Bruce:

Hiroyuki Nagahara

UNIVERSITY OF CALIFORNIA

Los Angeles

Toward An Explicit Phonological Representation For American Sign Language

A thesis submitted in partial satisfaction of the requirements for the degree Master of Arts in Linguistics

by

Hiroyuki Nagahara

1988

The thesis of Hiroyuki Nagahara is approved.

Stephen R. Anderson

Patricia A. Keating

Bruce P. Hayes, Committee Chair

University of California, Los Angeles

1988

TABLE OF CONTENTS

1. Preliminary Remarks (1)

2. Formational Parameter Analysis (3)

3. Tier Analysis (11)

4. Representation of Hand and Forearm Movement: Preliminaries (16)

5. Hand Movement (19)

6. Forearm Flexion and Rotation with Neutral Position of the Elbow (24)

7. Polar Movement (36)

8. Signs with Body Locations (44)

9. Elbow Movement (54)

10. Conclusions (58)

11. References (60)

ACKNOWLEDGEMENTS

I would like to thank the members of the committee, Pat, Bruce, and Steve for their help and patience with me and this thesis. Particularly, I would like to thank Bruce for his help with completion of this thesis. Perhaps, I am not a stranger in a strange land.

I acknowledge the use of the drawing material from Edward Klima and Ursula Bellugi, 1979, *The Signs of Language*, Harvard University Press, Cambridge, Massachusetts and Tom Humphries, Carol Padden, and Terrence O'Rourke, 1981, *A Basic Course in American Sign Language*, T. J. Publishers, Silver Spring, Maryland.

ABSTRACT OF THE THESIS

Toward An Explicit Phonological Representation
For American Sign Language

by

Hiroyuki Nagahara
Master of Arts in Linguistics
University of California, Los Angeles, 1988
Professor Bruce P. Hayes, Chair

The objective of the present thesis is to devise an explicit representational schema for American Sign Language within the framework of Autosegmental Phonology. In the framework I propose, the sign is conceived of as a synchronized combination of forearm, hand, and digital movement, and is represented movement by movement in tiers. I propose globe-like frames and define segments of movement with reference to them. These segments are initial and terminal locations, orientations, and handshapes for forearm, hand, and digital movement, respectively.

1. Preliminary Remarks

American Sign Language, ASL, is the primary communication medium of the deaf and some of the hearing population in the United States. Stokoe (1960) made it possible to represent the signs in the language in discrete terms. However, in his work and the work by others since then, the representation of signs, particularly the movement parameter, has been left more or less inexplicit. The objective of the present thesis is to devise a more explicit representational schema for sign movement, represented as sequences of segments with reference to their appropriate frames of reference.

The theoretical framework the present thesis adheres to is Autosegmental Phonology (Goldsmith 1976) with its claims concerning SEGMENTATION, GEOMETRY, INDEPENDENCE, and SYNCHRONIZATION: The linguistic signal is represented as a sequence of segments, organized into geometrically structured, independent, but synchronized tiers. In the present thesis, however, I will be concerned mostly with the segmentation of sign movement.

The methodological goal of the thesis is to devise a sufficiently constrained schema in which morphological relations are represented as transparently as possible, abstracting away from irrelevant aspects such as the position of the elbow. However, since I am concerned with a single language, I am not able to determine whether the regularities I present are particular to ASL, or prevalent in sign language in general.

The data I will present in the present thesis are from the published literature, including Klima and Bellugi (1979) and Humphries, Padden, and O'Rourke (1981) which will be referred to as K/B and ABC, respectively. The data include only the

unimanual signs in the language, and exclude bimanual signs, pantomimic signs, and facial expressions altogether.

The transcription of signs follows standard practice:

SIGN represents a single sign: e.g. DANCE.

SIGN-SIGN represents a single sign in ASL, but its English translation is not a single word: e.g. LOOK-AT.

SIGN+SIGN represents a compound sign: SLEEP+DRESS 'pajamas'.

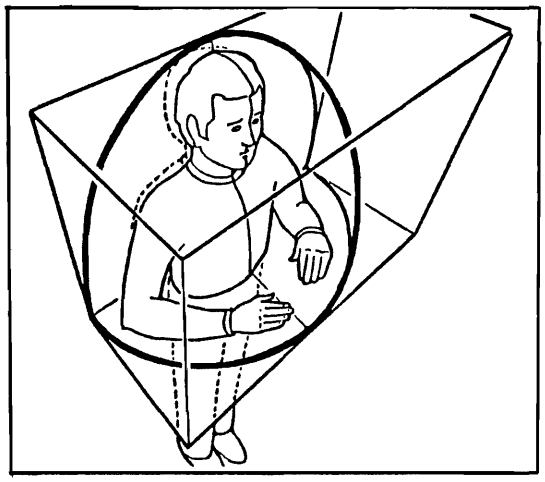
S-I-G-N is a single sign in ASL, but finger-spelled in the English manual alphabet: e.g. P-A-T.

The following sections are organized as follows. The first of the preliminary sections introduces FORMATIONAL PARAMETER ANALYSIS to initiate the reader, not only to ASL, but also to a standard analysis against which to measure the plausibility of the framework of the present thesis. The second of the preliminary sections outlines TIER ANALYSIS, my preliminary solution to the inadequacies associated with Parameter analysis, in which the sign is represented movement by movement in tiers. The body of the thesis is divided into three sections. The first outlines a representational schema for hand and forearm movement, for the signs with the normal, lower side position of the elbow. The second is concerned with signs made with specific reference to locations on the body. The third is concerned with variability of the position of the elbow. The concluding section summarizes the claims of the thesis.

2. Formational Parameter Analysis

Definitions for some of the key terms I will refer to are in order. The term SIGNING SPACE refers to the area above the waist line within reach of the forearms, with the position of the elbow relatively fixed at the level of the waist line (Klima and Bellugi 1979):

Signing space (K/B p.73):



The term DOMINANT FOREARM refers to the right forearm for the right-handed and the left forearm for the left-handed. The term FOREARM MOVEMENT is the same as PATH MOVEMENT, and refers to the flexional and rotational movement of the forearm at the elbow. The term HAND MOVEMENT refers to the flexional and rotational movement of the hand at the wrist. The term DIGITAL MOVEMENT refers to the flexional movement of the digits.

The sign is a synchronized combination of the movement of limbs at a specific location in space or on/near the body, with the hand in a specific shape, and in specific orientation. The aspects or parameters in which the sign is represented in FORMATIONAL

PARAMETER ANALYSIS (Friedman 1977, Klima and Bellugi 1979, Siple 1978, Wilbur 1979) are: PLACE OF ARTICULATION, MOVEMENT, HANDSHAPE, and ORIENTATION.

PLACE OF ARTICULATION refers to the location in space or on the body, where the sign is made. MOVEMENT refers to the quality of movement, such as straight path movement. ORIENTATION refers to the direction of the hand, defined relative to the signer and the signing space. In the system of Wilbur (1979), for example, orientation is specified in directional features of the palm and the metacarpus, regardless of whether the fingers are closed or not. HANDSHAPE refers to the shape of the hand. It is standard to refer to ASL handshapes by the names of the letter signs in the English manual alphabet. However, there are ASL handshapes not in the English manual alphabet, and there are alphabet signs not distinctive in ASL. I will use the names of the handshapes such as G, primitively, for the sake of simplicity. Klima and Bellugi (1979) illustrate these parameters and the prime and subprime values of the handshape parameter:

Signs contrasting only in place of articulation (K/B p.42):

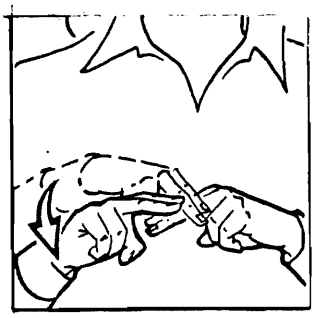
SUMMER

UGLY

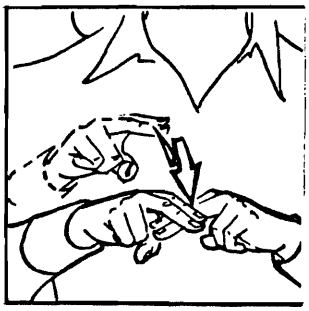
DRY

Signs contrasting only in movement (K/B p.42):

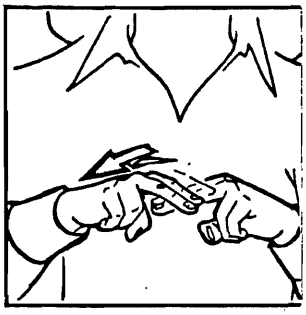
TAPE



CHAIR

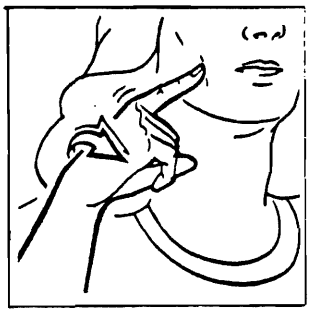


TRAIN

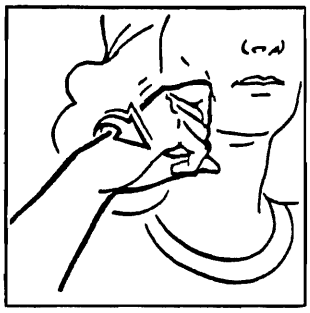


Signs contrasting in handshape (K/B p.42):

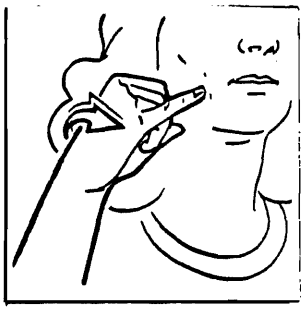
CANDY



APPLE

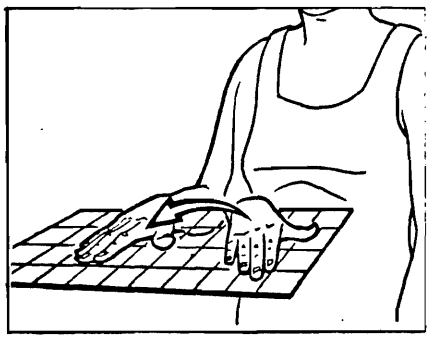


JEALOUS

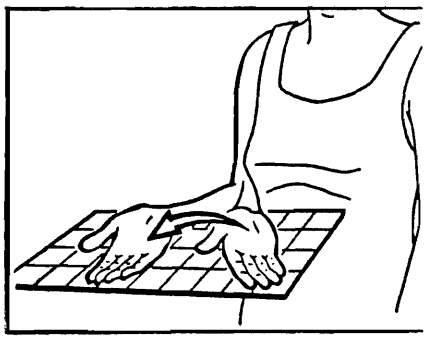


Signs contrasting only in orientation of the palm (K/B p.48):

CHILD



THING



Prime and subprime values of the handshape parameter (K/B p.44):

Primes	/B/	/A/	/G/	/C/	/5/	/V/
Major subprimes	[B]	[A]	[G]	[C]	[5]	[V]
Other representative subprimes	[$\dot{B}$]	[$\dot{A}$]	[G_1]		[5_4]	[$\ddot{V}$]
	[B_b]	[A_s]	[G_g]		[$\ddot{5}$]	
	[$\hat{B}$]	[A_t]	[G_d]		[$\hat{5}$]	

Primes	/O/	/F/	/X/	/H/	/L/	/Y/
Major subprimes	[O]	[F]	[X]	[H]	[L]	[Y]
Other representative subprimes	[$\hat{O}$]			[$\ddot{H}$]	[$\ddot{L}$]	[$\dot{Y}$]
	[bO]					[$\dot{Y}$]

Primes	/8/	/K/	/I/	/R/	/W/	/3/	/E/
Major subprimes	[8]	[K]	[I]	[R]	[W]	[3]	[E]
Other representative subprimes	[8]					[$\ddot{3}$]	

The inadequacies associated with Parameter analysis are summarized as follows.

Regarding the place of articulation and the movement parameters, Parameter analysis allows representational indeterminacy and redundancy. For example, the place of articulation could be specified in the place of articulation parameter, or as initial and terminal places of movement in the movement parameter, since specification of initial and terminal places of movement implies where the sign is made. Moreover, Parameter analysis allows redundancy, since it allows specification of the place of articulation both in the place of articulation and the movement parameters.

The least desirable aspect of any version of Parameter analysis is its mere labelling of the quality of movement, expressed in features such as [straight path movement]. More current Autosegmental analyses (Liddell 1984, Liddell and Johnson 1987, Perlmutter 1987, Sandler 1986, Wilbur 1987) represent path movement as the sequence [initial place] [movement] [terminal place], or as a sequence of [movement] and [hold] segments. However, the representation of the [movement] segment expressed in similar features makes these analyses no different from Parameter analysis, regarding the movement parameter.

Parameter analysis allows representational indeterminacy and redundancy, regarding the change in orientation. Specification of the change in orientation in signs such as CANDY is indeterminate, and could be any of the following:

Representation of CANDY (K/B p.42) in Parameter analysis:

Initial orientation:	palm outward metacarpus against cheek
Movement:	clockwise twisting

Final orientation:	palm inward metacarpus against cheek
Movement:	clockwise twisting

Initial orientation:	palm outward metacarpus against cheek
Final orientation:	palm inward metacarpus against cheek
Movement:	clockwise twisting

Change in orientation:	clockwise twisting
Movement:	-

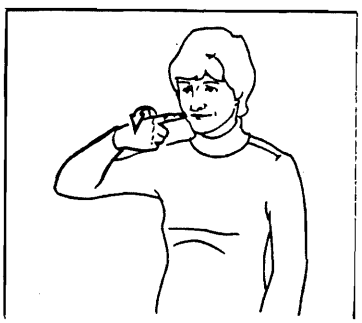
Orientation:	-
Movement:	clockwise twisting

Such specification allows redundancy as well, since the change in orientation could be specified both in the orientation parameter and in the movement parameter.

The least desirable aspect regarding the change in orientation is the inability of Parameter analysis to naturally state the relationship between forearm movement and the change in orientation. Contrast CANDY with AGENT:

Representation of CANDY (ABC p.86) in Parameter analysis

Place of articulation:	cheek
Movement:	clockwise palm twisting
Initial orientation:	palm outward metacarpus against cheek
Final orientation:	palm inward metacarpus against cheek
Handshape:	G



Representation of AGENT (ABC p.17) in Parameter analysis

Place of articulation:	neutral space chest high
Movement:	downward forearm movement
Initial orientation:	palm sideways metacarpus oblique up
Final orientation:	palm sideways metacarpus oblique down
Handshape:	B

The former is a sign of palm twisting and the latter is a sign of downward movement of the forearm. Not only palm twisting but mere forearm movement change the initial orientation of the sign. There has been no clear statement or analysis of the relationship between forearm movement and the change in orientation. It is possible to state and formalize such dependencies, but only at the risk of ignoring the physiological fact that the flexional and rotational movement of the forearm at the elbow does not affect and is not affected by the flexional and rotational movement of the hand at the wrist.

In summary, the inadequacy of Parameter analysis, regarding the orientational parameter, is its indeterminacy and redundancy regarding the change in orientation, and its inability to state in a natural way the dependency of orientational change on forearm movement.

Likewise, regarding the handshape parameter, Parameter analysis allows indeterminate and redundant representation of the change in the shape of the hand. For example, any of the following representations is possible for the extension of the index finger of S (fist) to G (just index finger extended):

Representation of index extension in Parameter analysis:

Initial handshape:	S
	extension of index
Movement:	-

Initial handshape:	S
	extension of index
Final handshape:	G
Movement:	-

Initial handshape:	S
Movement:	extension of index of S

Initial handshape:	S
Movement:	extension of index of S to G

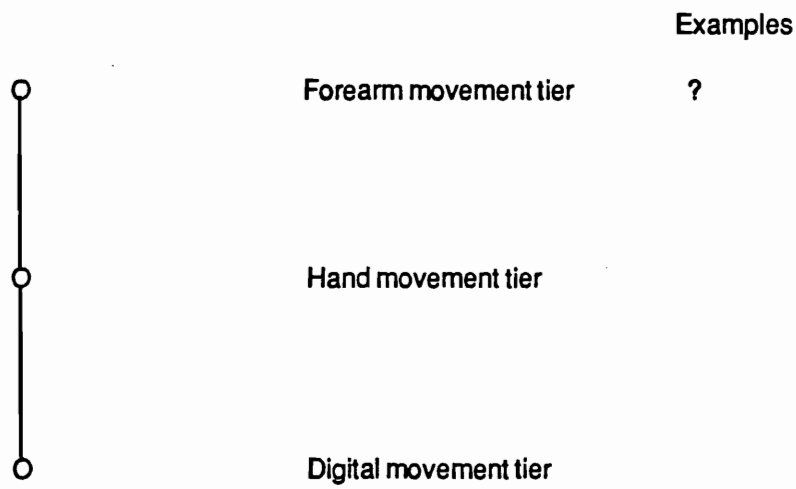
Parameter analysis allows indeterminacy and redundancy, in the sense that in principle, digital extension such as index extension could be specified either in the handshape parameter or in the movement parameter or both. Moreover, movement features such as [index extension] must be duplicated for the internal specification of the handshape. For example, [- index extended] and [+ index extended] must be part of the internal specification of S and G, respectively, in order for them to be contrastive with each other.

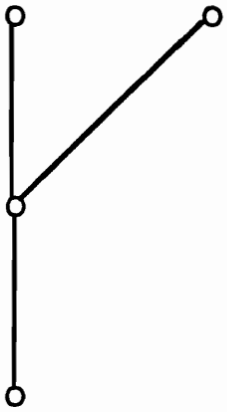
In the following section, I will outline a different analysis, Tier analysis, which partially fills these gaps, conceptually and formally.

3. Tier Analysis

I will represent the sign as a set of synchronized tiers for forearm, hand, and digital movement, at the elbow, the wrist, and the hand, respectively. In this analysis, forearm movement is a change of the position of the hand, and will be represented as a sequence of initial and terminal places. Hand movement is a change in the orientation of the hand at the wrist, and will be represented as a sequence of initial and terminal orientations. Digital movement is a change of the shape of the hand, and will be represented as a sequence of initial and terminal shapes of the hand.

The logical possibilities of this analysis are illustrated in the following typology, in which nodes represent initial and terminal values of movement:



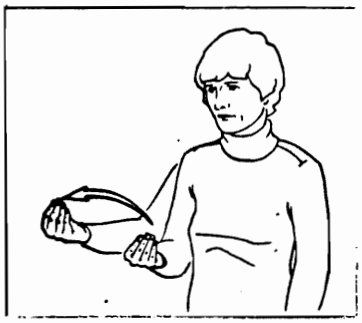


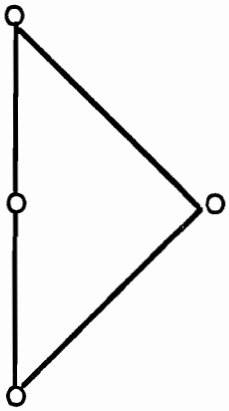
Forearm movement tier

Hand movement tier

Digital movement tier

GIVE (ABC p.65)



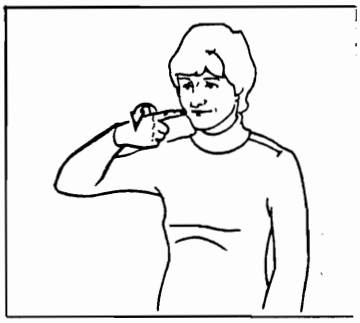


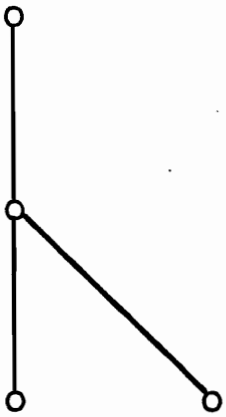
Forearm movement tier

Hand movement tier

Digital movement tier

CANDY (ABC p.88)



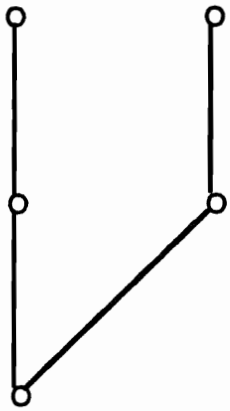


Forearm movement tier

Hand movement tier

Digital movement tier

RABBIT (ABC p.77)

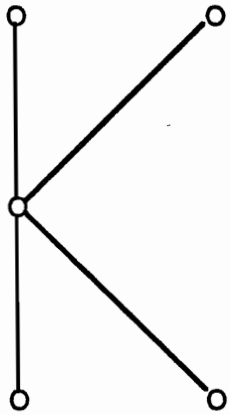


Forearm movement tier

Hand movement tier

Digital movement tier

INCREASE (ABC p.173)

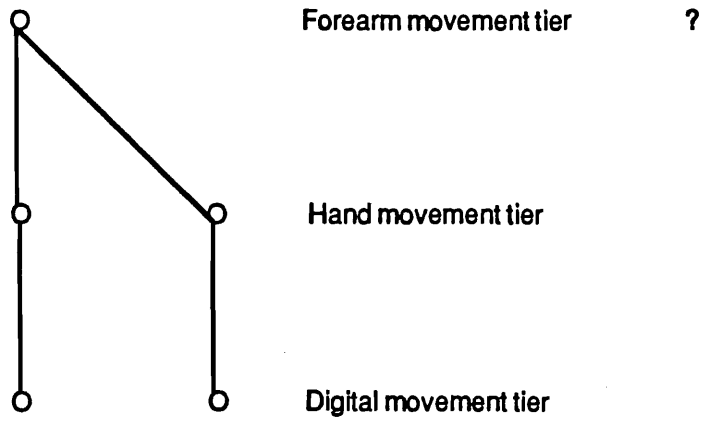


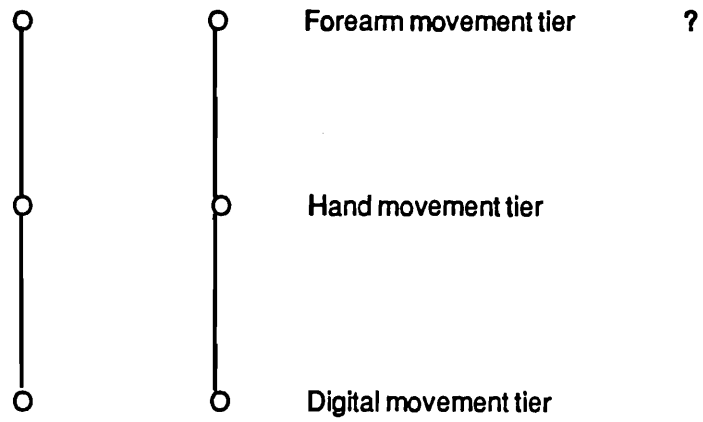
Forearm movement tier

Hand movement tier

Digital movement tier

ASK (ABC p.64)





The tiers are arranged so that they look exactly like the physical arrangement of the forearm and the hand. Other arrangements could be argued for. However, I will not be concerned here and elsewhere with the geometry of tiers.

There are eight logically possible unfoldings of movement, but only five of these are actually realized. I assume that these follow from certain Minimality and Maximality Conditions on the number of movements (Stack 1988).

The advantage of this schema is its ability to represent forearm, hand, and digital movement as sequences of initial and terminal values, uniformly and in the least redundant manner.

Regarding the change in orientation and the change in the shape of the hand, it is sufficient to specify just their initial and terminal values, to determine the path of the change. For example, the movement in the derivationally related signs, 1-YEAR, 2-YEAR, and 3-YEAR, is the change in the shape of the hand from S (fist) to 1 (just index finger extended), S to 2 (index and middle fingers extended), and S to 3 (thumb, index, and middle fingers extended), respectively. It is sufficient to specify just the initial and final shapes of the hand to predict the flexional path of the digits (Liddell and Johnson 1987, Perlmutter 1987). In contrast, representation in mere movement features such as [+ extend] would be either inadequate or excessive. The initial and final handshapes as well as [+ extend] must be specified for these signs, to predict the flexional path of the digits; since the initial and final shapes are specified, the feature [+ extend] would be unnecessary.

However, this analysis remains inexplicit in its specification of the orientational and positional values, giving rise to its inability to naturally state the relationship between the change in orientation and forearm movement. The objective of the following section is to show that it is possible to naturally state such dependencies, if appropriate frames of reference are supplied.

4. Representation of Hand and Forearm Movement: Preliminaries

The central claims of the following sections are summarized as follows.

FRAMES OF REFERENCE. The movement of the hand at the wrist can be best represented with reference to an imaginary globe centered at the wrist. The movement of the forearm can be best represented with reference to an imaginary globe centered at the elbow, with its north pole being the shoulder, and its south pole being the position of the wrist when the forearm makes a straight line with the upper arm. Arc movement, and not straight-line movement, is primitive on the surface of a globe, since the path of arc can be interpolated on the surface of a globe, just given its initial and final positions. Global frames of reference suggest not only that arc movement is primitive, but that straight-line movement is phonologically absent in ASL.

POSSIBLE MOVEMENT. Movement is represented as a sequence of positions on the surface of a globe. Logically, interpolation between any two positions should be possible. However, it is my claim that movement in general in ASL is always along longitudinal and latitudinal lines. In terms of articulation, the digits just flex or extend; the hand either flexes along a longitudinal line, or rotates along a latitudinal line on the globe centered at the wrist; and the forearm either flexes along a longitudinal line, or rotates along a latitudinal line on the globe centered at the elbow. In addition, rotational movement along a latitudinal line around an oblique polar axis will be discussed below.

The representation of movement restricted along latitudinal and longitudinal lines is rich in its predictions. First, a movement is not a sign, if it is neither flexional nor rotational. Second, modulation or 'secondary movement' on the path of forearm movement in ASL morphology is either flexional or rotational (Klima and Bellugi 1979, Padden and Perlmutter 1987). Third, certain cooccurrence restrictions can be

stated either flexionally or rotationally. For example, outward extension of the forearm and inward flexion of the hand do not cooccur when the palm faces inward. Fourth, regarding handshapes, their internal specifications are along the flexional/extensional dimension (Friedman 1977, Klima and Bellugi 1979, Wilbur 1979, 1987), and their diachronic changes have been attested to be along the flexional/extensional dimension (Battison 1978).

MOVEMENT INDEPENDENCE. A particular set of global frames is selected, to account for the fact that the limbs move, not only flexionally or rotationally within the fixed length of the limb, but move independently of each other. For example, the orientation of the hand in the present analysis is defined with reference to the globe centered at the wrist, regardless of where the wrist is, whereas the orientation in any version of Parameter analysis is defined with reference to the signer and signing space centered at the signer. In the former analysis, the orientation of the hand is altered, just in case the hand flexes or rotates at the wrist. In the latter analysis, it is altered by either hand or forearm movement. To the best of my knowledge, in the latter analysis, there has been no formal way to naturally state the dependency of the change in orientation on forearm movement. My proposal captures the fact that the movement of the forearm does not affect and is not affected by the movement of the hand, by representing the movement of each limb at its joint with reference to its global frame centered at the joint.

MOVEMENT SEGMENTATION. Movement in general can be best represented as a sequence of segments within its relevant frame of reference. Forearm and hand movement can be best represented as a sequence of positional values with reference to their respective frames, and digital movement as a sequence of shapes of the hand. This is the spirit of Tier analysis, which I will flesh out in the subsequent sections.

THE POSITION OF THE ELBOW. The position of the elbow for most of the signs in ASL is relatively fixed. Further, even in the cases in which the position of the elbow is variable, such variability does not seem to be distinctive. It is my claim that the position of the elbow, like the position of the jaw in oral phonology, is not relevant, at least at the level of underlying representation. Since the position of the elbow is irrelevant, it is possible to represent forearm movement as a sequence of positional values on a global frame, without specifying the position of the center of the globe, at least at the level of underlying representation.

The rest of the thesis is organized as follows. The first of the following sections outlines the framework for the flexional and rotational movement of the hand at the wrist. The second outlines the framework for the flexional, rotational, and polar movement of the forearm with the normal, fixed, lower side position of the elbow. The third is concerned with signs made with specific reference to locations on the body. These are signs with the position of the elbow fixed, but at a different location than usual. The final section before the final conclusions is concerned with the variability of the position of the elbow.

5. Hand Movement

Hand movement will be represented as a sequence of coordinates on the surface of an imaginary globe centered at the wrist. Flexion and rotation are movement along longitudinal and latitudinal lines, respectively. I will define the position of the hand on the surface of the globe, by the degrees or states of hand flexion and rotation. I will propose just three states of flexion and three states of rotation: NEUTRAL, FLEXED, and RAISED states of flexion; and NEUTRAL, SUPINATED, and PRONATED states of rotation.

FLEXION. The hand is NEUTRAL when extended straight from the forearm. For example, the initial orientation of SHOWER is neutral:

SHOWER (ABC p.154):

The hand is FLEXED when flexed forwards. For example, the terminal orientation of SHOWER is flexed. The hand is RAISED when flexed backwards.

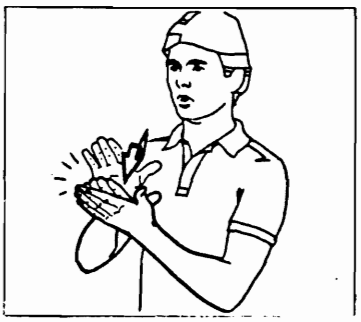
ROTATION. The NEUTRAL, SUPINATED, and PRONATED states of rotation are defined in terms of the plane of the palm and the plane of forearm flexion. The plane of forearm flexion is the plane delimited by the forearm and the upper arm, in which the forearm flexes. The NEUTRAL state of rotation is when the palm is parallel to the plane of forearm flexion. The hand is SUPINATED when the palm is perpendicular to the plane of forearm flexion and faces toward the shoulder, and PRONATED when the palm faces away from the shoulder. For example, the palm is supinated for SHOWER. The

following three signs illustrate the three-way contrast between neutral, supinated, and pronated states of rotation (Stokoe 1960):

STOP (ABC p.96):
hand [neutral state of flexion]
[neutral state of rotation]

MONEY (ABC p.30):
hand [neutral state of flexion]
[supinated state of rotation]

SCHOOL (ABC p.42):
hand [neutral state of flexion]
[pronated state of rotation]



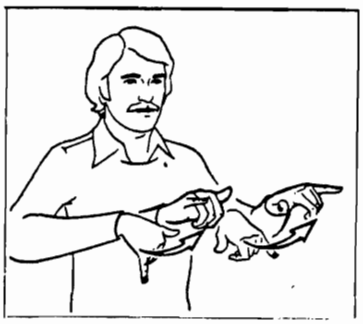
The movement of the hand is represented by a sequence of states of flexion and a sequence of states of rotation, in this order, in separate lines. FLEXION is the movement in the direction from RAISED to NEUTRAL to FLEXED states. For example, SHOWER is a sign of flexion. EXTENSION is flexion in the reverse direction. SUPINATION is the rotation in the direction from PRONATED to NEUTRAL to SUPINATED

states, and PRONATION in the reverse direction. Supination is clockwise or screw-in rotation, and pronation is counterclockwise or screw-out direction, for the right hand, looking in the direction from the shoulder to the wrist. Examples include:

THAT-ONE (ABC p.120):
hand [neutral] [flexed] [pronated]

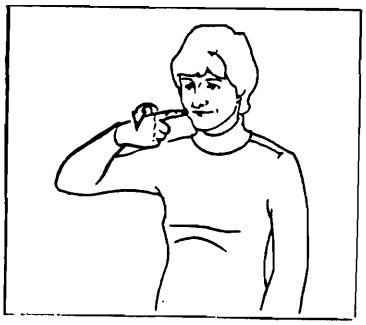
COOL (ABC p.9):
hand [neutral] [flexed] [supinated]

STILL (ABC p.78):
hand [flexed] [neutral] [neutral]



CHAT (ABC p.117):
hand [raised]
[neutral] [supinated]

CANDY (ABC p.86):
hand [neutral]
[neutral] [supinated]



STOP-IT (ABC p.78):
hand [neutral]
[supinated] [neutral]

In the terminology of Marr (1982), we can say that the definition of orientation with reference to the forearm is OBJECT-CENTERED, whereas the definition with reference to the signer and the signing space in Parameter analysis is VIEWER-CENTERED. The former, but not the latter, captures our intuitive sense of flexion and rotation at the wrist. In the former system, there is a formal change in orientation, if and only if there is flexion or rotation at the wrist, whereas in the latter system, there is a formal change in orientation, if there is flexion or rotation of the hand at the wrist and/or of the forearm at the elbow. For example, in the former system, there is no formal change in

orientation for the sign AGENT, a sign of forearm extension with no flexion or rotation at the wrist:

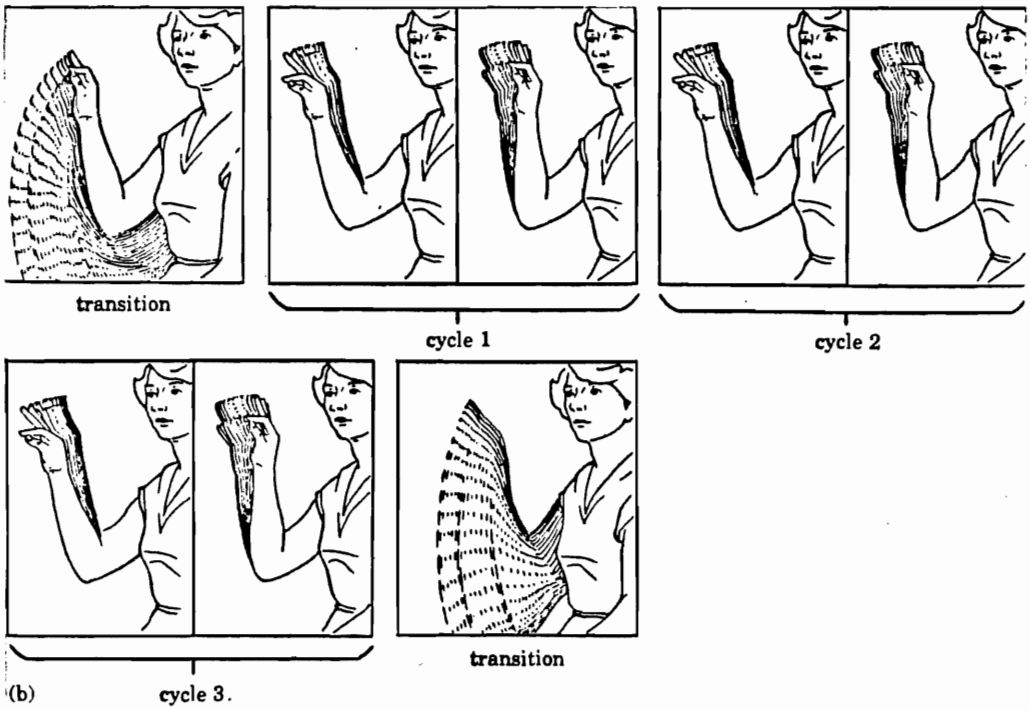
AGENT (ABC p.17):
hand [neutral]
[neutral]

In the latter system, there would be a formal change in orientation, since there is a change in the direction of the metacarpus, relative to the signer.

6. Forearm Flexion and Rotation with Neutral Position of the Elbow

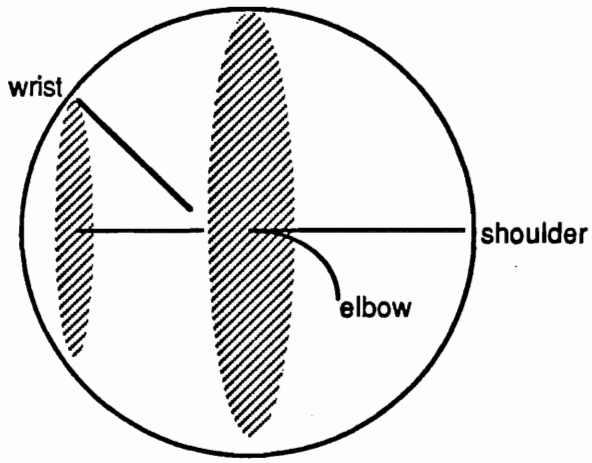
The position of the elbow for the signs made with no specific reference to locations on the body is relatively fixed. For example, the position of the elbow for PREACH, a sign of repeated forearm extension, is relatively fixed:

PREACH (K/B p.62):



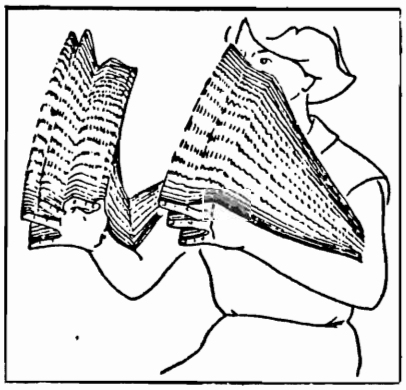
In this section, I will define a frame of reference for forearm flexion and rotation for the signs with no specific reference to locations on the body, with their fixed, lower side position of the elbow.

THE AXIS OF THE GLOBE for forearm movement is the line from the shoulder (north pole), through the elbow (center), to the imaginary position of the wrist (south pole) when the forearm makes a straight line with the upper arm:



THE PLANE OF FOREARM FLEXION is the plane delimited by the forearm and the upper arm, in which the forearm flexes. It is the plane delimited by a longitudinal line on the imaginary globe. In flexion and extension (keeping constant the angle of forearm rotation), the forearm moves within the plane of forearm flexion, and the hand outlines a longitudinal line:

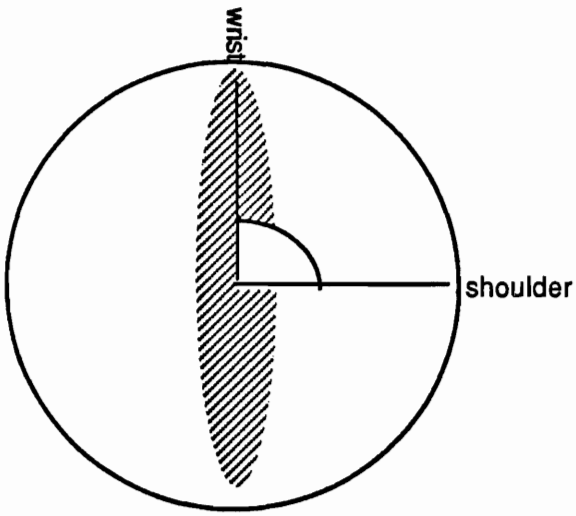
DECIDE (K/B p.39):



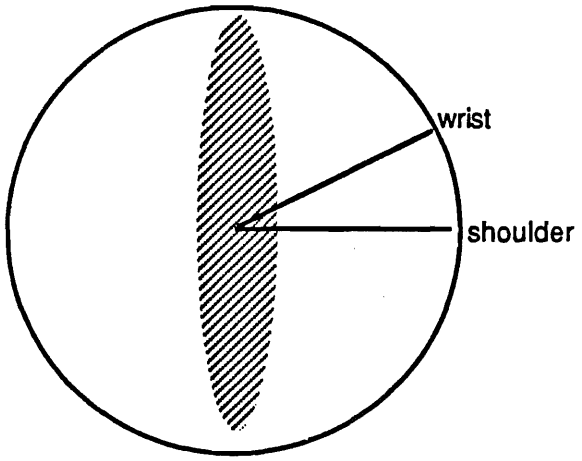
In rotation (keeping constant the angle of forearm flexion), the hand outlines a latitudinal line:

COME-ON (ABC p.75):

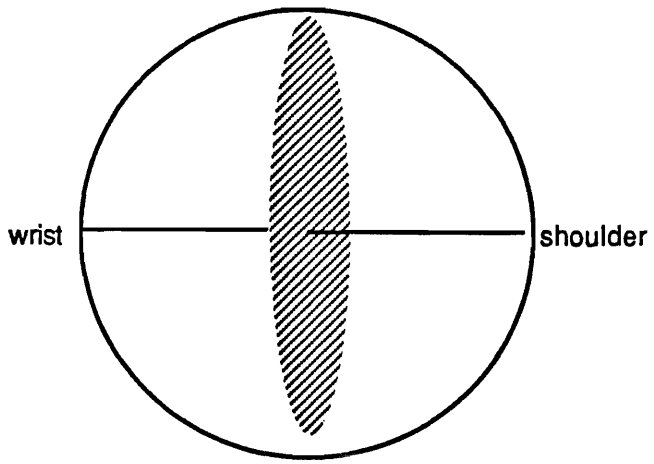
FLEXION. The forearm is 0° FLEXED or EXTENDED when it makes an angle of 90° with the upper arm:



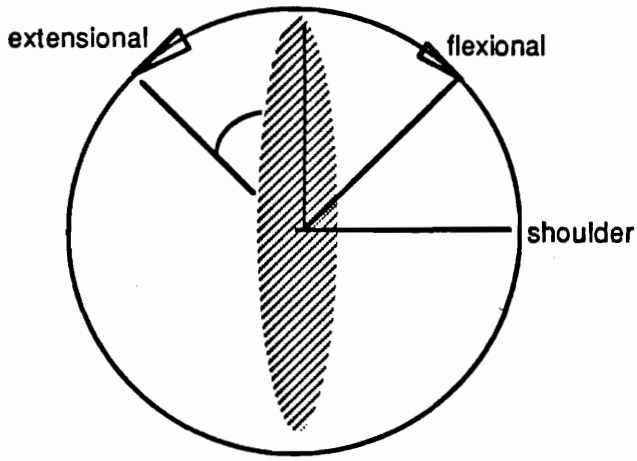
The forearm is 60° FLEXED when flexed maximally close to the shoulder:



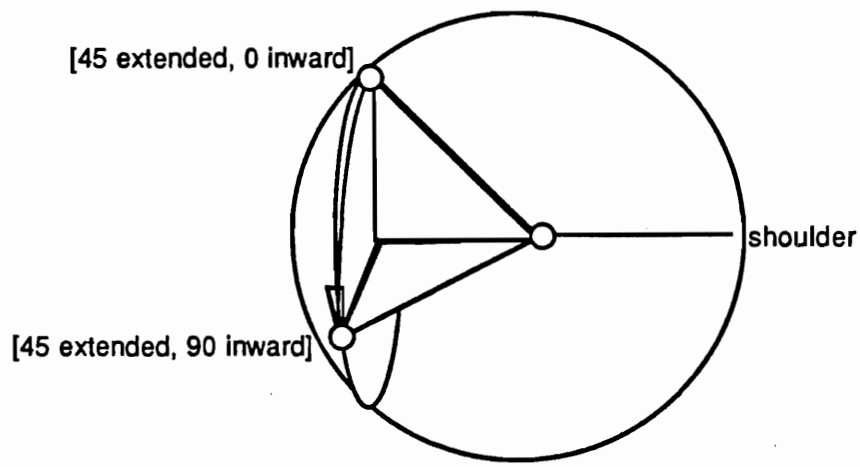
The forearm is 90° EXTENDED when fully extended, making a straight line with the upper arm:



Movement in the plane of forearm flexion in the direction toward the shoulder will be referred to as FLEXIONAL, and movement in the reverse direction as EXTENSIONAL:



ROTATION. The forearm is 0° INWARD when rotated maximally outward around the axis of the globe, and 90° INWARD when rotated maximally inward:



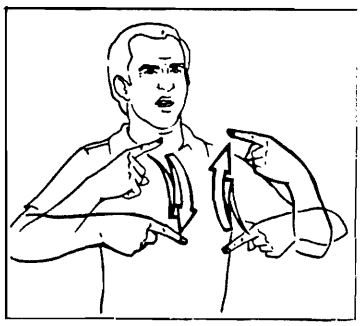
Rotation toward a greater angle will be referred to as INWARD, and rotation toward a lesser angle of rotation as OUTWARD. Looking in the direction of the elbow (center) from the shoulder (north pole) of the right hand, inward rotation is counterclockwise, and outward rotation clockwise.

Flexion and rotation are physically possible between 60° FLEXED and 90° EXTENDED, and between 0° INWARD and 90° INWARD. Linguistically, possible values seem to be multiples of 15° between 60° FLEXED and 60° EXTENDED, and between 0° INWARD and 90° INWARD. However, further research is necessary to determine the possible and actual values of flexion and rotation in ASL.

The global coordinates will be represented in the order latitude, longitude. The movement of the forearm will be represented as a sequence of states of flexion and a sequence of states of rotation, in this order, in separate lines. In the following examples, the non-repeated movement of the dominant hand and forearm are represented, and represented without the degree sign:

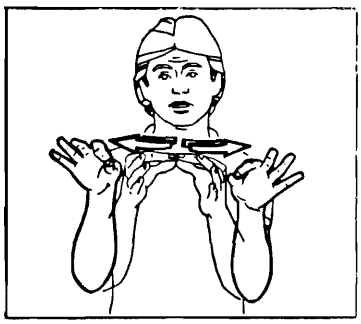
ARGUE (ABC p.181):

forearm	[30 flexed]
	[60 inward] [90 inward]
hand	[neutral]
	[neutral]



CAPTION (ABC p.181):

forearm	[30 flexed]
	[30 inward] [0 inward]
hand	[neutral]
	[neutral] [pronated]



BROKE (ABC p.181):

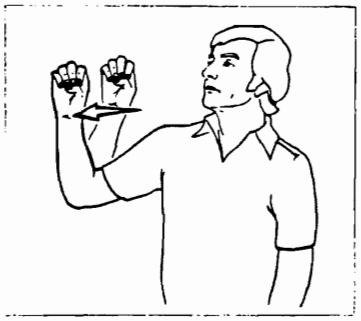
forearm	[30 flexed]
	[0 inward] [30 inward]
hand	[neutral]
	[supinated]

NOTHING-TO-IT (ABC p.183):

forearm	[30 flexed]
	[0 inward] [30 inward]
hand	[neutral]
	[pronated]

EAST (ABC p.182):

forearm	[30 flexed] [0 flexed]
	[0 inward]
hand	[neutral]
	[neutral]



PUT-IN (ABC p.183):

forearm	[30 flexed] [0 flexed]
	[30 inward]
hand	[neutral] [flexed]
	[pronated]

PAST (ABC p.174):

forearm	[30 flexed] [60 flexed]
	[0 inward]
hand	[neutral] [flexed]
	[supinated]

AGENT (ABC p.17):

forearm	[30 flexed] [30 extended]
	[30 inward]
hand	[neutral]
	[neutral]

In the following derivationally related forms, I adapt ( )* notation (Chomsky and Halle 1968) to indicate that a sequence is repeated an indefinite number of times. This is shown in Klima and Bellugi's figure by a zigzagging arrow.

COMPARE (verbal) (K/B p.296):

forearm	([60 flexed] [30 flexed]) *
	[45 inward]
hand	[raised]
	([pronated] [supinated]) *

COMPARISON (nominal) (K/B p.296):

forearm	[30 flexed]
	[45 inward]
hand	[raised]
	([pronated] [supinated]) *

Not only forearm but hand movement are repeated for the verbal form, while only hand movement is repeated for the nominal form. It seems natural to analyze the whole forms, and not individual tiers, as repeated:

COMPARE (verbal):

forearm	([60 flexed] [30 flexed]
	[45 inward]
hand	[raised]
	[pronated] [supinated]) *

COMPARISON (nominal):

forearm	([30 flexed]
	[45 inward]
hand	[raised]
	[pronated] [supinated]) *

I will refer to the forms inside the parentheses as their respective stem forms:

COMPARE (stem):

forearm	[60 flexed] [30 flexed]
	[45 inward]
hand	[raised]
	[pronated] [supinated]

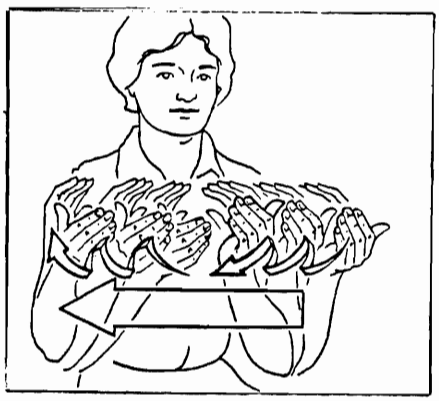
COMPARISON (stem):	forearm	[30 flexed]
		[45 inward]
	hand	[raised]
		[pronated] [supinated]

The verbal and nominal forms support the claim that paths in ASL are defined flexionally or rotationally. The nominal stem is derived from the verbal stem by deletion of the flexional state [60 flexed].

Let us look at other related forms in which the repetition is indefinite:

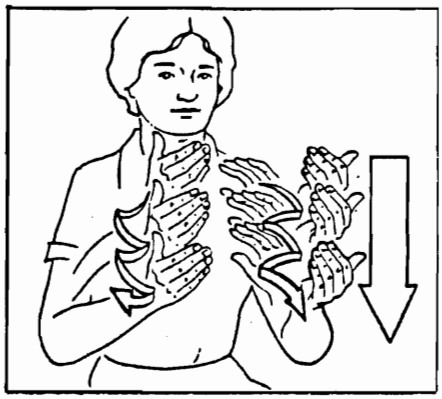
COMPARE (seriated external) 'to compare a line of' (K/B p.291):

forearm	([60 flexed] [30 flexed]) *
	[45 inward] [0 inward]
hand	[raised]
	([pronated] [supinated]) *



COMPARE (seriated internal) 'to compare with respect to' (K/B 291):

forearm	[60 flexed] [30 flexed]
	[45 inward]
hand	[raised]
	([pronated] [supinated]) *



The derivational relationship seems to be:

	COMPARE (stem)	==>	COMPARE (verbal)
forearm	[60 flexed] [30 flexed]		([60 flexed] [30 flexed]
	[45 inward]		[45 inward]
hand	[raised]		[raised]
	[pronated] [supinated]	==>	[pronated] [supinated]) *

	COMPARE (stem)	==>	COMPARISON (stem)
forearm	[60 flexed] [30 flexed]		[30 flexed]
	[45 inward]		[45 inward]
hand	[raised]		[raised]
	[pronated] [supinated]	==>	[pronated] [supinated]

==> COMPARISON (nominal)

forearm	([30 flexed]
	[45 inward]
hand	[raised]
	[pronated] [supinated]) *

	COMPARE (stem)	==>	COMPARE (seriated external)
forearm	[60 flexed] [30 flexed]		([60 flexed] [30 flexed]) *
	[45 inward]		[45 inward] [0 inward]
hand	[raised]		[raised]
	[pronated] [supinated]	==>	([pronated] [supinated]) *

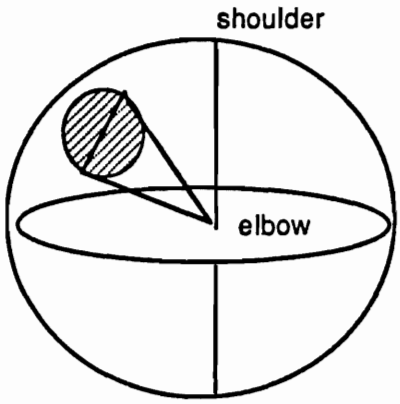
	COMPARE (stem)	==>	COMPARE (seriated internal)
forearm	[60 flexed] [30 flexed]		[60 flexed] [30 flexed]
	[45 inward]		[45 inward]
hand	[raised]		[raised]
	[pronated] [supinated]	==>	([pronated] [supinated]) *

The repetition for the seriated forms is different from the repetition for the bare verbal and nominal forms. In the former, individual tier sequences are repeated indefinitely, whereas in the latter, the whole word is repeated a few times. I will refer to the former as SECONDARY and the latter as PRIMARY. The secondary repetition supports the claim that path modulation is either flexional or rotational, since it affects flexional or rotational paths individually.

7. Polar Movement

Polar movement refers to the conic movement of the forearm. The elbow serves as the apex of the cone; the forearm outlines its side; and the hand traces its circular base. The axis of polar movement is the line through the apex (elbow) and the center of of the base. ALWAYS is a sign of polar movement with 15° of radius:

ALWAYS (ABC p.140)



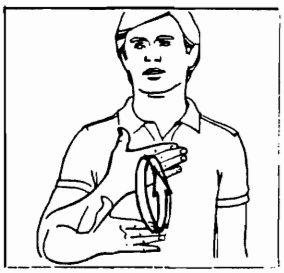
Since the direction of the axis of polar movement cannot be predicted, it must be specified, and will be specified with normal coordinates of latitude and longitude. For example, the non-repeated form of ALWAYS is represented with the position of the axis and its radius:

ALWAYS (ABC p.140):	forearm	pole	[0 flexed]
			[30 inward]
		radius	[15]
	hand		[neutral]
			[supinated]

The sign HAPPY is another example of polar movement:

HAPPY (ABC p.9):

forearm	pole	[0 flexed]
		[90 inward]
	radius	[15]
hand		[neutral]
		[supinated]

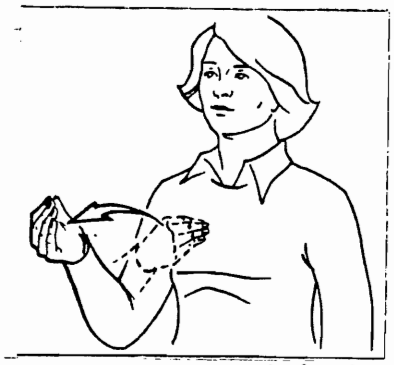


Polar modulation as well as secondary repetition are illustrated in the following derivationally related forms of GIVE (K/B p.313). I will not specify orientation for the following forms, since it is [neutral state of flexion] and [supinated state of rotation], and the same for all of the forms, thanks to the global definition of orientation.

GIVE:

[60 flexed] [0 flexed]

[30 inward]



GIVE (exhaustive) 'to give to each':

([60 flexed] [0 flexed]) *

[60 inward] [0 inward]

GIVE (iterative) 'to give again and again':

[pole: 30 flexed]

[60 flexed] [0 flexed] [60 flexed]

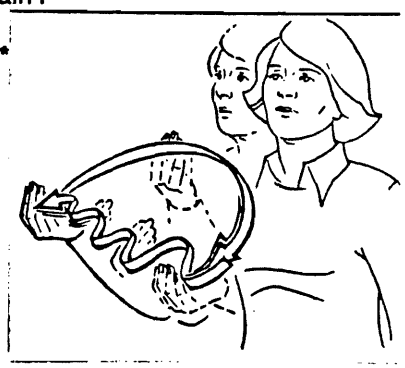
[30 inward]

GIVE ((exhaustive) iterative) 'to give to each, again and again':

([60 flexed] [0 flexed]) *

[60 inward] [0 inward] [60 inward]

[pole: 30 inward]



GIVE ((iterative) exhaustive) 'to give again and again, to each':

[pole: 30 flexed]

[60 flexed] [0 flexed] [60 flexed]

[60 inward] [0 inward]

Not illustrated.

The repetition in the iterative form is primary. The repetition in the exhaustive and ((iterative) exhaustive) forms is secondary. The repetition in the ((exhaustive) iterative) form is both primary and secondary. In primary repetition, the whole word is repeated, and repeated just a few times. In secondary repetition, individual sequences are repeated, and repeated indefinitely. I will refer to the forms with no primary repetition as their respective stem forms:

GIVE (stem):

[60 flexed] [0 flexed]

[30 inward]

GIVE (exhaustive) stem

([60 flexed] [0 flexed]) *

[60 inward] [0 inward]

GIVE (iterative) stem:

[pole: 30 flexed]

[60 flexed] [0 flexed] [60 flexed]

[30 inward]

GIVE ((exhaustive) iterative) stem:

([60 flexed] [0 flexed]) *

[60 inward] [0 inward] [60 inward]

[pole: 30 inward]

GIVE ((iterative) exhaustive) stem:

([pole: 30 flexed] [60 flexed] [0 flexed] [60 flexed]) *

[60 inward] [0 inward]

The exhaustive stem is derived from the verbal stem by secondary repetition of the verbal flexional path [60° flexed] [0° flexed], along the rotational path [60° inward] [0° inward]:

GIVE (stem)	==>	GIVE (exhaustive) stem
[60 flexed] [0 flexed]		([60 flexed] [0 flexed]) *
	==>	
[30 inward]		[60 inward] [0 inward]

The secondary repetition in the exhaustive form supports the claim that path modulation is either flexional or rotational, since individual flexional or rotational sequences, and not the whole word, are repeated in such repetition.

The iterative stem is derived from the verbal stem by polar modulation:

GIVE (stem)	==>	GIVE (iterative) stem
		[pole: 30 flexed]
[60 flexed] [0 flexed]		[60 flexed] [0 flexed] [60 flexed]
	==>	
[30 inward]		[30 inward]

In the derivation, the rotational state [30° inward] is associated with every flexional state. Polar modulation of the return path [0° flexed] [60° flexed] of the stem path [60° flexed] [0° flexed] is represented by the association line with the polar axis at [30° flexed, 30° inward]. The fact that the return of the stem path is a permutation of the stem sequence gives credence to the segmentation of the stem path. Moreover, the fact that polar modulation affects flexional states individually supports, not only the overall framework, but also the claim that path modulation is either flexional or rotational.

Suppose that instead of the above account, we represented the iterative form in terms of movement features. I will show that such representation is either inadequate or excessive. Featural representation such as [arc] [circular] for the iterative form is inadequate, since the initial and terminal positions of the path cannot be predicted. Such representation as [arc: path p q] [circular: path q p] is not adequate yet, since the orientation of the plane of the circle through p and q cannot be predicted. Note that the number of circular planes through p and q is infinite. Such representation as [arc: path p q] [circular: axis x; path p q] with the added specification of the axis or orientation of the plane of circular path is adequate, but more than necessary, since the quality features such as [arc] are predictable, given our global frames of reference. In summary, featural representation of movement is either inadequate or redundant.

The ((exhaustive) iterative) and ((iterative) exhaustive) forms show that iterative and exhaustive modulations feed each other, and that such modulation is flexional or rotational. The derivations of the ((exhaustive) iterative) and ((iterative) exhaustive) forms are represented as follows:

GIVE (exhaustive) stem ==> GIVE ((exhaustive) iterative) stem

([60 flexed] [0 flexed]) * ==> ([60 flexed] [0 flexed]) *

[60 inward] [0 inward] [60 inward] [0 inward] [60 inward]

[pole: 30 inward]

GIVE (iterative) stem ==> GIVE ((iterative) exhaustive) stem

[pole: 30 flexed] [pole: 30 flexed] *

[60 flexed] [0 flexed] [60 flexed] [60 flexed] [0 flexed] [60 flexed]

==>

[30 inward] [60 inward] [0 inward]

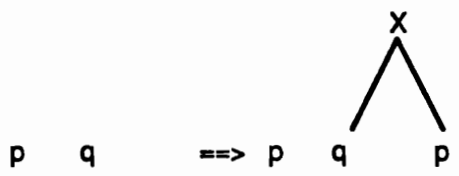
The interaction of iterative and exhaustive modulation shows that polar modulation as well as secondary repetition affect flexional and rotational paths, and affect them individually. It should be noted that to be certain that such is the case all the time, it would be necessary to exhaust all the cases of path modulation. However, I will leave it to future research, since in the present thesis, it is my aim to show the feasibility of the overall framework, not to exhaust all possible cases.

The exhaustive and iterative modulational processes for GIVE are as follows:

Exhaustive secondary repetition for GIVE:

Flexion	p	q	==>	(p q) *
Rotation				[60 inward] [0 inward]

Iterative polar modulation for GIVE:

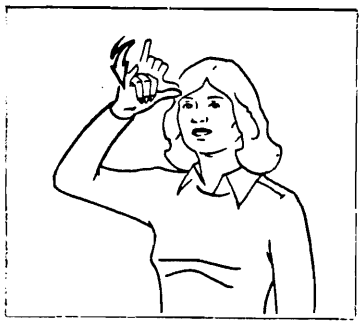


(p q) is a flexional or rotational path. X is the position of the polar axis, at the middle of the path (p q).

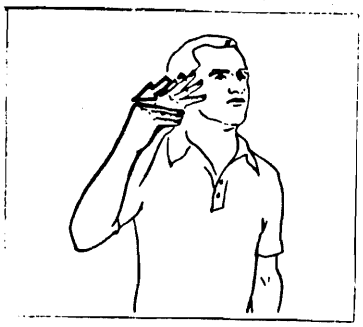
8. Sign with Body Locations

Normally, the position of the elbow is at the lower side of the body. However, there are signs made with specific reference to locations on the body, in which the position of the elbow is fixed, but at a different position than usual. I will refer to them as signs with body locations. These signs appear to argue against the claim that the position of the elbow is irrelevant, since the position of the elbow for these signs is not at the normal, lower side, and cannot be assigned a default value. However, the position of the elbow for these signs is predictable, given the body locations associated with them. Excluding signs made with reference to the nondominant hand, they include:

Location	SIGN	Forearm movement
Forehead	COW (ABC p.172)	stationary

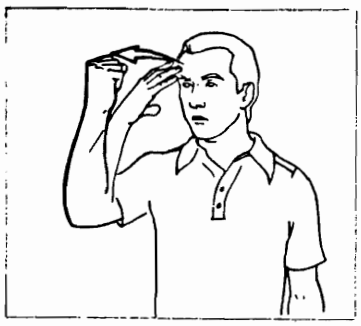


	EXPERIENCE (ABC p.173)	sideways



GALLAUDET (ABC p.173) sideways

MEMORIZE (ABC p.105) away



INTELLIGENT (ABC p.141) away

Nose

BORED (ABC p.172)

stationary

MOUSE (ABC p.173)

sideways

Mouth

BIRD (ABC p.172)

stationary

TALK (ABC p.119)

away

LAUGH (ABC p.105)

sideways

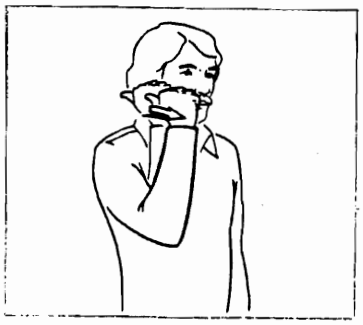
LIPREAD (ABC p.105)

circular

Cheek

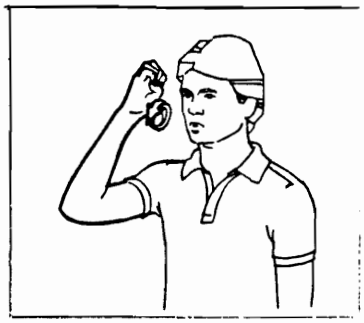
DAILY (ABC p.172)

away



EUROPE (ABC p.173)

circular



Face

CRAZY-FOR (ABC p.141)

sideways

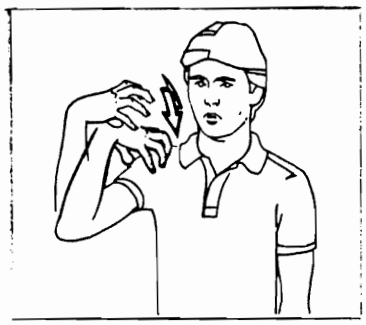
Shoulder

BACKPACKING (ABC p.172)

toward

BOSS (ABC p.172)

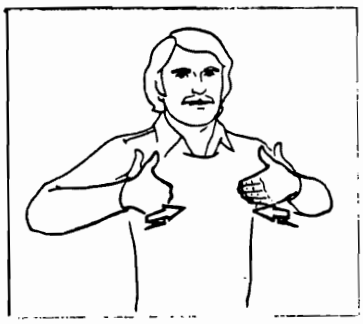
toward



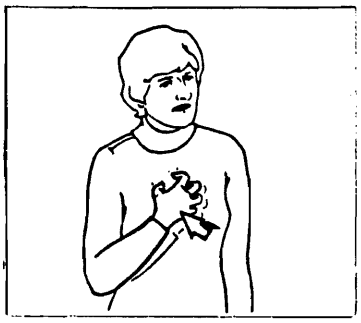
Chest (side)

ANIMAL (ABC p.172)

stationary



Chest COMPLAIN (ABC p.172) stationary



Waist NOT-YET (ABC p.105) toward

The generalizations which must be accounted for for this class of signs are summarized as follows. First, the position of the elbow for these signs is fixed. Second, the position of the elbow for the signs made at the same location is not only fixed, but the same. For example, the position of the elbow is the same for the signs BIRD, TALK, LAUGH, and LIPREAD signed at the mouth. Third, the movement of the forearm made at a location is either stationary, away/toward, sideways, or circular. For example, the movement of the signs BIRD, TALK, LAUGH, and LIPREAD are stationary, away/toward, sideways, and circular, respectively.

It is not sufficient, however, to specify the movement just as a sequence of locations, even if such locations are interpreted to be [mouth: + contact], [mouth: -

contact], [mouth: + side], and so forth. Such an interpretive extension of locations would still fail to account for the four-way contrast for the signs BIRD, TALK, LAUGH, and LIPREAD.

The fact that given the location, mouth, there are four and just four different movement types, stationary (BIRD), away (TALK), sideways (LAUGH), and circular (LIPREAD), suggests that they are really signs of stationary, flexional, rotational, and polar movement, respectively. Therefore, I propose that the signs with body locations be represented as if they were signs with the normal, fixed, lower side position of the elbow, except for their additional specification for the location. Since each body location is associated with a unique, fixed position of the elbow, it is associated with a unique, fixed elbow globe. The elbow globe associated with each location has the same flexional and rotational coordinate reference as the globe at the normal, lower position of the elbow, although it is tilted, so that the hand can reach the location. Some of the signs with body locations including BIRD, TALK, LAUGH, and LIPREAD are represented below:

BIRD (ABC p.172):	forearm	([30 flexed] [30 inward])	mouth
	hand	[neutral] [pronated]	
TALK (ABC p.119):	forearm	([30 flexed] [0 flexed] [30 inward])	mouth
	hand	[neutral] [neutral]	

LAUGH (ABC p.105):	forearm	[30 flexed] [30 inward] [0 inward]	mouth
	hand	[neutral] [neutral]	
LIPREAD (ABC p.105):	forearm	pole [30 flexed] [30 inward] radius [15]	mouth
	hand	[neutral] [supinated]	
GALLAUDET (ABC p.173):	forearm	[45 flexed] [45 inward] [30 inward]	forehead
	hand	[neutral] [pronated]	
MEMORIZE (ABC p.105)	forearm	[45 flexed] [0 flexed] [45 inward]	forehead
	hand	[neutral] [supinated]	
BACKPACKING (ABC p.172):	forearm	[45 flexed] [60 flexed] [0 inward]	shoulder
	hand	[neutral] [supinated]	

The fact that in principle, signs with body locations can be represented with reference to global frames, exactly the same way as signs with the normal elbow position, gives credence to the validity of such global representational schema. The binary division between signs made with the normal, fixed, lower side position of the elbow and signs made with a unique, fixed position of the elbow for each body

location accounts for the standard binary division, in terms of place of articulation, between signs made in neutral space and signs made at body locations.

9. Elbow Movement

The signs with variable position of the elbow appear to argue against the claim that the position of the elbow is irrelevant phonologically, at least at the level of underlying representation. It is my claim that variability of the position of the elbow does not argue against the overall framework, since such variability does not seem to be contrastive.

There are three classes of signs in which the elbow moves. Informally, they are signs in which the elbow moves in the plane of forearm flexion, signs in which the elbow moves in the plane parallel to the plane of forearm rotation, and some of the bimanual signs in which the two hands form a single articulator. I will not be concerned with the last case.

The following signs are signs in which the position of the elbow is variable, but variable within the plane of forearm flexion:

SEND (ABC p.66):

forearm	[0 extended] [60 extended] [45 inward]
hand	[neutral] [pronated]

WALK-TO (ABC p.120):

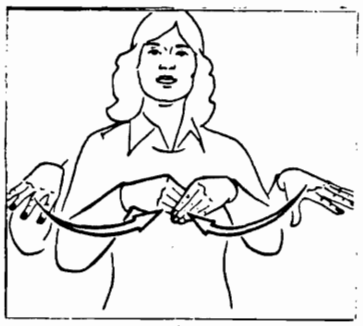
forearm	[30 flexed] [30 extended]
	[45 neutral]
hand	[neutral]
	[pronated]

Variability of the position of the elbow for signs of flexional movement occurs, but occurs in the plane of forearm flexion.

The following signs are signs of rotational or polar movement, in which the elbow moves, but moves in the plane parallel to the rotational plane of the forearm:

WEDDING (ABC p.107):

forearm	[30 flexed]
	[0 inward] [45 inward]
hand	[flexed]
	[pronated] [neutral]



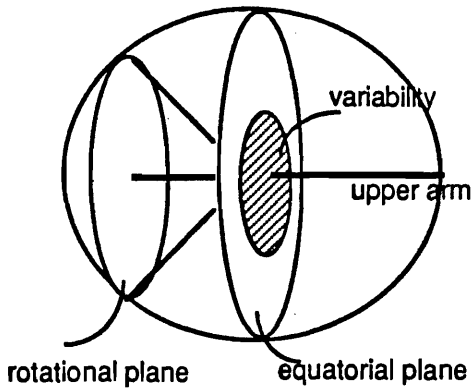
WIN (ABC p.107):

forearm	[0 flexed]
	[0 inward] [45 inward]
hand	[neutral]
	[neutral]

MISS (ABC p.129):

forearm	[45 flexed]
	[0 inward] [45 inward]
hand	[neutral]
	[neutral]

For signs of rotational or polar movement, the elbow moves along the outer edge of the shaded area (in the following illustration) in the equatorial plane, the plane delimited by the equator of the globe:



Since such flexional or rotational variability does not seem to be contrastive, and its range is restricted to a small area within either the plane of forearm flexion or the equatorial plane, it seems safe to assume that these signs are just like the signs with the fixed position of the elbow with or without specific reference to body locations.

It is my claim that variability of the position of the elbow occurs, either in the plane of forearm flexion, or in the equatorial plane of forearm rotation. Therefore,

excluding pantomimic signs, a movement is not a sign if variability of the position of the elbow is neither flexional nor equatorial, or if it is fixed, but neither at the normal, lower side, nor at the location uniquely associated with each body location. In fact, one of the characteristics of pantomimic signs is the use of the space within reach of the full arms, and not the forearms (Klima and Bellugi 1979).

In summary, variability of the position of the elbow occurs flexionally within the plane delimited by a longitudinal line or rotationally within the equatorial plane of the elbow globe. Since such variability does not seem to be distinctive, it seems safe to assume that it is not relevant phonologically, at least at the level of underlying representation.

10. Conclusions

The objective of the present thesis was to devise a representational framework for sign movement, using sequences of segments defined with respect to their appropriate frames of reference. The major features and claims of such a framework are summarized as follows.

MOVEMENT INDEPENDENCE. The sign is a synchronized combination of the movement of the limbs at joints, and is represented movement by movement in tiers. Such representation captures the fact that the movement of a limb does not affect and is not affected by the movement of another.

MOVEMENT SEGMENTATION. Movement can be best represented as a sequence of segments. Hand and forearm movement can be best represented as sequences of coordinates on the surface of the globe centered at the wrist and the elbow, respectively. Digital movement can be best represented as a sequence of handshapes.

FRAMES OF REFERENCE. The segments of movement can be best defined with reference to a globe of reference centered at the joint of the limb. Such frames of reference define the orientational and positional values of the hand explicitly and independently of each other.

VARIABILITY OF THE POSITION OF THE ELBOW. The position of the elbow is relatively fixed in ASL. I claimed that it is not contrastive phonologically, and the position of the center of the elbow globe is not relevant, at least at the level of underlying representation.

POSSIBLE MOVEMENT. The basic form of movement on the surface of a globe is arc movement, and not straight-line movement. Flexion, rotation, and polar movement

all follow arcs. In fact, straight-line movement cannot be represented in the present framework, and I claim that it does not exist, at least in non-pantomimic ASL.

Since movement is an interpolated path of states of flexion and rotation, possible movement is a possible combination of states of flexion and rotation. However, certain combinations are impossible in ASL. I claimed that only strictly flexional and strictly rotational interpolations are relevant phonologically and morphologically. Even the signs with variable position of the elbow support the claim that possible movement is either flexional or rotational, since variability occurs either flexionally or rotationally. Morphologically, I presented examples of derivationally related forms in which path modulation is either flexional or rotational.

Signs with body locations, in which the position of the elbow is fixed, but at a different location than usual, are represented in a parallel fashion to signs with the normal, fixed position of the elbow. Such parallelism supports the claim that possible movement is either flexional or rotational.

11. References

Battison, Robbin: 1978, LEXICAL BORROWING IN AMERICAN SIGN LANGUAGE, Linstok Press, Silver Spring, Maryland.

Chomsky, Noam and Morris Halle: 1968, THE SOUND PATTERN OF ENGLISH, Harper and Row, New York.

Friedman, Lynn: 1977, Formational Properties of American Sign Language, In L. Friedman (ed.), 1977, ON THE OTHER HAND: NEW PERSPECTIVES ON AMERICAN SIGN LANGUAGE, Academic Press, New York.

Goldsmith, John: 1976, AUTOSEGMENTAL PHONOLOGY, doctoral dissertation, MIT, Cambridge, Massachusetts.

Humphries, Tom, Carol Padden, and Terrence O'Rourke: 1981, A BASIC COURSE IN AMERICAN SIGN LANGUAGE, T. J. Publishers, Silver Spring, Maryland.

Klima, Edward and Ursula Bellugi: 1979, THE SIGNS OF LANGUAGE, Harvard University Press, Cambridge, Massachusetts.

Liddell, Scott: 1984, THINK and BELIEVE: Sequentiality in American Sign Language, LANGUAGE 60: 372–399.

Liddell, Scott and Robert Johnson: 1987, American Sign Language Compound Formation Processes, Lexicalization, and Phonological Remnants, NATURAL LANGUAGE AND LINGUISTIC THEORY 4: 445–513.

Marr, David: 1982, VISION: A COMPUTATIONAL INVESTIGATION INTO THE HUMAN REPRESENTATION AND PROCESSING OF VISUAL INFORMATION, W. H. Freeman, San Francisco, California.

Padden, Carol and David Perlmutter: 1987, American Sign Language and the Architecture of Phonological Theory, NATURAL LANGUAGE AND LINGUISTIC THEORY 5: 335–375.

Perlmutter, David: 1987, Prosodic Properties of Lexical and Surface Representations in American Sign Language Phonology, ms.

Sandler, Wendy: 1986, The Spreading Hand Autosegment of American Sign Language, SIGN LANGUAGE STUDIES 50: 1–28.

Siple, Patricia: 1978, Linguistic and Psychological Properties of American Sign Language: An Overview, In P. Siple (ed.), 1978, UNDERSTANDING LANGUAGE THROUGH SIGN LANGUAGE RESEARCH, Academic Press, New York.

Stack, Kelly: 1988, Tiers and Phonotactics in American Sign Language, ms.

Stokoe, William: 1960, SIGN LANGUAGE STRUCTURE: AN OUTLINE OF THE VISUAL COMMUNICATION SYSTEMS OF THE AMERICAN DEAF, Studies in Linguistics: Occasional Papers 8. (Revised, 1978, Linstok Press, Silver Spring, Maryland.)

Wilbur, Ronnie: 1979, AMERICAN SIGN LANGUAGE AND SIGN SYSTEMS, University Park Press, Baltimore, Maryland.

Wilbur, Ronnie: 1987, AMERICAN SIGN LANGUAGE: LINGUISTIC AND APPLIED DIMENSIONS, Little Brown, Boston, Massachusetts.