Modality Differences in Sign Language

Phonology and Morphophonemics

Diane Brentari

Purdue University

Correspondence:
Diane Brentari
Linguistics Program
Purdue University
West Lafayette, IN 47907-1353

1. Introduction [1]

In this chapter it is taken as given that phonology is the level of grammatical analysis where primitive structural units without meaning are combined to create an infinite number of meaningful utterances. It is the level of grammar that has a direct link with the articulatory and perceptual phonetic systems, either visual/gestural or auditory/vocal. There has been work on sign language phonology for about 40 years now, and at the beginning of just about every piece on the topic there is some statement like the following:

> "The goal is, then, to propose a model of ASL [American Sign Language] grammar at a level that is clearly constrained by both the physiology and by the grammatical rules. To the extent that this enterprise is successful, it will enable us to closely compare the structures of spoken and signed languages and begin to address the broader questions of language universals . . ." (Sandler 1989: vi)

The goal of this chapter is to articulate some of the differences between the phonology of signed and spoken languages that have been brought to light in the last 40 years and to illuminate the role the physiological bases have in defining abstract units, such as the segment, syllable, and word. There are some who hold a view that sign languages are just like spoken languages except for the substance of the features (Perlmutter 1992). I disagree with this position, claiming instead that the visual/gestural or auditory/ vocal mode of communication infiltrates the abstract phonological system, causing differences in the frequency of a phenomenon's occurrence, as well as differences due to the signal, articulatory, or perceptual properties of signed and spoken languages (see Meier, this volume).

I will argue that these types of differences should lead to differences in the phonological representation. That is, if the goal of a phonological grammar is to express generalizations as efficiently and as simply as possible, and ultimately give an explanatory account of these generalizations, the frequency with which a given phenomenon occurs should influence its representation. A grammar should cover as many forms as possible with the fewest number of exceptions, and frequent operations should be easy to express, while infrequent or non-occurring operations should be difficult to express; these premises are some of the most basic of those in phonology (Chomsky and Halle 1968, cf. 330-335; Clements 1985). If a true comparison of signed and spoken language phonology is to be made, representations must take issues of frequency into account. The areas of differences between signed and spoken languages that I will be describing and the organization of the chapter are given in (1).

(1) Areas of difference described in this chapter:

a. Perceptual differences between audition and vision (Section 2.1)

b. Articulatory differences: the roles that articulators play in the system (Section 2.2)

c. Distribution of information in the signal: (i) consonants; (ii) vowels (Section 3)

d. Segmental differences: (i) the need for segments; (ii) the relationship between segments and root nodes (Section 4)

e. Lexical differences: (i) word shape; (ii) minimal pairs

In the background throughout this chapter are these questions: "How much can the phonological representation of spoken languages elegantly and efficiently express sign language phonology?" "How far into the phonology do the effects of the phonetics (modality) reach?" "At what level of description are phonological units equally applicable to signed and spoken languages?" In terms of lost insight about human language, how much cost is there if sign languages are expressed through spoken language representations that are not designed for them?

2. Bases for Differences in Signed and Spoken Languages

In this section, differences between vision and audition that might play a role in phonological evolution will be discussed, and, in Section 2.2, fundamental points about sign language phonology that will figure in the discussions to follow will be discussed.

2.1. Some Key Differences Between Vision and Audition

Many aspects of vertical and horizontal processing take place in both vision and audition (Bregman 1990). "Vertical processing" is a cover term for our ability to process various input types presented roughly at the same time (e.g., pattern recognition, paradigmatic processing); "horizontal temporal processing" is our ability to process temporally discrete inputs into temporally discrete events (e.g., ordering and sequencing of objects in time, syntagmatic processing). There are, however, differences in the inherent strengths built into the design of the visual and auditory systems due to signal transmission and peripheral processing, and a view are listed in (2).

(2) Differences between vision and audition

	vision	audition
speed of signal transmission	186,000 mps	1089 ft/sec
peripheral temporal resolution	25-30 ms	2 ms
spatial arrangement information	peripheral	non-peripheral

In general, the advantage in vertical processing tasks goes to vision, while the advantage horizontal processing tasks goes to audition. For example, the time required for a subject to detect temporally discrete stimuli is a horizontal processing task. Hirsch and Sherrick (1961) show that the time required for the higher order task of <u>recognition</u>, or labeling of a stimulus, called "threshold of identification" (involving more cortical involvement) is roughly the same in both the same in both vision and audition—approximately 20 ms. The time required for the more peripheral task of <u>detection</u>, called "threshold of flicker fusion" in vision (Chase and Jenner 1993) and "threshold of temporal resolution" in audition (Kohlrausch, Püschel, and Alphei 1992), is quite different. Humans can temporally resolve auditory stimuli when they are separated by an interval of only 2 ms, (Green 1971, Kohlrausch, Püschel, and Alphei 1992), while the visual system requires at least a 20 ms. interstimulus interval to resolve visual stimuli presented sequentially (Chase & Jenner 1993). The advantage here is with audition. Meier (1993) also discusses the ability to judge duration and rate or stimulus presentation; both of these tasks also give the advantage to audition.

Comparing vertical processing tasks in audition and vision—e.g., pattern recognition, localization of objects—is inherently more difficult, because the nature of sound and light transmission. To take just two examples, vision has no analogue to harmonics, and the difference between the speed of transmission of light waves vs. sound waves is enormous—186,000 miles/sec for light waves vs. 1,089 feet/sec for sound waves. As a result of these major differences, I could find no tasks have exactly the same experimental design or control factors; however, we can address vertical processing in a more general way. One effect of speed of light transmission on the perception of objects is that vision can take advantage of light waves reflected not only from the target object, but also by other objects in the environment, thereby making use of "echo" waves—i.e., those reflected by the target object onto other objects. These echo waves are available simultaneously with the waves reflected from the target object to the retina (Bregman 1990). This same echo phenomenon in audition is available to the listener much more slowly. Only after the sound waves produced by the target object have already struck the ear will echo waves from other objects in the environment do the same. The result of this effect is that a more three-dimensional image is available more quickly in vision due, in part, to the speed at which light travels. Moreover, the localization of visual stimuli is registered at the most peripheral stage of the visual system, at the retina and lens, while the spatial arrangement of auditory stimuli can only be inferred by temporal and intensity differences of the signal between the two ears (Bregman 1990). Meier (1993, this volume) also discusses the transmission property of bandwidth, which is larger in vision, and spatial acuity, which is the ability to accurate pinpoint an object in space (Welsh & Warren 1986); both of these properties also give the advantage to vision.

In sum, the auditory system has an advantage in horizontal processing, while the visual system has an advantage in vertical processing. An expected result would be that phonological representations in signed and spoken languages reflect these differences. This would not present a problem for a theory of universal grammar (UG), but it may well have an effect on proposals about the principles and properties contained in the part of UG concerned with phonology. At the end of the chapter, a few such principles for modality-independent phonology will be proposed, which are principles that can exploit either type of language signal.

2.2. Introduction to Sign Language Phonology and to the Prosodic Model

This section is a summary of results in the area of sign language phonology, in general, and in the Prosodic Model (Brentari 1998), in particular. I hold the view that a specific theory must be employed in order to illuminate areas of difference between sign and spoken languages; however, many of the topics covered in this chapter enjoy a large degree of consensus and could be articulated in several different phonological models of sign language structure. At the center of the work on sign language phonology are several general questions concerning how much of a role such factors as those discussed in Section 2.1. play in our phonological models.

Basically, signed words consist of a set of three or four parameters, each consisting of featural material, as shown in (3).

(3) Traditional "Parameters" in Sign Language Phonological Structure and one representative feature

Parameters:	Handshape	Place of Articulation	Movement	Orientation
Features:	[open]	[distal]	[direction]	[pronation]

It is often assumed that these parameters all have more or less of equal status in the system. I would attribute the source of this assumption to transcription systems, which create symbols for a sign's handshape (henceforth, called articulator), place, and movement (Stokoe 1960; Stokoe, Casterline, and Croneberg 1965), and orientation (Battison 1978) without investigating carefully how these properties fit together as a phonological system.[2] This is not to underestimate the contribution that this early, groundbreaking work made to the field; however, each of these parameters was found to have at least one contrastive property, which creates a minimal pair in such systems of transcription, and so each parameter was considered equal.[3]

In general, the more recent innovations in phonological theory, such as autosegmental phonology (Goldsmith 1976), feature geometry (Clements 1985; McCarthy 1988; Clements and Hume 1995), and prosodic phonology (Nespor & Vogel 1986, Itô 1986), have made it possible for more common ground in sign language and spoken language phonological work. To take one example, it is relatively easy to make the connection between the sign language entities in (3) and feature geometry. The traditional sign language parameters (i.e., articulator, movement, etc.) are class nodes and the features (i.e., [open], [direction], etc.) are terminal nodes dominated by class nodes; however, the class nodes in (3) are not equal if we consider these parameters according to how much consensus there is about them. As soon as we move beyond the articulator parameter, the one on which there is the most consensus, or place of articulation, on which there is a fair amount of consensus, there are controversies about major issues. Those include the necessity of movement and orientation parameters as phonological entities; the nature and type of other possible structures, such as the segment and mora; and, the articulatory and/or perceptual bases for features in sign languages.

Let us now turn to the Prosodic Model (Brentari 1998), since this is phonological model that is used in this chapter. In the Prosodic Model, features are organized hierarchically using feature geometry. The primary branches of structure are given in (4a); the complete structure is given in (4b). While phonological theory emphasizes that feature organization is based on phonological behavior rather than the physical nature of the articulators, it is worth discussing this point in sign language phonology in some detail, because it brings to light a difference in the phonetic roles of signed and spoken language articulators.

(4) Prosodic Model Feature Geometry

a.

root

inherent features (IF)   prosodic features (PF)

articulator (A)   place of articulation (POA)

b.

The "vocal mechanism" in speech includes the tongue, lips, and larynx as the primary active articulators, and the teeth, palate, and pharyngeal area as target places of articulation (i.e., the passive articulators). Although there are exceptions to this, since the lips and glottis can be either active or passive articulators, other articulators have a fixed role. The tongue is always active and the palate always passive in producing speech, so to some extent, structures have either an active or a passive role in the articulatory event. This is not the case in sign languages. Each part of the body involved in the "signing mechanism"—the face, hands, arms, torso—can be active or passive. For example, the hand can be an active articulator in the sign THINK, a passive articulator in the sign TOUCH, and a source of movement in the sign UNDERSTAND, shown in Figure 1. The lips and eyes are the articulator in the bound morpheme CAREFUL(LY) but the face is the place of articulation in the sign BEAUTIFUL. This is one reason models of sign language phonology must be grouped by phonological role; however, just as in spoken languages, articulatory considerations play an important secondary role in these groupings.

--Figure 1 here--

Within the Prosodic Model features are divided into mutually exclusive sets of inherent features (IF) and prosodic features (PF). Movement features are grouped together as prosodic features, based on the use of the term by Jakobson, Fant and Halle (1951), in which it is stated that prosodic features are "defined only with reference to a time series." The inherent features are the articulator and place of articulation features. The articulator actually refers to features of the active articulator, and place of articulation (POA) refers to features of the passive articulator. The relation of the articulator with the POA is the orientation relation.

There are several arguments for organizing features in the representation this way, rather than according to articulatory structure. A few are given here; for more details and for additional arguments see Brentari (1998). When considering their role in the phonological grammar, not only the number of distinctive features, but also the complexity and the type of constraints on each of the IF and PF feature trees must be considered. The number of IFs is slightly larger (24) than the number of PFs (22). The structure of the IF branch of structure is also more complex and yields more potential surface contrasts than the PF branch.

In addition, the constraints on outputs of the PF tree are much more restrictive than those on the outputs of IF tree. A specific PF branch constraint sets a minimum of 1 and a maximum of 3 of movement components in any lexical item, and another PF branch constraint limits the number of features from each class node to 1 in stems. PFs are also subject to principles of Alignment, which insure that a sign with movements involving both handshape and arm movements will have the correct surface pattern; examples of such signs are INFORM, DESTROY, and BACKGROUND, shown in Figure 2. The IF branch is subject to fewer and more general constraints, and IFs are generally realized across the entire prosodic word domain.

--Figure 2 here--

PFs also have the ability to undergo “movement migration,” while IFs do not. A joint of the arm or even the torso can realize movements specified as handshape movements (i.e., aperture changes) or wrist movements. Some of the reasons for movement migration that have been documented in the literature: lexical emphasis (Wilbur 1999, 2000), linguistic maturation (Meier 1998, 2000; Holzrichter & Meier 2000), loudness (Crasborn 2001) and motor impairment due to Parkinson’s Disease (Brentari & Poizner 1994). Finally, PFs participate in the operation of “segment generation”, while IFs do not. This will be explained further in the segment section below.

Within the Prosodic Model, the following units of analysis are used, and they are defined as follows.

(5) Units of phonological analysis

a. prosodic word (p-words): the phonological domain consisting of a stem+affixes

b. root node: the node at which the phonological representation interfaces with the morphosyntactic features of the form; "the node that dominates all features and expresses the coherence of the melodic material as a phonological unit." (Clements & Hume 1995)

c. syllable: i. the fundamental parsable prosodic unit

ii. (in sign language) a sequential, phonological movement

d. weight unit: a branching class node in the PF tree, which adds complexity to the syllable nucleus and can be referred to by phonological and morphophonological processes

e. timing unit (segment): the smallest concatenative unit on the timing tier (X-slots)

P-words and root nodes are defined in ways recognizable to phonologists working on spoken languages, and these need no further explanation; let us therefore address the syllable, timing unit, weight unit in turn.

Sign language syllables, defined in terms of the number of sequential movements in a form, are necessary units in the phonological grammar, because if one considers the grammatical functions that these units serve for a sign language such as ASL, they parallel those served by the syllable in spoken languages. The reason for calling such units syllables is related to facts regarding language acquisition; sonority; minimal word constraints, and word-internal 2-movement combinations.[4] First, regarding language acquisition, it has been shown that Deaf babies learning ASL as a first language engage in pre-linguistic babbling whose structure is that of a linguistic movement (Petitto and Marentette 1991, Petitto 2000). This type of movement functions in a similar way to vocal babbling in babies acquiring a spoken language in temporal patterning, and it is distinct from rhythmic, excitatory motoric activity. This activity involving movement serves as the basic prosodic structure upon other aspects of the phonology can be added. Second, regarding sonority, there is evidence that movements (hand-internal movements, wrist movements, elbow movements and shoulder movements) are subject to an evaluative procedure that decides the relative suitability of a movement for constructing a lexical movement according to the joint producing it. Movements articulated by a more proximal joint are preferred over those articulated by more distal joints. For example, more movements articulated by the wrist and forearm are preferred over movements articulated by the knuckles in loan signs that come from fingerspelling. This type of evaluation mechanism in sign phonology is similar to the one in spoken languages that evaluates the local maximum of sonority to determine a sound's suitability as a syllable nucleus. I consider this visual salience a type of sign language sonority, which is a property of syllables. Third, regarding minimal word constraints, no sign is well formed unless it has a movement of some type (Wilbur 1987, Stack 1988, Brentari 1990a, 1990b). When one is not present in the underlying form, there are insertion rules that repair such forms. Finally, regarding 2-movement combinations, there are restrictions on the types of movement sequences a signed word may contain (Uyechi 1995:104-106), as compared with a sequence of two signs or polymorphemic forms. Bi-directional repeated, unidirectional repeated, and circle + straight movements are possible combinations. Straight + circle movement combinations are disallowed as are all combinations containing an arc movement.

Timing units (or segments) in the Prosodic model are defined as minimal concatenative units—i.e., the smallest temporal phonological slice of the signal. Attempts to establish a phonology which contrasts movement and stasis as the two types of fundamental phonological entities in sign languages (Liddell and Johnson 1983, 1984, 1989) were gradually replaced when new evidence came to light showing that all stasis in a monomorphemic sign is predictable from phonological context. Such contexts include position in a phrase (Perlmutter 1992) and contact with the body (Liddell and Johnson 1986, Sandler 1987). There are no minimal pairs in ASL which involve segmental geminates in any of the sign parameters.[5] Abstract timing units are necessary, however, in order to account for a variety of duration-based, phonological operations, such as lengthening effects, which target several prosodic class nodes at once (handshape, setting, etc.) when they occur in the same phonological context (e.g., word-initially or word-finally).

In the Prosodic Model, the number of timing units is predictable from the PFs in a form; these are calculated as follows. Path features (located at the path node) and abstract PFs (located at the node at the top of the PF tree) generate 2 "x" timing slots; all other PFs generate one timing slot. The class node with the highest number of potential segments determines the number of segments in the word. A process of alignment then takes place (right to left) so that all features associate to their correct segments. The features of each of the class nodes in the PF tree are given in (6). IFs do not generate any timing slots at all.

(6) Segment Generation in the Prosodic Model (Brentari 1998, chapter 5)

a. 2 segments generated

prosodic node features: [straight], [arc], [circle]

path features: [direction], [tracing], [pivot], [repeat]

b. 1 segment generated

setting features: [proximal], [distal], [top], [bottom], [ipsilateral], [contralateral]

wrist/orientation: [supination], [pronation], [abduction], [adduction], [flexion], [extension] aperture: [open], [closed]

Finally, let us turn to weight units. Weight units in the Prosodic Model are assigned based on the complexity of the movement. A sequential movement may have one component (i.e., features at one class node in the PF tree—e.g., UNDERSTAND); these are called simple movements. A sequential movement can have more than one component as well (i.e., features at more than one class node—e.g., INFORM); these are called complex movements. Each branching class node contributes a weight unit to the structure. As we will see later in this paper, ASL phonology is sensitive to this difference.

3. The Distribution of "Consonant" and "Vowel" Information

All languages—both spoken and signed— are organized such that certain features are members of sets having rich paradigmatic contrast, while other features are members of sets that do not carry much contrastive power. Moreover, these (ideally mutually exclusive) feature sets are assigned to different parts of the signal. In spoken languages the former description is appropriate for the set of consonants, and the latter description appropriate for the set of vowels. The general findings in this section about sign languages are as follows. First, the IF branch of structure carries more lexical contrast than the PF branch of structure, just as consonants carry more potential for lexical contrast in spoken languages. Second, movements (PFs) function as the "medium" of the signal, just as vowels function as the medium of spoken languages. Third, movements (PFs) function as syllable nuclei in sign languages, just as vowels function as syllable nuclei in spoken languages. For these reasons, the IF branch of structure is analyzed as more consonant-like and the PF branch is analyzed as more vowel like. Fourth, and finally, in

Section 3.2, it is shown that the complexity of vowels and the complexity of movements is calculated differently in signed and spoken languages, respectively. These result leads to the differences in the distribution of vowel and consonant information in sign and spoken languages given in (7).

(7) Differences between the nature of consonant and vowel information in signed and spoken languages.

a. Cs and Vs are realized at the same time in sign languages, rather than as temporally discrete units. [6]

b. With respect to movements (i.e., vowels), the phonology is sensitive to the number of simultaneous movement components present in a form.

3.1. Consonants and Vowels in Sign Languages

The Hold-Movement model of sign language phonology was the first to draw parallels between vowels in spoken languages and movements in sign languages (Liddell and Johnson 1984). There are good reasons for this, given in (8) and explained further below.

(8) Reasons for a vowel: PF analogy

a. Signed words can be parsed without movements, just as spoken words can be parsed without vowels.

b. In sign languages, the number of paradigmatic contrasts in the PF tree (movements) is fewer than the number of contrasts in IF tree (articulator + poa), just as in spoken languages the number of paradigmatic contrasts in vowels is fewer than the number of consonant contrasts.

c. It is the movements, which make signs perceptible at long distances in a sign language, just as vowels make the signal perceptible at long distances in spoken languages—i.e., it is the “medium” of the signal.

d. It is the vowels that function as syllable nuclei in spoken languages; the movements in sign languages function as syllable nuclei

First, if the movement of a sign is removed, a native signer is still likely to be able to parse it in context, just as in spoken languages a native speaker is likely to be able to parse a word in context if the vowels are removed. In sign, this finding can be inferred from the numerous dictionaries in use, which are generally still, photographic images. For speech, this is true for derived media, such as orthographic systems without vowels, such as Hebrew (Frost and Bentin 1992), reading activities in English involving “cloze” tasks (Seidenberg 1992), as well as vowel recognition tasks in spoken words with silent-center vowels (Strange 1987, Jenkins et al. 1994). Second, the number of paradigmatic contrasts is much larger than the number of movement contrasts because of combinatoric principles that effects the IF and PF branches of structure. Third, work by Uyechi (1995) and Crasborn (in prep) propose that “visual loudness” in sign languages is a property of movements, just as loudness in spoken languages is a property of vowels. Without movement, the information in the signed signal could not be transmitted over long distances. Fourth, as I have described in Section 2.2, in the sign signal, it is the vowels that behave like syllable nuclei.

We can contrast movement features, which contribute to the dynamic properties of the signal within words, with IFs, which are specified once per word. The complete set of reasons for an analogy between the IFs and consonants in spoken languages is summarized in (9); they are further explained in the next paragraph.

(9) Reasons for a Consonant: IF analogy

a. The IF tree is more complex hierarchically than the PF tree

b. The combinatoric mechanisms used in each yield more surface IF contrasts than PF contrasts, respectively.

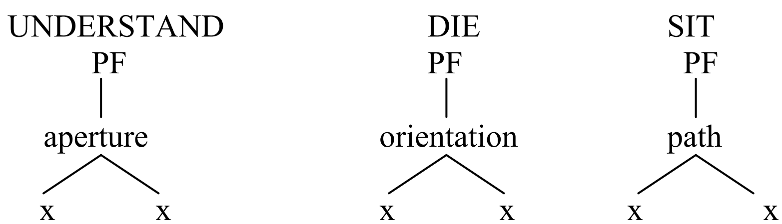
c. There is a larger number of features in the IF tree than in the PF tree.

These facts about IFs and PFs have been mentioned already in Section 2.2., but here they have new relevance because they are being used to make the consonant: IF and vowel: PF analogy. In summary, if sign language Cs are properties of the IF tree and sign language Vs are properties of the PF tree, the major difference between sign and spoken languages in this regard is that in sign languages IFs and PFs are realized at the same time.

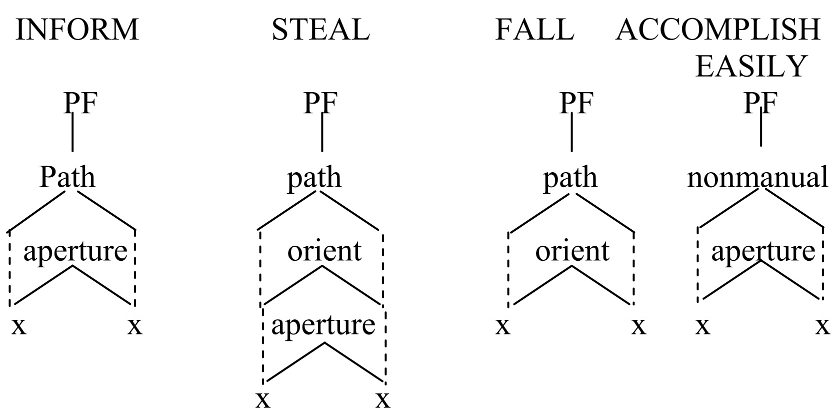
3.2. Vowels and Movements: Sensitivity to Movement-Internal Components

Even though vowels are similar to movements in overall function in the grammar, as we have seen in the previous section, movements in ASL are different from vowels in the way in which their complexity is calculated. In ASL, the phonological grammar is sensitive to the number of movement components present in a word, not simply the number of sequential movements in a form. For a spoken language it would be like saying that vowels with one feature, and those with more than one feature behaved differently in the vowel system; this is quite rare in spoken languages. Llogoori is one exception, since long vowels and those with a high tone are both counted as “heavy” in the system (Goldsmith 1992). In the Prosodic Model, movements with one component (defined as a single branching class node in the PF tree) are called simple movements ((10); see Figure 1 for UNDERSTAND). Movements with more than one component are called complex movements ((11); see Figure 2 for INFORM).

(10) Simple movement: 1 branching class node in the PF tree



(11) Complex movement: 2 or more branching class nodes in the PF tree



The grammar exhibits sensitivity to the distinction between simple and complex movements in nominalization of 2 types—reduplicative nominalization, and in the formation of activity verbs (i.e., gerunds)—and in word order preferences. The generalization about this sensitivity is given in (12).

(12) Movement-internal sensitivity

The grammar is sensitive to the complexity of movements, expressed as the number of movement components.

With regard to nominalization, only simple movements—shown in (10)—undergo either type of nominalization. The first work on noun-verb pairs in ASL (Supalla and Newport 1978) describes reduplicative nominalization: the input forms are selected by the following criteria: (a) they contain a verb that expresses the activity performed with or on the object named by the noun, and (b) they are related in meaning. The structural restrictions for reduplicative nominalization are given in (13); typical forms that undergo this operation are given in (14). All of the forms in the Supalla and Newport (1978) study, which undergo reduplication, are simple movement forms.[7] There are also a few reduplicative nouns which do not follow the semantic conditions of Supalla & Newport (1978), but these also obey the structural condition of being simple movements (14c-d); a typical form that undergoes reduplication is shown in Figure 3.

(13) Reduplication Nominalization Input Conditions

a. they contain a verb that expresses the activity performed with or on the object named by the noun

b. they are related in meaning

c. they are subject to the following structural condition: simple movement stems

(14) Possible reduplicative noun/verb pairs:

a. Reduplicated movement: CLOSE-WINDOW/WINDOW, SIT/CHAIR, GO-BY-PLANE/AIRPLANE

b. Reduplicated aperture change: SNAP-PHOTOGRAPH/PHOTOGRAPH, STAPLE/STAPLER, THUMP-MELON/MELON

c. No activity performed on the noun: SUPPORT, DEBT, NAME, APPLICATION, ASSISTANT

d. No corresponding verb: CHURCH, COLD, COUGH, DOCTOR, CUP, NURSE

--Figure 3 here---

Another nominalization process that is sensitive to simple and complex movements is the nominalization of activity verbs (Padden and Perlmutter 1987), resulting in gerunds. The input conditions are given in (15), with relevant forms given in (16). The movement of an activity noun is "trilled"; that is, it contains a series of rapid, uncountable movements.[8] Like reduplicative nouns, inputs must be simple movements, as defined in (10).[9]

(15) Activity Nouns Input conditions:

a. simple movement stems

b. activity verbs

(16) Possible activity verb/noun pairs: READ/READING, DRIVE/DRIVING, SHOP/SHOPPING, ACT/ACTING, BAT/BATTING

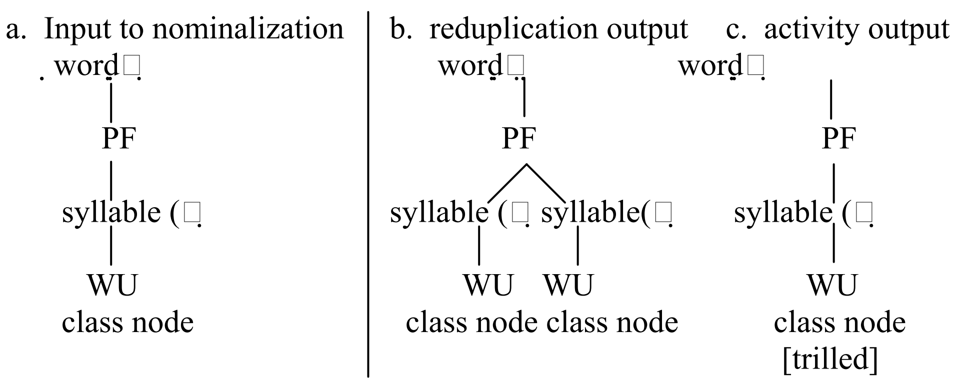
*THROW/THROWING (violation of (15a)—complex movement)

*KNOW/KNOWING (violation of (15b)—stative verb)

--Figure 4 here--

The formalization of the nominalization operations for reduplicative and activity nouns is given in (17). A weight unit (abbreviated WU) is formed by a branching node of the PF tree. Reduplication generates another simple movement syllable, while activity noun formation introduces a [trilled] feature at the site of the branching PF node.

(17) Formalization of Input and Output Structures word



Another phenomenon that shows sensitivity to movement complexity is seen in the gravitation of complex movements to sentence-final position (18). This type of phenomenon is relatively well known in spoken languages—i.e., when heavy syllables have an affinity with a particular sentential position (Zec and Inkelas 1990). In (18a), the complex movement co-occurs with a person agreement verb stem (Padden 1983). In (18b) the complex movement occurs co-occurs with a spatial agreement verb stem (Padden 1983). In (18c) the complex movement occurs in a "verb sandwich" construction (Fischer and Janis 1990). In such constructions, which are a type of serial verb construction, a noun argument occurs between two instances of the same verb stem. The first instance is uninflected; the second instance, in sentence-final position—has temporal and spatial affixal morphology, which also makes the form phonologically heavy. [10]

(18) Word Order and syllable weight:

a. in agreement verbs

i. ${}_{1}$GIVE$_{2}$ BOOK (simple movement: 1 branching PF class node)

'I give you the book'

ii. ?${}_{1}$GIVE$_{2}$ [habitual] BOOK (complex movement: 2 branching PF class nodes)

'I give you the book repeatedly.'

iii. BOOK ${}_{1}$GIVE$_{2pl}$ [exhaustive] (complex movement: 3 branching PF nodes)

'I give each of you a book.'

iv. *${}_{1}$GIVE$_{2pl}$ [exhaustive] BOOK

b. in spatial verbs

i. ${}_{a}$PUT$_{b}$ NAPKIN (1 branching PF class node)

'(Someone) placed the napkin there.'

ii. ?${}_{a}$PUT$_{b}$ [habitual] NAPKIN (2 branching PF class nodes)

'(Someone) placed the napkin there repeatedly.'

iii. NAPKIN ${}_{a}$PUT$_{b}$ [exhaustive] (3 branching PF class nodes)

'(Someone) placed a napkin at each place.'

iv. *${}_{a}$PUT$_{b}$ [exhaustive] NAPKIN

c. With verb sandwich constructions (Fischer and Janis1990)

i. S-H-E LISTEN R-A-D-I-O (2 branching PF class nodes)

'She listens to the radio.'

ii. S-H-E LISTEN R-A-D-I-O LISTEN [continuous]

(LISTEN [continuous] has 3 branching PF class nodes)

'She was continuously listening to the radio. . .'

iii. *S-H-E LISTEN [continuous] R-A-D-I-O LISTEN

4 Differences Concerning Segments

In this section, three kinds of feature and segment behavior in sign languages will be addressed. First, it will be made clear that even though segments are predictable by the features present in the structure, yet are needed by the grammar because they are referred to in the system of constraints. Second, the canonical relationship between root nodes and segments will be discussed.

4.1. Segments: Predictable, Yet required by the Grammar

A segment in the Prosodic Model is defined as the minimal concatenative unit required by the grammar for timing (i.e., duration) or ordering effects.[11] As described in Section 2.2., features in the PF tree generate segments, the ones in the IF tree do not. The difference between the placement of segments in spoken and sign language phonological structure is given in (19).

(19) Spoken language hierarchy of units: segments dominates features[12]

Sign language hierarchy of units: features dominates segments

Since features predict segmental structure in the Prosodic Model, we can say that features dominate segmental structure. Despite their predictability, segments cannot be dispensed with altogether, since they are needed to capture the environment for morphophonemic operations, as will be shown below.

Segments are needed in order to account for several lengthening effects in ASL. Two of them are the result of morphophonemic operations—intensive affixation (20) and delayed-completive aspect affixation (21). A third is a purely phonological operation—phrase-final lengthening (22). One cannot capture lengthening effects such as these unless all of the features associated to a particular timing unit are linked together. The point is that for each operation, signs that have one or more than one branching PF class node(s) undergo the lengthening operation in an identical way. Feature information must be gathered together into segmental units so that forms in (20b), (21b) and (22b) do not require a separate rule for each feature set affected by the rule. The sets of features can include any of those under the PF tree—non-manual, setting, path, orientation, and aperture.

--Figure 5 here--

A form, such as UNDERSTAND, has an handshape (aperture) change at the forehead. In the form meaning 'intensive' ((20); Klima and Bellugi 1979), and in the form meaning 'delayed completive' ((21); Brentari 1996), the duration of the initial handshape is longer than in the uninflected form. The form ACCOMPLISH-EASILY has both an aperture change and a non-manual movement (the mouth starts in an open position and then closes). Both the initial handshape and nonmanual posture are held longer in both of the complex morphological forms in (20) and (21). In the intensive form, the initial segment lengthening is the only modification of the stem.

(20) Intensive affixation: $ø \longrightarrow x_i$ / ___ $_{stem}[x_i$

Prose: Copy the leftmost segment of a stem to generate a form with intensive affixation.

a. signs which undergo this operation containing <u>one</u> branching PF node:

UNDERSTAND, TAN, DEAD, CONCENTRATED, INEPT, GOOD, AGREE

b. signs which undergo this operation containing <u>more than one</u> branching PF node:

ACCOMPLISH-EASILY, FASCINATED, FALL-ASLEEP, FINALLY

In the delayed completive form, the initial segment is lengthened, and a [trilled movement] is added to the resulting initial geminate.

(21) Delayed completive aspect: $ø \longrightarrow \underset{[wig]}{x_i}$ / ___ $_{stem}[x_I$

Prose: Copy the leftmost segment of a stem and add a [wiggle] feature to generate a form with delayed completive affixation.

a. signs which undergo this operation containing <u>one</u> branching PF node:

UNDERSTAND, FOCUS, DEAD

b. signs which undergo this operation containing <u>more than one</u> branching PF node:

INFORM, ACCOMPLISH-EASILY, RUN-OUT-OF, FALL-ASLEEP, FINALLY

In the phonological operation of phrase-final lengthening (first discussed in Perlmutter 1992 as Mora-Insertion), the final segment is targeted for lengthening, the simple and the complex movement forms are lengthened identically (22), just as they were in (20) and (21)

(22) Phrase-final lengthening : $\text{ø} \longrightarrow x_i \,/\, x_I$ ______$]_{\text{p-phrase}}$

Prose: At the end of a phonological phrase, copy the rightmost segment.

a. signs which undergo this operation containing one branching PF node:

UNDERSTAND, TAN, DEAD, FOCUS CONCENTRATED, INEPT, GOOD

b. signs which undergo this operation containing more than one branching PF node:

INFORM, ACCOMPLISH-EASILY, FASCINATED, RUN-OUT-OF, FALL-ASLEEP, FINALLY

Because the segment, defined as above, is needed to capture these lengthening phenomena, this is evidence that it is a necessary unit in the phonology of sign languages.

4.2. Root Nodes and Timing Slots

Now we turn to how segments and root nodes are organized in the phonological representation. In spoken languages the root node has a direct relation to the timing or skeletal tier, which contains either segments or moras. While affricates and diphthongs demonstrate that the number of root nodes to timing slots is flexible in spoken languages, the default case is one timing slot per root node. The Association Convention (23) expresses this well, since in the absence of any specification or rule effects to the contrary, the association of tones to tone bearing units proceeds one-to-one.

(23) Association Convention (Goldsmith 1976)
In the absence of any specification or rule effects to the contrary, TBUs are associated to tones, one-to-one, left -to right.

This canonical one-to-one relationship between root nodes and segments does not hold in sign languages, since the canonical shape of root to segments corresponds closely to that of a diphthong—i.e., one root node to two timing slots. For this reason, I would argue that segments are not identified with the root, but are rather predictable from features, thus the canonical ratio of root nodes to timing slots in sign languages is 1:2, rather than 1:1 as it is in spoken languages, as given in (24).

(24) The canonical ratio of root nodes to segmental timing slots in sign languages is 2:1, rather than 1:1 as it is in spoken languages.

This state of affairs is due to two converging factors. First, segments are predictable from features, but they are also referred to in rules (20)-(22), so I would argue their position in the representation should reflect this, placing feature structures in a position of dominance over segments. Second, there is no motivation for assigning the root node either to the IF or the PF node only.[13] The inventory of surface root-to-segment ratios for English and ASL are given in

(25)-(26). A schema for the root-feature-segment relation for both spoken and signed languages is given in (27a-b).[14]

(25) spoken language phonology—root-segment ratios (English)

(26) sign language phonology—root-to-segment ratios (ASL)

(27) schema of root/feature/segment relationship

Spoken language Sign language

To summarize, at the segmental level sign language structure as defined in the Prosodic Model, there are two differences between signed and spoken language: segments are necessary—but predictable—and the canonical relationship between roots and segments is 1:2, rather than 1:1 as it is in spoken languages.

5. Differences at the Lexical Level

The differences in this section are concerned with the preferred form that words assume in signed and spoken languages, and how words are recognized as distinct from one another in the lexicon.

5.1. Word Shape

One area of general interest within the field of phonology is cross-linguistic variation in canonical word shape; that is, what is the preferred phonological shape of words across languages. For an example of such canonical word properties, many languages, including the Bantu language Shona (Myers 1987) and the Austronesian language Yidin (Dixon 1977), require that all words be composed of binary branching feet. With regard to statistical tendencies at the word level, there is also a preferred canonical word shape exhibited by the relationship between the number of syllables and morphemes in a word, and it is here that sign languages differ from spoken languages. In general, sign language words tend to be monosyllabic (Coulter 1982), even when the forms are polymorphemic. The difference exhibited by the canonical word shape of sign language words is given in (28).

(28) Unlike spoken languages, sign languages have a proliferation of monosyllabic, polymorphemic words.

This relationship between syllables and morphemes is a hybrid measurement, which is both phonological and morphological in nature, in part due to the shape of stems and in part due to the type of affixal morphology in a given language. A language, such as Chinese, contains words that tend to by monosyllabic and monomorphemic, because it has monosyllabic stems and little overt morphology (Chao 1968). A language, such as West Greenlandic, contains stems of a variety of shapes and a rich system of affixal morphology that lengthens words considerably (Fortescue 1984). In English, stems tend to be polysyllabic, and there is relatively little affixal morphology. In sign languages, stems tend to be monosyllabic (i.e., one movement; Coulter 1982). There is a large amount of affixal morphology, but the most of these forms are less than a segment in size; hence, polysyllabic and monosyllabic words are typically not different in word length. In (29), a chart schematizes the canonical word shape in terms of the number of morphemes and syllables per word.

(29) Canonical word shape according to the number of syllables and morphemes per word

	monosyllabic	polysyllabic
monomorphemic	Chinese	English
polymorphemic	sign languages	West Greenlandic

Except for the relatively rare morphemic change by ablaut marking past preterit in English (*sing*-pres./*sang*-preterit, *ring*-pres./*rang*-preterit), or for person marking in Hua (Haiman 1979), indicated by the [±back] feature on the vowel, spoken languages tend to create polymorphemic words by adding sequential material in the form of segments or syllables. Even in Semitic languages, which utilize nonconcatenative morphology, lexical roots and grammatical vocalisms alternate with one another in time; they are not layered onto the same segments used for the root as they are in sign languages. This difference is a remarkable one; sign languages constitute a typological class unto themselves in this regard. No spoken language has been found that is both as polysynthetic as sign languages and yet makes the morphological distinctions primarily in monosyllabic forms. An example of a typical polymorphemic, monosyllabic structure in a sign language is given in Figure 6.[15]

--Figure 6 here--

5.2 Minimal Pairs

This final section addresses another word-level phenomenon—i.e., the notion of minimal pairs in signed and spoken languages. Even though minimal pairs in phonological theory have traditionally been based on a single feature, advances in phonological representation make it possible to have minimal pairs based on a variety of types of structure. Any pair of forms that differs crucially in one and only one respect (whatever the structural locus of this difference) can be called a minimal pair. For example, the difference between the signs AIRPLANE and MOCK is based on the presence vs. absence of a thumb structure—AIRPLANE has a thumb structure and MOCK does not (Figure 6; structures in (30)). For reason having to do with the way the thumb behaves with respect to the other fingers, the thumb is a branch of structure, not a feature, yet this type of difference can still be referred to as a minimal pair.

(30) a. AIRPLANE

handshape$_a$(hs$_a$)
IF
fingers1
fingers0 thumb
[unopposed]
quantity ref
[one] [ulnar]
[all

b. MOCK

handshape$_b$ (hs$_b$)
IF
fingers1
fingers0
quantity ref
[one] [ulnar]
[all]

--Figure 7 here--

Unlike the other sections of this chapter, the point of this section is to show that minimal pairs in signed and spoken language are <u>not</u> fundamentally different, but that a different structure is required for sign languages if we are to see this similarity. If features dominate segments, as I have described is the case for sign languages, this similarity is quite clear; if segments dominate features, as is the case for spoken languages, the notion of the minimal pair in sign language becomes difficult to capture.

The reason for this is as follows. If the handshape for AIRPLANE and MOCK are minimally different, then all things other structures being equal, the signed words in which they occur should also be minimally different. This is the intuition of native signers, and this is the basis upon which Stokoe (1960) and Klima and Bellugi (1979) established minimal pairs. In the Hold-Movement phonological model proposed by Liddell and Johnson (1983, 1989), which is a model where segments dominate features, such signs are not minimal pairs, because MOCK and AIRPLANE are signs where differences exist in more than one segment. MOCK and

AIRPLANE each have 4 segments, and the handshape is the same for all of the segments. In the Prosodic Model, barring exceptional circumstances, IFs spread to all segments.

(31) Prosodic and Hold-Movement Representations of AIRPLANE (hs_a)and MOCK (hs_b)

a. Hold-Movement Model Representations

AIRPLANE MOCK

b. Prosodic Model Representations

AIRPLANE MOCK

I have suppressed the details of the representations that are not relevant here. The important point is that the handshape features are represented once in Prosodic Model, but once per segment in the Hold-Movement Model. The Prosodic Model representation allows handshape and place of articulation features to be represented only once, and then allowed to spread to all segements. Sandler (1986, 1987) first proposed the autosegmental representation for handshape; the autosegmental representation for place of articulation is a more recent innovation in Prosodic Model (Brentari 1998) and in the Dependency Phonology Model (van der Hulst 1993, 1995). Without the type of structure expressed in (31b), most forms considered to minimally different by native signers are not counted as such.

6. What Comprises a Modality-Independent Phonology?

Within the Prosodic Model, the menu of units available to signed and spoken languages is the same, but because of modality effects, the relative distribution of the units within the grammar is different. Based on the evidence in Sections 3-5, I conclude that modality is—at least in part—responsible for the phonological differences between signed and spoken languages. To be precise, these differences due to the advantage of the visual system to process more paradigmatic information more quickly and with greater accuracy. We have seen that the grammar has exploited these advantages in several ways. These structural differences warrant a different organization of the units within the representation in several cases.

Some properties of phonology that are common to signed and spoken languages are given in (32), and some that are different in (33).

(32) Phonological properties common to both sign and spoken languages

a. There is a part of structure that carries most of the paradigmatic contrasts—
Consonants in spoken languages; Handshape+Place (IFs)
in sign languages.

b. There is a part of structure that comprises the medium by which the signal is carried over long distances—Vowels in spoken languages; Movements in sign languages.

c. There is a calculation of complexity done at levels of the structure independent from the syntax—i.e., in prosodic structure.

d. One of the roles of the root node is to function as a liaison point between the phonology and the syntax, gathering all of the feature information together in a single unit.

(33) Phonological properties that differ between sign and spoken languages

a. The default relationship of root node-to-timing-slots is 1:2, not 1:1.

b. Timing units are predictable, rather than phonemic.

c. Cs and Vs are realized at the same time, rather than sequentially.

d. The phonology is sensitive to the number of movement components present.

e. The calculation of prosodic complexity in sign languages is more focused on paradigmatic structure than spoken languages.

What this chapter has shown is that all of the divergent properties in (33) are due to greater sensitivity to paradigmatic structure. This sensitivity can be traced to the advantage of the visual system for vertical processing. Certain structural re-arrangement and elaboration is necessary to represent sign languages efficiently, well beyond simply re-naming features. The common properties in (32) are not nearly as homogeneous in nature as the divergent ones, since they are not attributable to physiology; these are likely candidates for UG.

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Figure Captions

Figure 1. The handshape parameter used as an articulator in THINK (left), as a place of articulation in TOUCH (middle) and as a movement in UNDERSTAND (right).

Figure 2. ASL signs showing different timing patterns of handshape and path movement INFORM(left) shows the handshape and path movement in a cotemporal pattern. DESTROY (middle) shows the handshape change happening only during the second part of the bidirectional movement. BACKGROUND (right) shows a handshape change occuring during a transitional movement between two parts of a repeated movement.

Figure 3. Nominalization via reduplication: CLOSE WINDOW (left); WINDOW (right)

Figure 4. Nominalization via trilled movement affixation: READ(left); READING (right)

Figure 5. UNDERSTAND (simple movement sign (left)); ACCOMPLISH-EASILY (complex movement sign (right)).

Figure 6. Polymorphemic form with the following morphologogical structure (conservative estimate of 6 morphemes): "two (1); hunched-upright-beings (2); make-their-way-forward (3); facing-forward (4); carefully (5); side-by-side (6)"

Figure 7. Handshape used in AIRPLANE with a thumb specification (left); Handshape used in MOCK with no thumb specification (right).

fig. 1

fig. 2

fig.3

fig. 4

fig.5

fig. 6

fig. 7

[1]I am grateful to Arnold Davidson, Morris Halle, Michael Kenstowicz, Richard Meier, Mary Niepokuj, Cheryl Zoll, and two anonymous reviewers for their helpful discussion and comments on a previous version of this paper.

[2]Stokoe notation was never intended to be a phonological representation, but rather a notation system; however, this distinction between a notation system and a phonological representation is not always well-understood.

[3]For other overviews of sign language phonology, please see Coulter and Anderson (1993), Corina & Sandler (1993), Brentari (1995), and van der Hulst and Mills (1996).

[4]Perlmutter (1992) has independently arrived at the same conclusion.

[5]I am considering only forms from different morphological paradigms, so FLY and FLY-THERE would not be a minimal pair. Perlmutter (1992) refers to some signs as having geminate Positions, but the two Positions in such cases have different values, so they are not, strictly speaking, geminates.

[6]It is important to mention that in spoken languages, it is a misconception to see Cs and Vs as completely discrete, since spreading, co-articulatory effects, and transitions between Cs and Vs cause them to overlap considerably .

[7]The movements of both syllables are also produced in a restrained manner. I am referring here only to the nominalization use of reduplication. Complex movements can undergo reduplication in other contexts—e.g., in various temporal aspect forms.

[8]This definition of 'trilled movement' is based on Liddell (1990). Miller (1996) argues that the number of these movements is, at least in part, predicable due to the position of such movements in the prosodic structure.

[9]If a [trilled] movement feature does co-occur with a stem having a complex movement, it is predicted that the more proximal of the movement components will delete (e.g., LEARNING, BEGGING)

[10]The phonological explanation may be only one part of a full account of these phenomena. Fischer and Janis (1990) propose a syntactic explanation for the verb sandwich construction.

[11]Some models of sign language phonology (van der Hulst 1993, 1995) equate the root node and the segment. They are referred to as monosegmental models. In such models, all ordering or duration phenomena that involves more than one set of features, such as the phenomena discussed in this section, would need to be handled by a different mechanism.

[12]This point is also made in van der Hulst (2000).

[13]Space does not permit me to give more detailed set of arguments against these alternatives here.

[14]These are surface representations; for example, in English (25b) the /u/ in /dud/ is lengthened before a voiced coda consonant resulting in an output [du:d]. Also, in ASL (26b) DESTROY, the input form generates 4 segments due to the two straight path shapes located at the highest node of the PF tree; however, since the second and third segments are identical in bi-directional movements (indicated by the [repeat: 180^{o}] feature), one is deleted to satisfy the OCP (Brentari 1998, chapter 5).

[15]The number of morphemes present in this form is subject to debate. The handshape might be 1-2 morphemes, and the movement (with its beginning and ending points) may be 1-4 morphemes. Orientation of the hands towards each other, and in space, adds another 1-3 morphemes. Until a definitive analysis is achieved, I would say that the total number of morphemes for this form is minimally five and maximally nine.