so, the child apparently conceptualized the sign in a manner that increased the abstractness of the mapping between form and its meaning.

**--Figure 3 about here--**

Another interesting aspect of the deaf child's development is the onset of linguistically relevant sign babbling around the ages 7 through 12 months (Petitto, in press; Petitto & Roberge, in preparation); these babbling forms are fundamentally distinct from the deaf child's prelinguistic gestures.

Finally, detailed accounts now exist of the deaf child's acquisition of "phonology" (i.e., states of manual articulation; e.g., Petitto, 1979; McIntire, 1977), acquisition of complex verb morphology (Fischer & Gough, 1973; Meier, 1982; Petitto, 1981; Supalla, 1982), development of gramatical and semantic categories (Launer, 1982; Newport & Ashbrook, 1977), and studies of later acquisition of pronominal and anaphoric referencing (Bellugi and Klima, 1980; Hoffmeister, 1978; and Loew, 1983). These important studies have firmly established that despite the differences in modality, deaf children acquire ASL as a first language in ways that are very similar to those of hearing children acquiring spoken language.

Sign Language and Sign Language Aphasia. The study of the breakdown of sign language in brain-injured deaf people offers a direct window into the organization of language in the brain. Language and visual-spatial information have been thought to have distinct neuroanatomical realizations, with the right hemisphere of the brain said to be dominant for processing visual-spatial information, and the left for language. Because human language has evolved in conjunction with

sound, the sound-language relationship has been regarded as the critical determinant for the development of this pattern of hemispheric specialization (Lieberman, 1975). The intriguing question with respect to deaf signers is, what is the pattern of cerebral organization for a language that has evolved in the absence of sound? Because signed languages are visual and spatial, they might be expected to be represented primarily in the right hemisphere. Becasue they are languages, however, they might be represented on the left.

The surprising finding from initial studies of brain damaged deaf signers was that their language functions were lateralized on the left side of the brain, even though ASL's linguistic units are visual-spatial in nature; Bellugi, Poizner & Klima, in press). Other important findings include the observation that brain-injured deaf signers exhibit selective loss of linguistic functions depending on the exact location and nature of the lesion (Bellugi, Poizner, & Zurif, 1982). Remarkably, patterns of sign "aphasia" have been uncovered that closely resemble those observed in hearing persons with left hemisphere brain damage. Left hemisphere brain-damaged deaf people have been found with sign deficits corresponding to the two classical aphasias: (1) articulatory impairments in the production of signs, although semantically appropriate with generally unimpaired sign comprehension (analogous to Brocca's aphasia), and (2) phonologically intact, but semantically anomolous utterances with impaired comprehension (analogous to Wernicke's aphasia; Bellugi, Poizner, & Zurif, 1982).

The above findings raise important questions about the causes of cerebral specialization and neurological plasticity. Sign langauges offer a powerful way to explore the links among language, perception and gestural-mortoric activity, and their effects on brain organization. Comparative study of aphasias among signing and speaking persons provides a way to determine whether it is the type of information which is relevant to cerebral organization (visual-spatial vs. oral-aural). Evidence concerning the selective impairments following brain injury also provides further information concerning the structure of the sign code, its mental representation, and its relation to non-linguistic knowledge.

## Summary and Future Research

The study of signed languages is an exciting area of research that provides a novel scientific way to address basic issues in human cognition. We can learn more about the nature of language and gestural symbols, the effects of modality on language structure, and the relationship between language and the brain. Additionally, research on the linguistic and psycholinguistic properties of signed languages addresses a major question in Cognitive Science. Specifically, is knowledge organized along distinct domain-specific faculties or "modules" (e.g., language, space), or are there general cognitive capacities that serve multiple functions? On the latter view, one's ability to use language or perceive spatial relationships is thought to be governed by general cognitive processes (e.g., memory, learning) implicated in all types of knowledge, rather than domain-specific types of knowledge. Signed languages provide a way to address this issue because linguistic and non-linguistic information are of the same visual-gestural form. Differentiation between linguistic and non-linguistic use of visual-gestural information in language acquisition and breakdown would provide behavioral evidence for the existence of domain-specific types of knowledge including a distinct language faculty that exists irrespective of the mode of language transmission. Further, comparative studies of the structure and processing of signed languages provide important information about the modality-free versus channel-specific constraints on the human language faculty.

## FOOTNOTES

1. This research was funded both by a fellowship from the John D. and Catherine MacArthur Foundation's "San Diego Node" (Dr. Elizabeth Bates, Director), and by a grant from the Natural Sciences and Engineering Research Council of Canada.

2. The illustrations in this paper were drawn by the sign artist, Frank Paul, and are the exclusive, copyrighted property of Dr. Ursula Bellugi, Director, Neurolinguistic Laboratory, The Salk Institute for Biological Sciences, P.O. Box 85800, San Diego, California, 92138, U.S.A.; these illustrations may not be used without the written permission of Dr. Bellugi.

## REFERENCES

Bahan, B., and Petitto, L.A. Aspects of rules for character establishing and reference in American Sign Language storytelling. Working Paper. The Salk Institute for Biological Studies, La Jolla, California, 1980.

Battison, R. Lexical borrowing in American Sign Language. Silver Spring: Linstok Press, 1978.

Bellugi, U. The structuring of language: clues from the similarities between signed and spoken language. In U. Bellugi and M. Studdert-Kennedy (Eds.), Signed and spoken language. Biological constraints on linguistic form. Dahlem Konferenzen. Weinheim/Deerfield, Fla.: Verlag chemie, 1980, 115-140.

Bellugi, U., and Klima E. The acquisition of three morphological systems in American Sign Language. In Papers and Reports on child language development. Stanford, CA.: Stanford University, 1982, 21, 1-35.

Bellugi, U., Poizner, H., and Klima, E. What the hands reveal about the brain. MIT Press, in press.

Bellugi, U., Poizner, H., and Zurif, E. Prospects for the study of aphasia in a visual-gestural language. In M.A. Arbib et al. (Eds.), Neural Models of Language Processes. NY :Academic Press, 1982, 271-292.

Bellugi, U., and Siple, P. Remembering with and without words. In F. Bresson (Ed.), Current Problems in Psycholinguistics. Paris: Centre National de la Recherche Scientifique, 1974, 214-236.

Bellugi, U., and Studdert-Kennedy, M. (Eds.), Signed and spoken language: Biological constraints on linguistic form. Dahlem konferenzen. Weinheim/Deerfield Beach, Fla.: Verlag Chemie, 1980.

Chomsky, N. Aspects of the theory of syntax. Cambridge, Mass.: M.I.T. Press, 1965.

Chomsky, N. The logical structure of linguistic theory. New York: Plenum Press, 1975.

Fischer, S. and Gough, B. Verbs in American Sign Language. Sign Language Studies. 1973, 18, 17-48.

Frishberg, N., Arbitrariness and Iconicity: Historical change in ASL. Language, 1975, 51, 696-719.

Hoffmeister, R.J. The acquisition of American Sign Language by deaf children of deaf parents: the development of demonstrative pronouns, locatives, and personal pronouns. Unpublished doctoral dissertation. University of Minnesota, 1978

Kegl, J. Pronominalization in American Sign Language. Unpublished manuscript. Cambridge, Mass.: M.I.T. Department of Linguistics, 1979.

Klima, E., and Bellugi, U. The signs of language. Cambridge, Mass.: Harvard University Press, 1979.

Launer, P. "A plane" is not "to fly": Acquiring the distinction between nouns and verbs in American Sign Language. Unpublished doctoral dissertation. City University of New York, 1982.

Lieberman, P. On the origins of language. New York: Macmillan, 1975.

Loew, R. Roles and reference in American Sign Language: A developmental perspecitve. Unpublished doctoral dissertation. University of Minnesota, 1983.

Marmor, G.S., and Petitto, L.A. Simultaneous communication in the classroom: How well is English grammar represented? Sign Language Studies, 1979, 3, 99-136.

McIntire, M. The acquisition of American Sign Language hand configurations. Sign Language Studies, 1977, 16.

Meier, R. Icons, analogues and morphemes: The acquisition of verb agreement in American Sign Language. Unpublished doctoral dissertation. University of California, San Diego, 1982.

Newport, E., and Ashbrook, E. The emergence of semantic relations in American Sign Language. Papers and Reports on Child Language Development, 1977, 13, 16-21.

Padden, C. Verbs in American Sign Language. Working Paper. The Salk Institute for Biological Studies, Laboratory for Language and Cognitive Studies, LaJolla, California, 1979.

Padden, C. Some arguments for syntactic patterning in ASL. Sign Language Studies, 1981, 32, 239-259.

Padden, C. Interaction of morphology and syntax in American Sign Language. Unpublished doctoral dissertation. University of California, San Diego, 1983.

Petitto, L.A. The acquistion of phonology in deaf children learning American Sign Language. Paper presented at the

NATO Advanced Study Institutes Programme: Conference on Sign Language Studies, Copenhagen, Denmark, August, 1979.

Petitto, L.A. On the acquisition of anaphoric reference in American Sign Language. The Salk Institute for Biological Studies, La Jolla, California, 1981.

Petitto, L.A. From gesture to symbol: The relationship between form and meaning in the acquisition of personal pronouns in American Sign Language. Unpublished doctoral dissertation. Harvard University, 1983 (a).

Petitto, L.A. From gesture to symbol: The relationship between form and meaning in the acquisition of personal pronouns in American Sign Langauge. Papers and Reports on Child Language Development, 1983, 22, 100-107, (b).

Petitto, L.A. "Language" in the Pre-linguistic Child. In F. Kessel (Ed.) The development of language and language researchers. Hillsdale, New Jersey: Lawrence Erlbaum Associates, in press.

Petitto, L.A. and Roberge, M. Sign babbling in deaf infants. Department of Psychology, McGill University, in preparation.

Stokoe, W. Sign language structure: An outline of the visual communication systems of the American Deaf. Studies in Linguistics, Occasional Papers, University of Buffalo, 1960.

Supalla, T. Acquisition of morphology of American Sign Language verbs of motion and location. Unpublished doctoral dissertation. University of California, San Diego, 1982.

Wilbur, R. B., and Petitto, L. A. How to know a conversation when you see one: Discourse structure in American Sign Language conversations. Journal of the National Student Speech Language Hearing Association, 1981, 9L66-81.

Wilbur, R.B., and Petitto, L.A. Discourse structure of American Sign Language conversations. Discourse Processes, 1983, 6:3, 225-241.

Places of Articulation

SUMMER

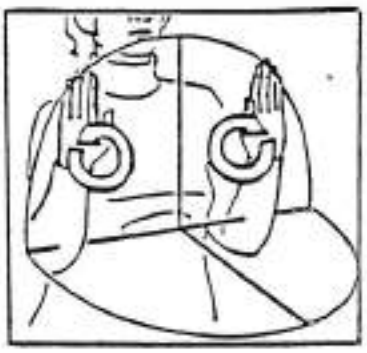
UGLY

DRY

BIRD

NEWSPAPER

HERE



SUNDAY

Figure 1: Places of articulation important for lexical contrasts

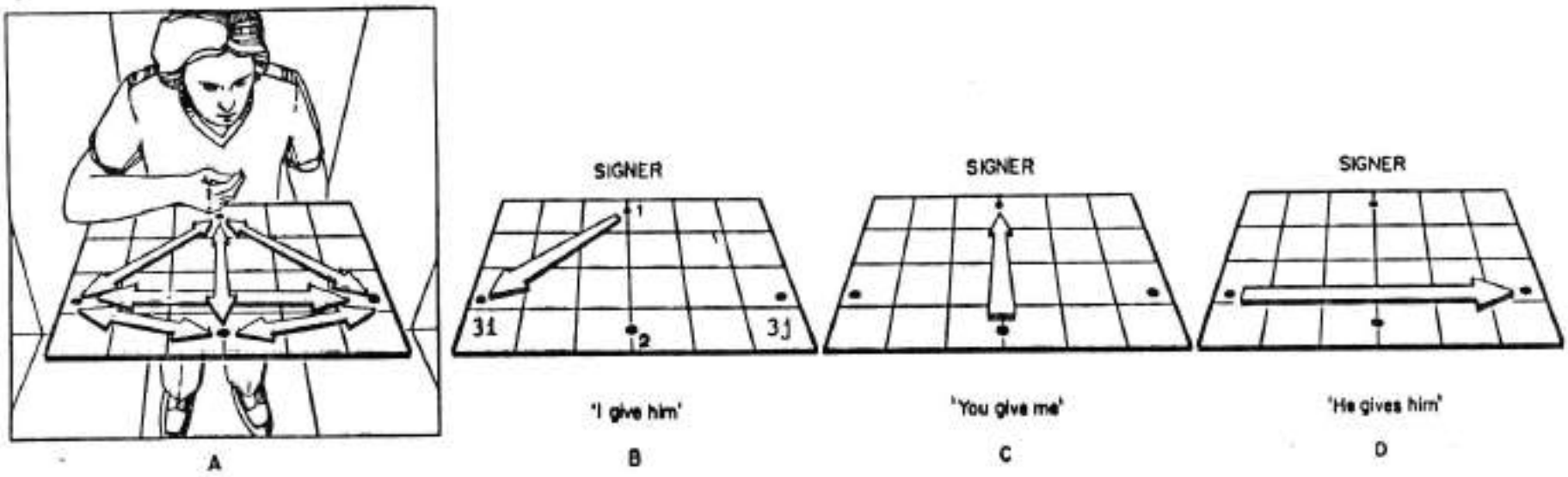



Figure 2: Signs are established within an indexic plane in front of the signer's body. A large class of verbs move along this spatial plane to form the verb agreement and anaphoric referencing systems in ASL. For example, the verb GIVE (a) can be moved along the signing plane to indicate «I give him» (b), «You give me» (c), and «He gives him» (d).


Figure 3: Child's pronoun reversing error (age 1;11).