ASL Movement Phonemes and Allophones

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1. Introduction

The phonological movements of signed languages can be analyzed as independent phonemic segments, in contradistinction to “non-movement” phonemes (comprised of hand configuration, location, contact, and so on). Research is under way whereby the concept of the phoneme is being applied to the movement portion of American Sign Language (ASL). Thus far, approximately two dozen movement phonemes have been identified, with ongoing analysis expected to further refine this number. These movement phonemes are articulated through their respective allophones, whose phonetic factors are predictable from adjacent “non-movement” segments (analogous to syllable onset and coda). This chapter shares background information on sign language movements, briefly explains two views of the phoneme, and describes a method for segmenting signs. This chapter then shows how to determine phonemic contrast and offers examples of ASL movement phonemes with their allophones.

Movement phonemes refer to a phonological target while movement allophones are the phonetic manners of achieving that target. The relationship between these two is captured through the phonemic statement (irrespective of theoretical processes involved: rules, constraints, etc.). The phonological movement segment (conceived as an abstract mental representation) refers to the “type” of movement, which involves finger, wrist, and arm (path, arc, circle, and pivot) movements, as well as referring to the “direction” of the movement, which is the final target of what moves (such as the fingers being extended and spread, the palm facing downward, or the forearm having a sagittal orientation). Allophonic movements express the physical manner of achieving the target, such as wrist supination or pivoting the forearm forward then downward.

As the claim of this project involves the phonemic status of sign language movements, background information is provided in section 2, beginning with an overview of the role of “movement” in sign language phonological theory (2.1), followed by a short discussion of the concept of the
phoneme (2.2). Section 3 describes the methodology used for determining segments (3.1) and movement phonemes (3.2) in ASL. Section 4 offers a variety of movement phonemes with their respective allophones and the conditions under which the allophones occur. Section 5 concludes the chapter, summarizing the conditioning factors for the movement allophones, mentioning unresolved issues, and showing possible future applications of this approach.

2. Background

Stokoe (1960) identified three dimensions of contrast in his groundbreaking work: location, handshape, and movement (using current terminology). He considered these to be sign language equivalents of phonemes, which showed phonological contrasts similar to the phonemes of spoken languages. The constructs of location, handshape, and movement have remained within phonological theory, although they are now considered “parameters” rather than “phonemes”. Other parameters have since been noted, such as focus or contacting region (Battison 1978, Klima and Bellugi 1979, Mandel 1981), point of contact (Liddell 1984), palm orientation (Frishberg 1975, Battison 1978), proximity (Mandel 1981), and selected fingers (Mandel 1981).

2.1 Sign language movements

The formal study of sign language movement begins with Stokoe’s (1960) original analysis of movement as the sign language equivalent of a phoneme. He identified 24 movements, which included gross arm movements, wrist movements, and finger movements, as well as various interactions between the two hands. In Stokoe’s analysis, all movement types were classified as “movement” and were distinct from and independent of location and handshape.

In the 1980’s, Liddell and Johnson (Liddell 1983, 1984, Johnson and Liddell 1984, and Liddell and Johnson 1989) introduced the division of signs into “Movements” and “Holds”, with their corresponding segment types, M and H. The M and H segments occur along a syntagmatic axis, meaning that they are sequentially ordered relative to each other. Each H segment associates with one feature bundle that indicates the physical posture of that portion of the sign. The M segment associates with two feature bundles, capturing the postures at the beginning and at the ending of the movement. Because these
beginning and ending postures of the movement are identical to the adjacent H segments, they are conflated, with the result that the M segment associates with the feature bundles of the preceding and following H segments. The movement is the articulation between these two feature bundles, being interpolated from the two H segments. Modifications or further characteristics of the movement, such as finger wiggling, speed, tension, and shape, are captured by features within the M segment itself. Such features distinguish, for example, a path from an arc, since the beginning and ending postures of these signs would be identical between them while the actual movement differs.

This Movement-Hold model is based on the generative concept of feature bundles, although it has an element of autosegmental phonology through the M segment associating to two H segments. As autosegmental phonology became more widespread, sign language movements were represented by feature geometries, as with Sandler (1989). With a feature geometry, the sign as a unit is represented through class nodes that are organized around the articulators used in sign language. Certain class nodes associate with segmental units along a skeletal tier (which captures the syntagmatic axis). In Sandler’s model, these skeletal tier units are labeled “L” for “location” and “M” for “movement”. The movement segment carries features that modify the movement, such as [tense], [restrained], and [arc]. Path movements in an LML sign begin at one location (the first L) and end at a different location (the second L). Hand configuration movements divide into handshape change and orientation change. Handshape change is captured through two different feature values associated with the Fingers node. Orientation change is captured through two different feature values associated with the Orientation node. In both of these cases, the difference between the two feature values for the class node indirectly represents the movement.

The next major shift in representing sign language movements came with Brentari’s (1998) Prosodic Model. While also using a feature geometry, this model gathers the movements under one class node, the Prosodic Features (PF) branch of the feature tree. This collection of the movements under one label alludes back to Stokoe, who classified the movements as a single group. In Brentari’s model, the articulator node (capturing handshape) and the place of articulation node (capturing location) are subsumed under the Inherent Features (IF) branch. Thus a division is made, via the structure of the geometry, between the movement and the non-movement portions of the sign. The PF branch captures different types of path movements, orientation changes, and finger movements. Paths and finger movements are represented indirectly by interpolation whereby the value of a location or setting feature
(for paths) or of an aperture feature (for finger movements) in the PF branch differs from the value of its corresponding node in the IF branch. Orientation changes are represented by features capturing dynamic movements in the PF branch ([supination], [pronation], etc.). The path and finger movement features, then, represent static postures while the orientation features refer to dynamic movement. Path movements associate with two timing slots (x-slots) on a timing tier (the syntagmatic axis), one for the beginning and one for the ending of the path, while finger and orientation movements each associate with a single timing slot. The movements are unified within a single branch of the feature tree while varying in how they are treated within that branch.

The current proposal continues to develop the notion of phonological movements. Conceptualization of movement began as a “phoneme” occurring simultaneously with other “phonemes” of the sign, then shifted to a segment type, M, occurring sequentially with H (Hold) segments. After this, various feature geometries viewed phonological movement as changes in the feature values of class nodes, not being a segment type at all. Over time, then, movement was regarded less and less as a phoneme or as a segment in its own right, instead becoming the result of a change in feature values with the consequent interpolated movement. One common thread, however, involves movement as a separate aspect of the sign. For Stokoe, it was a separate phoneme. In the Movement-Hold model, Hold segments associate with one feature bundle while Movement segments associate with two. In feature geometries, the non-moving aspects are represented by one feature value per class node while the movements are captured by two feature values per class node, with one of these models capturing movement in its own branch. In the model proposed here, the distinction between movements and the non-movement portions is maintained, as well as the concept of sequentially-ordered movement segments. However, in this model, movement is not interpolated. Rather, it has phonemic status as a distinct segment type. If represented by a feature geometry, the movements and the non-movement segments would have separate root nodes along the skeletal or timing tier, with each root node having its own feature tree. Thus, a sign with three segments would have three root nodes and three feature trees. The innovation presented in this proposal is that movement segments are discrete syntagmatic phonemes, phonologically independent from the non-movement segments. The movements are not dependent on non-movement parameters: If the non-movement information were removed from the phonological system, the movement system would remain.
2.2 Phonemes

Phonemic status was attributed to location, handshape, and movement by Stokoe (1960). This status was the result of applying the structuralist method of phonemics to the manual communication system that became known as ASL. The term “phoneme” (or Stokoe’s analogue, “chereme”) was subsequently replaced by the term “parameter” as the American structuralist view of the phoneme was being questioned, in conjunction with the rise of generative linguistics, which disregarded the notion of the phoneme.

Structuralism has had two main schools of thought: American structuralism and European structuralism. Between these two groups, the notion of the phoneme differed. A simple description of the difference is that the European structuralists considered the phoneme to be a mental concept while the American structuralists viewed it as a family of phonetic segments. The European view stemmed from Saussure’s “sound image” as a mental construct of segmented speech (Anderson 1985) while the American structuralists were influenced by the theory of behaviorism, whereby mental constructs were disregarded; however, some American structuralists, notably Kenneth Pike and Edward Sapir, retained the phoneme as a mental construct. The American view included the condition of “biuniqueness”, which claimed a one-to-one correspondence between the spoken segment and the phoneme. Biuniqueness was later shown to be flawed (Chomsky 1964), and this played a role in the subsequent disregard of the phoneme as a phonological construct. This disregard can be seen in the shift of the representation of sign language movement, as shown above (including the shift of the term “phoneme” to “parameter”).

Fundamental to the structure of language, according to the European view, was the concept of oppositions (Trubetzkoy 1933[1969], Baltaxe 1978). The phonetic difference between two opposing (that is, contrasting) segments was the articulatory element or mark that distinguished them from each other. For example, in English, “zeal” and “seal”, which signify different concepts, differ only in their first segment (thus showing these two segments to be phonemic). The phonetic difference between these two segments is voicing: [z] is marked with voicing while [s] is not. The mark was the distinguishing feature, later to take on the name “distinctive feature”. (Herein, too, lies the beginning of the theory of markedness.)

Within generative phonology, oppositions do not play a role in the linguistic system (Chomsky and Halle 1968: 298). The contrastive phoneme was replaced by the non-contrastive “underlying representation”, and allophones were replaced by “surface representations”. The notion of biunique-
ness, a problem for American structuralism, was thereby eliminated, yet so was the notion of contrast within the phonological system, although the notion of contrast had not been problematic.

Returning to signed languages, Stokoe’s approach followed American structuralist methods. Stokoe noticed that certain signs which contrasted in meaning showed only one articulatory difference, which meant that that aspect of the articulation was contrastive. If we eliminate structuralism as a valid or viable form of analysis, then we invalidate Stokoe’s analysis, along with his foundational contributions to sign language linguistics. This is not a small matter. However, by combining the view that languages are structured as systems with the view of the mental construct of the phoneme as a unit in opposition to other phonemes, we can arrive at a definition of the phoneme that acknowledges the framework used by Stokoe while excluding its downfalls (such as biuniqueness).

The definition of “phoneme” offered here is as follows: The phoneme is a phonologically contrastive syntagmatic segment. The phoneme is phonological by being a mental representation, as opposed to a phonetic or articulatory expression. It is contrastive in that it is not predictable within a particular linguistic system, being distinct from other phonemes within the system. It is syntagmatic, occurring in a sequentially-ordered relationship with respect to other phonemes. It is a segment or segment-sized unit that is smaller than a syllable and larger than a feature, able to associate with syllable positions and being comprised of features. The allophone is the phonetic expression of the phoneme, conditioned by specific environments.

How phonemes are represented phonologically (e.g., feature bundles, feature geometry, base input for a constraint-based system) is not addressed in this chapter. The point is that sign languages have phonemes, specifically movement phonemes, irrespective of specific theoretical internal organization. Whether these phonemes equate with the root nodes of a feature geometry or some other system of representation is independent of the matter of phonemic movement and non-movement syntagmatic segment-sized units existing in sign language. However, if one were to consider a feature geometry (Sagey 1986), then the root nodes would carry the phoneme labels, and the class nodes and tiers would be based on the dimensions of contrast, as indicated by the respective linguistic system, with the features carrying only contrastive information. With this view, the feature tree would not necessarily be based on articulators but on dimensions of contrast, which ultimately refer to phonetic differences, since contrast is determined in part by the phonetics.
3. Methodology

The determination of phonemes and allophones is based on the distribution (and behavior) of phonetic segments within the linguistic system. Before determining phonemes, then, phonetic segments must be ascertained. For spoken languages, phonetic segments are recognizable because many spoken languages have been analyzed and described, showing cross-linguistic patterns in the dimensions of contrast that occur (major class, voicing, place of articulation, and so on). Such is not the case, at the moment, for signed languages. The analysis must begin at a more fundamental level. The sign language segment must be established (Section 3.1); then these segments may be analyzed for their phonemic status (Section 3.2). (Section 3.3 describes the data set used for this project.)

3.1 Determining segments

In discussing segments and syllables for signed languages, Wilbur (1990: 89-90) states that “the absence of a mechanically applied segmentation procedure does not necessarily rule out the possibility that a careful linguistic analysis could reveal phonologically significant segmental units...” She argues that “despite the difficulty of arriving at a segmentation, it exists and is in common use for spoken languages. That it has not been adequately done for signed languages does not mean that it is impossible to do” (p. 90). The current project shows her to be correct by introducing a method for determining segments in signed languages.

At a very basic level, any phonetic change that occurs during an articulation (whether signed or spoken) may be considered a change between two phonetic segments. This, then, is a starting point. Further analysis will show how the segments fit into the linguistic system.

Applying this to sign language, the basic approach for segmenting signs is as follows. Any sign that involves contact at one point in the articulation and no contact at another point in the articulation must, by definition, be comprised of two phonetic segments. The change between contact and no-contact shows a segmental difference at the phonetic level. This establishes two phonetic segments for any such sign. If a sign begins with contact, does not have contact during its movement, then ends with contact, three segments are involved, based on the two changes in the status of “contact”.
With phonetic segments being defined by change, what happens with movements? Movements involve a continuous state of change. One might argue that the changes within a movement constitute a vast number of separate segments, thereby invalidating the definition of phonetic segments (since a movement would consist of uncountable segments) or invalidating movements as segments (due to their constant changing). The argument against this is that the changes are continuous, not discrete (as a process rather than a state). With an infinity of postures within the movement, it is not possible to measure each and every one of them. (No level of measurement can capture all the minutiae of changes that are involved; regardless of the number of decimal places measured, there is always one more decimal place available to measure.) Rather, movement segments must be viewed holistically. On a perceptual level, a “path” movement is one movement; if it changes direction (perhaps from moving forward to moving downward), this is identifiable and perceptible and constitutes a change, signifying a different phonetic segment. When a movement stops, the constancy of moving is broken, and the existence of a separate phonetic segment must be considered.

Some signs have finger movement that results in the distal portion of the thumb contacting the distal portion of one or more fingers of the same hand (e.g., ASL TURN-OFF-LIGHT). Two changes are involved here: (1) finger movement changes to the fingers being static and (2) no contact between the thumb and finger(s) changes to contact between them. These changes coincide with each other in terms of timing along the syntagmatic axis. Since the changes co-occur, two segments are established.

In a sign such as BODY, four segments may be identified, with one possible transitional movement: (1) movement of both hands back (or in) toward the upper torso; (2) contact of the two hands with the upper torso; transition; (3) movement of both hands back (or in) toward the lower torso; and (4) contact of the two hands with the lower torso. The changes involve (1) movement without contact to contact without movement, (2) contact without movement to movement without contact, and (3) movement without contact to contact without movement. These three changes indicate four phonetic segments.

Some signs have no contact. Segmental analysis of such signs involves identification of the presence or absence of a period of no movement (stasis), when the sign is held in the signing space, either at the beginning or at the ending of the movement. Frame-by-frame video analysis may be required for this. If, for example, a transitional movement places a sign at the beginning of the sign’s movement, at which point the handshape is clear rather than blurry, then the hand is no longer moving; it is a phonetic segment, the beginning of the sign. As the hand moves, it blurs. Such a sign, with the description just
given, has two segments: (1) the initial static portion and (2) the movement portion. A similar situation would exist if the movement ended with a clear frame, indicating a static segment at the end of the movement.

If there is no stasis either at the beginning or ending of the movement, then an initial non-movement segment is assumed because the hand configuration must be specified, and this is part of the non-movement system, not the movement system. A non-movement segment must be involved, and the hand configuration exists at the beginning of the sign, so the onset of the sign is the non-movement segment. Segmentation of such signs is based on the structure of the system rather than on phonetic changes.

The movement of some signs occurs more than once. In cases of reduplication, the reduplicated portion simply occurs twice (or more than twice if reduplication exceeds two), and the reduplicated segments occur twice. In cases of uncounted movements (termed “oscillation” by Liddell 1990 and “trilled movement” by Padden and Perlmutter 1987), a separate mechanism exists to account for this, introduced in Section 4.1. In some signs, the articulators move simultaneously in opposite directions (such as one hand movement downward while the other hand moves upward, 180° out of synchronization with each other). This occurs when the syllable onset is one-handed and the movement is two-handed, with other conditions applying. (See Hansen 2006 for further details.)

3.2 Determining phonemes

Once the segments are identified, they are analyzed for their contrastive status within the phonological system. Implicit in the writings of Trubetzkoy (1969 [1939]), Pike (1947), and Jakobson, Fant, and Halle (1955) is the notion that discrete phonetic segments “default” to separate phonemes unless their distributions indicate otherwise. It is this distribution that must be analyzed. If two adjacent segments are identified in a language, whether spoken or signed (and every language has at least two phonetic segments which occur adjacent to each other), then a distributional analysis may determine if they are instantiations of the same phoneme or of different phonemes. The more phonetically similar two segments are, the more likely (or “suspicious”) they are to be allophones of the same phoneme. In the absence of evidence for allophonic distribution (in other words, if they are not allophones of the same phoneme), they may be considered distinct phonemes for the language under analysis. (At times, due to lack of data, determination of phonemic status may be suspended, pending further analysis.)
One guideline for identifying phonemes, proposed by Trubetzkoy (1969 [1939]), states that two adjacent non-identical segments, occurring within the same morpheme, are not members of the same phoneme. That is, for spoken language, a phonetic articulation of (monomorphemic) \([dt]\) (which differ only in voicing) is not an instance of phonemic /dd/ or /tt/. The [d] and the [t] segments are instantiations of separate phonemes (perhaps /d/ and /t/, respectively). (With the phoneme being a phonological unit and the articulation being a phonetic unit, the phonetic unit is an instantiation of its respective phoneme.)

Trubetzkoy does not claim that \([dt]\) cannot be an instance of a single phoneme. In English, the phoneme /d/ occurs as phonetic [dt] (shortened in length) insofar as it is partially devoiced when word-final. The matter of affricates is also not addressed by his claim; whether two adjacent phonetic segments pattern as an affricate is determined by the distribution and behavior of the segments within the system.

In support of Trubetzkoy’s guideline, we have the following example. One could assume that the phoneme /d/ has two allophones, [d] and [t]. [t] occurs when it follows [d] in the same morpheme. The notation to capture this is /d/ → [t] / [d] ___. (Elsewhere, /d/ → [d].) What would be the motivation for this? On what phonetic segmental or prosodic grounds could this be established? Cross-linguistically, consonant clusters tend to share voicing, rather than diverge in voicing. Devoicing of a segment because it is in a consonant cluster is unmotivated. Being unmotivated, any such rule could be posited: /g/ → [j] / [g] ___; or /r/ → [m] / ___ [r]. It could never be shown that [gi] is an instantiation of /gg/ or that [mr] is an instantiation of /rr/ (although it could be disproven by the existence of phonetic [gg] or [rr], which would be perceived as lengthened [gː] or [rː]). If timing slots and autosegmental phonology are assumed, then the presumed existence of two adjacent identical phonemes would actually be one phonological segment associating with two timing slots; it would involve only one phoneme, not two adjacent identical phonemes. There seems to be no motivation for identical (monomorphemic) phonemes to differ phonetically as a result of simply being adjacent to each other. Trubetzkoy’s guideline is accepted.

Pike (1947) provides a method for determining the phonemic (contrastive) nature of segments, one that does not rely on minimal pairs. This method is based on the distribution of phonetic segments and whether or not this distribution is predictable. If two (or more) phonetic segments complement each other in their distributions (explained below), then they may be considered separate instances of the same phoneme, with their phonetic differences corresponding with some factor in the environments in which
they occur. One tenet of this approach is that allophonic changes are motivated by segmental or suprasegmental (prosodic) factors. Another tenet is that the segments in question are phonetically similar. A third tenet is that the motivating factor is reasonable. (For example, devoicing of a voiced onset based on the voicelessness of a coda consonant that is two syllables away is not considered reasonable.)

A comparison of the distributions of two segments begins with noting the phonetic similarities and differences between the two segments in question. The similarities provide support for suspecting that the segments may be allophones of the same phoneme. The differences provide the impetus for ascertaining whether their respective occurrences can be predicted. If a phonetic difference correlates with some factor in the environment of these segments, then the phonetic difference is predictable from that environmental factor. In this case, the difference is not contrastive (phonemic); instead, the segments are allophones of the same phoneme.

Environmental factors involve segmental elements such as (for spoken language) nasality, manner, voicing, vowel height, etc., and (for sign language) handedness (whether one or two hands are involved in the articulation of a segment), proximity to place of articulation, forearm and finger postures, finger vs. metacarpal contact, place of articulation, movement type and direction, etc. Environmental elements may also involve prosodic or suprasegmental factors, such as stress or syllable position (for both signed and spoken languages).

Once the similarities and differences between two particular segments are noted, two token signs are selected that contain these segments (with one sign token containing one of the segments in question and the other sign token containing the other segment), controlling for identical environments as much as possible. If the environments are identical (which includes position within the syllable), then the signs form a minimal pair because the only difference between the two signs is the segment in question; in this case, these segments are contrastive (phonemic). If the environments are analogous (virtually similar) but not identical, a hypothesis is made that the difference between the two segments in question corresponds to a difference in the environment, such that segment A only occurs in environment X while segment B never occurs in environment X. A search is then conducted for words (signs) in that language that refute the hypothesis.

While hypothesizing that segment A only occurs in environment X and B never occurs there, if a search of the language reveals that segment A also occurs in environment Y (and not just in environment X), or else that segment B occurs in environment X (such that segment A is not the only
segment occurring in environment X), then the distributions of segments A and B overlap with respect to environments X and Y, and the hypothesis is refuted. If this situation occurs for each difference in the environments of the segments in question, then these segments are phonemic, not predictable. On the other hand, if the hypothesis is supported, then they are allophones of the same phoneme; the phonetic articulations of the phoneme are predictable from the environments in which they occur. (Detailed steps for the phonemic method are available in Pike 1947 and Hansen 2006.)

An example of contrastive distribution is shown in Table 1, involving arm pivot movements. The top row lists the initial postures of the forearm; the left column lists the targets of the pivot movement (resulting in a lateral, sagittal, or vertical forearm). (Note that the postures and targets are categorical. Phonetically, actual signs may show slight characteristics of more than one category.) The table has been simplified for expository purposes. (Some examples also have a path movement.) Considering the environments where each pivot direction occurs, there is overlap in the distributions, with each pivot direction occurring with at least two initial forearm postures. This distribution shows that pivot movements contrast (at least in this environment); they cannot be conflated into a single phoneme with predictable allophonic articulations based on initial forearm posture.

Table 1. Contrastive distribution of pivot movements: Rows contain data in multiple cells; conflation of columns would result in a loss of information.

<table>
<thead>
<tr>
<th>Initial Posture</th>
<th>Lateral forearm</th>
<th>Sagittal forearm</th>
<th>Vertical forearm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lateral pivot</td>
<td>AMONG(^5)</td>
<td>CLOSE-DOOR(^6)</td>
<td>DAY(^7)</td>
</tr>
<tr>
<td>Sagittal pivot</td>
<td></td>
<td>TRAVEL(^8)</td>
<td>LEND(^9)</td>
</tr>
<tr>
<td>Vertical pivot</td>
<td></td>
<td>BORROW(^{10})</td>
<td>GOODBYE(^{11})</td>
</tr>
</tbody>
</table>

For complementary distribution, Table 2 shows data for the fingers that move during finger movement (left column), based on the selected fingers (SF) (top row). The thumb has been disregarded because it belongs to a different system. Focusing on the movement, in considering which fingers move, the rows can be conflated into a single row with no overlap of data. In this example, the columns can also be conflated with no data overlap (such is not always the case). The table shows that the fingers which move are the fingers which are selected. Finger movement that is based on the fingers which move is not contrastive. If two signs each have finger curving, for instance, with only the index finger moving in one sign while all four fingers
move in the other sign, then the difference in the fingers which move is not a relevant factor for finger curving movement because it is predictable from the selected fingers. (Selected finger information is part of the non-movement system. Evidence for this comes from signs in which there is no finger movement yet the finger posture carries information.)

Table 2. Complementary distribution for which fingers move: Only one cell per row contains data; the columns may be conflated with no data overlap.

<table>
<thead>
<tr>
<th>SF Movement</th>
<th>Index finger</th>
<th>Index &amp; Middle</th>
<th>Middle Finger</th>
<th>All four fingers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Index finger</td>
<td>ASK\textsuperscript{12}</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Index &amp; Middle</td>
<td></td>
<td>BOTH\textsuperscript{13}</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle finger</td>
<td></td>
<td></td>
<td>DOG\textsuperscript{14}</td>
<td></td>
</tr>
<tr>
<td>All four fingers</td>
<td></td>
<td></td>
<td></td>
<td>BETTER\textsuperscript{15}</td>
</tr>
</tbody>
</table>

Beyond the determination of phonemes and allophones, the dimensions along which the phonemes contrast (such as type of movement, direction of movement, handedness of movement, contact during movement, or place of articulation, proximity to a place of articulation, spreadedness of the fingers, etc.) are noted, and features to capture these contrasts are labeled.

3.3 Data

The data used for this project come from the book *Gallaudet Survival Guide to Signing* (Lane 1990). This book explains the articulations of 507 different ASL signs (nouns, verbs, adjectives, adverbs, negations, and prepositions) through verbal descriptions and line drawings. Since the signs were already selected and described, it was not necessary to create a word list, record a signer, download the files, and code them. The descriptions were entered into a Filemaker Pro\textsuperscript{16} database which was designed for this project.

Some drawbacks of this approach became apparent while coding the data. The verbal descriptions and line drawings did not always correspond with each other, and sometimes the verbal descriptions and line drawings were inadequate. If there was a question about a phonetic articulation, it was not possible to review a recording of the sign. If time and resources are available, live recordings are preferred; however, even with the problems encountered in coding signs from this book, a system for the movement portion became
apparent. Given that impoverished data is producing results, this shows the strength of the approach used in the present analysis.

4. Results

This section presents numerous ASL movement phonemes that have been determined, along with their allophonic variations and the conditions under which the allophones occur. These are presented as modified phonemic statements, taking liberties in the format to save space (combining Pike [1947] and Chomsky and Halle [1968] and introducing new notations).

The list offers token movement phonemes for the different movement types and directions, not presenting the full list of contrastive movements. Two aspects have yet to be considered in more detail. Contact during movement has not been analyzed for each particular movement type and direction. However, contact during movement as a whole has been shown to be contrastive (Hansen 2006). Where it affects the phonetic movements, it is included as part of the movement phoneme; otherwise, it is omitted. Also, handedness (as defined in Section 3.2 and below in this section) is contrastive overall but has not been analyzed for the individual movement types and directions. Where it affects the phonetic movements, it is included as part of the movement phoneme; otherwise, it is omitted.

The format for the phonemic statement used here begins with the phoneme in slashes: /phoneme/, stated in prose, in the absence of a phonetic notation system that represents sign language segments. Following the phoneme is the first (or only) allophone, listed in square brackets: [allophone], stated as a prose description of its phonetic articulation. A slash (“/”) introduces the environment in which the allophone occurs. Onsets and codas are explicitly labeled for clarity, with an equal sign (“=”) indicating the relevant values. The blank line (“___”) shows where the phoneme appears with respect to the environment. Examples (ASL glosses) are then provided. Multiple allophones per phoneme are each listed in this fashion.

For example, the first phonemic statement in (1) below can be read as follows. “/Pivot, Lateral, No contact, One-handed/” means that the phoneme is one-handed, moving as a pivot from the elbow in a lateral direction with no contact during the movement. (Although the phoneme label contains several words, it is only one phoneme.) “[pivot contra then down]” means that this allophone is expressed as a pivot from the elbow that begins with the hand moving contralaterally and then the hand shifts to a downward direction, with the movement source still being the elbow, as a single movement. “/ Onset =
Forearm vertical ___” signifies that this allophone occurs in the environment (introduced by the slash) where the onset of the sign has a vertical forearm (for the active articulator). “Example: MISS” indicates that the sign MISS has this environment and this allophone.

Some explanations are in order. Abbreviated forms are used: “contralaterally” is shortened to “contra”, “ipsilaterally” to “ipsi”, “upward” to “up”, “backward” to “back”, and “downward” to “down”. If a movement segment is “two-handed”, then both hands move, regardless of handshape. If a non-movement segment is two-handed, then the two hands share all specifications (including handshape), being identical and bilateral. If a sign has a (phonologically) one-handed onset and a two-handed movement, the movement direction refers to the dominant hand (the one in the onset); typically, these are the signs that show alternating movement. Gaps exist in the allophone sets due to gaps in the data.

The phonemic statements begin with a discussion of /lateral pivot/. A detailed explanation of the terminology is found in Hansen (2006). Ex post facto recordings of the signs mentioned below accompany this volume.

4.1 /Lateral Pivot/

The class of /lateral pivot/ movements involves arm movement originating from the elbow that targets a lateral forearm posture (horizontal forearm with hand and elbow pointing generally ipsilaterally-contralaterally). (This posture may show phonetic variation in its degree of lateralness, being somewhat sagittal or somewhat vertical.) A pivot is distinguishable from a path by the presence of a change in the categorical orientation of the base knuckles (metacarpals). (Short pivots and short paths can be indistinguishable from each other.)

The movement of the ASL sign DAY has the phonological description /lateral pivot/ (Hansen 2006). This /lateral pivot/ contrasts phonemically with other pivot directions: /compact pivot/, as in BORROW, and /extended pivot/, as in LOAN. /lateral pivot/ also contrasts phonemically with other lateral arm movements: /lateral arc/, as in WE; /lateral circle/, as in LIBRARY; and /lateral path/, as in FLOOR.

Phonetically, DAY moves as a [pivot contralaterally then downward], where “pivot” indicates the type of movement, “contralaterally” states the first cardinal direction of the pivot, and “downward” indicates the following cardinal direction. That is, the movement begins with the hand and forearm heading in a contralateral direction, with the forearm rotating from the
elbow, and then, as the hand and forearm get lower, they move downward; hence, “contralaterally then downward”. The environment that conditions this particular phonetic execution of /lateral pivot/ is the vertical posture of the forearm in the initial position of the sign, which is the syllable onset, with the pivot being the syllable nucleus.

This allophonic articulation differs from the phonetic articulation of the /lateral pivot/ of READY (the version that occurs horizontally). This movement occurs as a [pivot ipsilaterally then backward]. (The articulation would move the arms toward the back if it were articulated for a full 90°. A similar situation exists for very, below.) The conditioning environment for the phonetic expression of the /lateral pivot/ of READY is the sagittal forearm of the segment at the beginning of the sign, in the syllable onset. Regardless of the initial forearm posture (vertical in DAY or sagittal in READY), a /lateral pivot/ invokes movement that results in the forearm having a lateral orientation (categorically, with physiological variation in the degrees of “lateralness”). DAY and READY differ in their phonetic articulations yet share the same phonological specification: a pivot movement to a lateral forearm.

While DAY begins with a vertical forearm and READY with a sagittal forearm, what happens if the forearm is lateral in the onset segment? How can a forearm that is already lateral be involved in a /lateral pivot/? In this case, there is still a phonological specification to execute a pivot movement. With the initial (onset) posture and target (movement) posture being the same, the arm moves by pivoting in place: the forearm oscillates (in this instance, shaking back and forth on the horizontal plane). This lateral pivot oscillation is exemplified by the sign AMONG. (AMONG also has a path movement, which does not oscillate. AMONG has two movement types in the same syllable. This is being called a “movement diphthong”. Path movements are immune to oscillation in movement diphthongs, suggesting that they are underspecified phonologically, having default values.)

The signs DAY and VERY are each specified for a /lateral pivot/ and each begins with a vertical forearm, yet the phonetic directions of the pivots differ. In DAY, the arm executes a [pivot contralaterally then downward]; for VERY, it makes a [pivot ipsilaterally then downward]. (As with READY, the movement in VERY does not clearly articulate the second movement direction, which is “downward”, yet it would if the movement were articulated for a full 90°.) This difference (contralateral vs. ipsilateral) is due to the presence or absence of contact (or close proximity) between the dominant hand (H1) and the place of articulation in the initial segment. (If the elbow touches the back of the non-dominant hand in DAY, this contact is irrelevant since the elbow is not the hand; also, this contact does not seem to be required.) If the syllable onset
specifies proximity (including contact) between H1 and a place of articulation, then the /lateral pivot/ begins its movement ipsilaterally. Without this initial proximity, the /lateral pivot/ starts moving contralaterally. Three /lateral pivot/ phonemes are shown with their allophonic variations in (1) through (3).

(1) /Pivot, Lateral, No contact, One-handed/  
→ [pivot contra then down] / Onset = Forearm vertical ___  
Example: MISS (as well as DAY)  
→ [pivot ipsi then back] / Onset = Forearm sagittal ___ No coda content  
Example: THEY\textsuperscript{17,18}  
→ [pivot contra then back] / Onset = Forearm sagittal ___ Coda content  
Example: CLOSE-A-GATE  
→ [pivot back-forward oscillate] / Onset = Forearm lateral ___ No coda content  
Example: AMONG

(2) /Pivot, Lateral, No contact, Two-handed/  
→ [pivot ipsi then down] / Onset = Forearm vertical, Manner proximal ___  
Example: VERY  
→ [pivot contra then down] / Onset = Forearm vertical, Manner non-proximal ___  
Example: DARK  
→ [pivot ipsi then back] / Onset = Forearm sagittal, Manner proximal ___  
Example: READY  
→ [pivot contra then back] / Onset = Forearm sagittal, Manner non-proximal ___  
Example: WIND

(3) /Pivot, Lateral, Contact, One-handed/  
→ [pivot back-forward oscillate] / Onset = Forearm lateral, Manner proximal ___ No coda/second mora content  
Example: WASH  
→ [pivot up-down oscillate] / Onset = Forearm lateral, Manner non-proximal ___ No coda/second mora content  
Example: DISCUSS
4.2 /Fingers Compact Flat/

The phoneme /fingers compact flat/ involves finger movement that targets closure of the selected fingers while not involving thumb movement. The designation “compact” reflects the closure while “flat” indicates that the thumb does not move. The allophones differ only in which fingers move, which is predictable from the selected fingers in the non-movement segment. A phonemic statement is provided in (4). (The examples also exhibit arm movement, which would associate with the syllable nucleus as a movement diphthong. The phonemic status of this diphthong as a unit is not yet determined.)

(4) /Fingers Flat, Compact/ → [α fingers close, not thumb] / Onset = α SF ___
Examples: BECAUSE, BETTER, FAST, LEAVE, PREFER

4.3 /Fingers Extend Round/

The phoneme /fingers extend round/ involves finger movement that specifies finger extension. The “round” designation indicates that the selected fingers spread apart, and the thumb, if selected, moves in conjunction with the finger(s).

One allophone of /fingers extend round/ is articulated with [finger extension and spreading]. This entails simultaneous extension and spreading of the selected fingers, occurring when the fingers are not initially extended. A second allophone is articulated with [finger wiggling], as small rapid uncounted wiggling of the selected fingers, occurring when the onset has extended fingers. A phonemic statement is provided in (5).

(5) /Fingers Round, Extend/ (regardless of contact or handedness status)
   → [α fingers wiggle] / Onset = α SF, Finger height extended ___ No coda
      Examples: COLOR, DIRTY, FINGERSPELLING, FIRE, SALT, WAIT
   → [α fingers extend and spread] / Onset = α SF, Finger height non-extended ___
      Examples: BRIGHT, DON’T-LIKE, GROW, NOTHING, QUESTION (second syllable)
4.4  /Compact Rotation/

The phoneme /compact rotation/ involves “wrist” movement which targets a compact palm orientation. The “rotation” designation indicates that the forearm rotates, as opposed to the wrist bending (flexing). The term “compact” indicates that the rotation occurs in a supinating manner, resulting in the palm facing upward or backward, depending on the posture of the forearm. The allophones and conditioning environments are stated in (6).

(6)  /Rotation, Compact/

→  [wrist supination to palm back] / Onset = Forearm vertical, Palm non-compact ___  
    Examples: FAMILY, SEEM
→  [wrist supination to palm up] / Forearm non-vertical (either onset or coda)  
    Examples: ALL, BOOK, HIRE, HOW, OPEN, TIRED

4.5  /Extended Flexion/

The phoneme /extended flexion/ involves wrist movement that targets an extended palm, which faces either downward or forward, depending on the forearm posture. The “flexion” designation indicates that the movement involves bending the wrist, as opposed to forearm rotation.

One allophone of /extended flexion/ is articulated with [oscillating wrist bend palmar]. This entails bending or nodding of the wrist with uncounted repetitions. The “palmar” description indicates that the palm of the hand bends toward the palmar side of the forearm. (Conversely, “dorsal” refers to the back of the hand bending toward the dorsal side of the forearm.) This allophone occurs when the forearm is vertical in the syllable onset and the palm orientation is extended (in this case, facing forward). A second allophone of /extended flexion/ is articulated with [oscillating wrist bend radio-ulnar]. This entails bending the wrist in a motion that alternates between moving toward the radial and ulnar sides of the hand, a “side-to-side” flexion. This allophone occurs when the initial palm orientation is extended (forward with a vertical forearm or downward with a horizontal forearm) with palmar contact at the hand location during movement. These and other allophones are listed in (7) and (8).
(7) /Flexion, Extended, No Contact/
→ [oscillating wrist bend palmar] / Onset = Palm extended ___ No coda/second mora content
   Example: YES
→ [wrist bend palmar] / Onset = Palm extended, Forearm vertical; Second mora content
   Examples: ANSWER, CAN
→ [wrist bend dorsal] / Onset = Palm extended, Forearm sagittal ___ (Possible hold in coda)
   Example: SELL

(8) /Flexion, Extended, Contact, One handed/
→ [oscillating wrist bend radio-ulnar] / Onset = Palm extended, Contact ___ No second mora content
   Example: CHEESE

4.6 /Lateral Path/

The phoneme /lateral path/ involves straight (or basically straight) movement of the hand. The “lateral” designation indicates that the path movement occurs in a contralateral or ipsilateral direction, as opposed to forward/backward or upward/downward.

One allophone of /lateral path/ is articulated with an [ipsilateral path]. This entails a basically straight movement of the (dominant) articulating hand toward its ipsilateral side. Another allophone is executed with a [contralateral path], where the (dominant) hand moves toward its contralateral side. The conditioning environments for /lateral path/ allophones are show in (9) through (12).

(9) /Path, Lateral, No Contact, One handed/
→ [ipsi path] / Onset = Manner proximal ___
   Examples: BECAUSE, BETTER, CAT
→ [ipsi path] / Onset = Manner non-proximal, Forearm non-lateral ___
   Examples: FINGERSPELLING, YOU plurality, RIGHT direction
→ [contra path] / Onset = Manner non-proximal, Forearm lateral ___ Second mora content (diphthong)
   Examples: AMONG, CUT
→ [contra path] / ___ Coda = Manner proximal
Examples: HEAR, LAW, TICKET
→ [ipsi path] / ___ Coda = Manner non-proximal
Examples: AND

There is a problem with LEFT direction because the onset is non-proximal with the forearm vertical (non-lateral), so it is expected to move ipsilaterally yet it moves contralaterally. One possible phonological explanation for this is that LEFT might end with a hold in space, thus having a coda. The path movements in general invite further study.

(10) /Path, Lateral, No Contact, Two handed/
   → [ipsi path] / Onset = Manner proximal ___
      Examples: ARRANGE, FLOOR, MOVE, PRESIDENT
   → [contra path] / Onset = Manner non-proximal ___
      Examples: AFRAID, BRING, DO (first syllable), PARTY (first syllable)
   → [contra path] / ___ Coda = Manner proximal
      Examples: GAME, INTRODUCE, MEET

An apparent exception to (11) is if the movement occurs in the second syllable of the sign, in which case proximity in the coda results in an ipsilateral path, as in SCHEDULE, unless this second syllable begins with a proximal onset.

(11) /Path, Lateral, Contact, One handed/
   → [ipsi path] / Onset = Manner proximal ___
      Examples: BLACK, DOLLAR, DRY, WEEK
   → [contra path] / ___ Coda = Manner proximal
      Examples: FULL, NEW, PAPER

(12) /Path, Lateral, Contact, Two handed/
   → [ipsi-contra path oscillation] / Onset = Forearm lateral ___ No
coda/second mora content
      Examples: BABY (contact in onset), ELECTRIC (no contact in onset)
   → [ipsi path] / Onset = Elsewhere ___
      Example: LEAD verb
4.7 /Lateral Circle/

The phoneme /lateral circle/ involves hand movement that targets a circular side-to-side motion. The “lateral” designation indicates that the circle contains or includes motions toward the ipsilateral and contralateral sides, while also including motion upward-downward or forward-backward.

One allophone of /lateral circle/ is articulated with a [horizontal counterclockwise lateral circle]. This movement entails a generally circular motion of the hand that occurs basically on the horizontal plane, moving counterclockwise as viewed from above. Another allophone of /lateral circle/ is articulated with a [vertical counterclockwise lateral circle]. This differs from the horizontal allophone in that the circular motion of the hand occurs vertically rather than horizontally, counterclockwise as viewed from the signer. Circle phonemes, allophones, and conditioning environments are offered in (13) through (16).

(13) /Circle, Lateral, No Contact, One handed/
    → [vertical circle counterclockwise] / Onset = Forearm vertical ___
        Examples: FACE, MOUTH
    → [horizontal circle counterclockwise] / Onset = Forearm non-vertical ___
        Examples: ABOVE, COLLEGE, BELOW

(14) /Circle, Lateral, No Contact, Two handed/
    → [horizontal circle counterclockwise oscillation] / Onset = Forearm lateral ___ No coda/second mora content
        Example: TRAVEL-AROUND

(15) /Circle, Lateral, Contact, One handed/
    → [horizontal circle counterclockwise] / Onset = Forearm sagittal, Manner proximal ___
        Example: COFFEE
    → [vertical circle counterclockwise] / Onset = Forearm non-sagittal, Manner proximal ___
        Examples: PLEASE, SORRY, USE
(16) /Circle, Lateral, Contact, Two handed/
    → [horizontal circle counterclockwise] / Onset = Forearm non-lateral
       ____
       Examples: AMERICA, SUPERVISE
    → [vertical circle counterclockwise oscillation] / Onset = Forearm lateral ____ No coda/second mora content
       Example: ENJOY

4.8 Oscillation

If a phonemic movement, as the syllable nucleus, specifies the very posture that exists in the syllable onset, then there can be no movement to that posture. However, there is a phonological specification for movement. To resolve this dilemma of moving to a posture where the articulator is already located, the articulator oscillates in place. Oscillation is invoked when the movement phoneme in the nucleus and the non-movement phoneme in the onset share certain phonological feature specifications. For finger movements, the finger posture is relevant. For wrist movements, the palm orientation is relevant. For arm movements, the forearm posture is the relevant factor.

Oscillation is precluded when there is phonological content in the coda or else in the nucleus as a movement diphthong. In other words, content in the second mora precludes oscillation (unless the first mora involves a path movement). For instance, the sign AND begins with a lateral forearm, which shares [lateral] and [arm] feature values with the /lateral path/ movement. This should induce oscillation. However, the sign ends with the fingers contacting the thumb (“distal thumb contact”). This distal thumb contact is specified in the coda. The movement does not oscillate due to content in the coda. (Support for distal thumb contact as a non-movement segment rather than as phonological finger movement comes from signs that exhibit distal thumb contact throughout the sign without finger movement, such as BUY and PUT, as well as signs that begin but do not end with distal thumb contact, such as GROW and BRIGHT.) Movement of the fingers to the final distal thumb contact is a phonetic effect of transitioning to the coda. In AND, oscillation is precluded by the coda content, the distal thumb contact. In other words, oscillation is precluded by a second mora in the syllable, path movements notwithstanding. (Perhaps oscillation behaves as a type of “vowel lengthening”, indicating that ASL prefers bimoraic phonetic syllables.)
5. Summary and conclusion

This chapter has argued that sign languages have phonemic segments, some of which are movements and some of which are non-movements. In support of this claim, ASL movement phonemes were presented with their allophonic variations, which correspond to the phonetic environments in which they occur. These phonemes and allophones were determined through the phonemic methodology of Pike (1947).

The conditioning factors for the movement allophones are summarized as follows. Finger movements are conditioned by the finger posture in the syllable onset. The selected fingers determine which fingers move. Wrist movements are conditioned by the palm orientation in the onset, in conjunction with the posture of the forearm. Pivot and circle allophones are conditioned by the posture of the forearm in the onset; pivots may also be conditioned by the manner (proximal, non-proximal) of the onset and the presence or absence of content in the second mora. Path allophones are conditioned by the manner of the onset segment, at times in conjunction with the forearm posture, or, if there is no onset, then the manner of the coda segment. Oscillation occurs for any movement type when the onset and nucleus share feature specifications between the relevant articulator and movement type and between the articulator posture and the movement direction. Oscillation is precluded if the coda contains phonological content or if there is a movement diphthong not involving a path movement.

Overall, allophonic variations for the movements of ASL are predictable from factors in the initial non-movement position, which is the segment in the syllable onset; from content in the coda segment; and from content in the second mora of a movement diphthong. This supports discrete syntagmatic movement and non-movement segments, as well as internal syllable structure along a syntagmatic axis (such as a skeletal tier, timing tier, or CV tier).

Several unresolved issues remain. The interpretation of the directions of path movements might not be correct. With natural signing, it can be difficult to determine if a path movement, for instance, is categorically [ipsilateral] or [extended] due to the physiology of having the two hands in contact with each other. A new system is being considered whereby the strict use of cardinal planes and axes is eliminated. Another issue involves wrist movements, which were difficult to analyze due to insufficient wrist movement data. The phonemic status of the various movement diphthongs has yet to be determined. The phonemic status of the non-movement segments is currently in progress. After the non-movement phonemes have been determined, at least as a first pass, it will be necessary to reconsider the phonological move-
ments in light of this newly-acquired information. In this case, some of the phonemes and allophones presented herein may be adjusted, modified, or refined as new evidence becomes available. Finally, frame-by-frame analysis of recorded live signing would help to identify possible static non-contact syllable onsets and codas, which would improve the accuracy of the environments for the allophonic variations.

The success of this approach suggests potential applications and benefits. If the phonemes of sign languages can be identified, then writing systems for sign languages can be based on phonemes rather than phonetic articulations, removing unnecessary elements and simplifying the writing systems. Allophonic notations could also be introduced in phonetic notation format. With such systems in place, syntactic and morphological analyses could be carried out by accessing the written form. This segmental approach could assist in addressing research areas such as agreement, determiners, affixation, classifiers, verb aspect, and so on. Besides research, books and other types of literature could be written in local sign languages by the respective Deaf communities. Already conceived and under discussion with computer programmers is the possibility of computer-generated animated signing read from phonemically-based written signed text.

The approach used for this analysis requires explicit phonological representations for contrastive movements, separate from phonetic movement information and distinct from phonological non-movement information. As shown here, considering the phonological systems of sign languages to be comprised of discrete movement and non-movement segments is a viable approach. Successful application of linguistic theory to both signed and spoken languages, as offered here, provides insight into language in general and into the similarities between the two modalities. To the degree that the segmentation of signs and the phonemic method are successful with signed languages, the concepts and methodologies are universally applicable across modalities.
Notes

1. With much gratitude to anonymous reviewers for extremely helpful comments. Special thanks to Bob Moore and others (who desire anonymity) for help with video recording and text editing.

2. TURN-OFF-LIGHT: Forearm horizontal and elevated, all fingers and thumb extended and spread, palm facing downward; fingers and thumb bend at metacarpal joint; thumb contacts distal portion of (some) fingers.

3. BODY: Path movement of both hands toward upper torso; for each hand, palmar side of all four fingers, extended unspread, contacts its ipsilateral chest; hands move away from body; both hands approach lower torso; for each hand, palmar side of all four fingers, extended unspread, contacts its ipsilateral waist area.

4. Transitional movements between signs, while being phonetic movements, are neither phonological movements nor allophones of movement phonemes. Thus, they are not part of this discussion.

5. AMONG: arm oriented laterally (elbow pointing ipsilateral, hand pointing contralateral), index finger pointing downward, approximating the finger tips of other hand, with all fingers extended and spread, palm back; arm moves contralaterally in a path while shaking back and forth (on horizontal plane) from the elbow.

6. CLOSE-DOOR: arm oriented sagittally, four fingers extended together, palm contralateral; arm pivots contralaterally and backward; palmar side of hand and arm contact dorsal side of other hand and arm, which is laterally oriented.

7. DAY: vertical arm, distal end of curved middle finger contacts distal thumb of same hand, index extended, other fingers closed, palm contralateral; arm pivots contralaterally and downward; palmar side of hand and arm contact dorsal side of other hand and arm.

8. TRAVEL: sagittal arm, index & middle fingers curved and spread, other fingers closed, palm down; path movement forward while arm oscillates (from elbow) side to side (on horizontal plane).

9. LEND: both arms vertical, index & middle fingers extended & spread, ulnar dominant hand (metacarpus) contacts radial non-dominant hand (metacarpus); both hands pivot forward and downward while maintaining contact.

10. BORROW: both hands sagittal, index & middle fingers extended & spread on both hands, ulnar dominant hand (metacarpus) contacts radial non-dominant hand (metacarpus); both hands pivot upward and backward while maintaining contact.

11. GOODBYE: arm vertical, fingers & thumb extended & spread, palm forward; arm pivots repeatedly from side to side (contralateral-ipsilateral).
12. ASK: index extended, forearm vertical, palm forward, dorsal side of finger near mouth; arm pivots forward & downward while index finger curves.

13. BOTH: index & middle fingers extended & spread, forearm vertical, dorsal side of fingers contact palm of other hand (with fingers nearly closed); hand moves downward while fingers come together, remaining extended.

14. DOG: distal middle finger contacting distal thumb of same hand, index extended, other fingers closed, forearm sagittal, palm up; middle finger closes repeatedly, rubbing contact with thumb during movement.

15. BETTER: all four fingers extended unspread, palmar side of fingers contact mouth, forearm oriented laterally; hand moves ipsilaterally and all four fingers close.

16. FileMaker Pro 7 software funded by National Institutes of Health Institutional Training Grant #T32 DC000030-14.

17. Lateral arm movements tend to displace the beginning location of the sign.

18. The pronoun system might be analyzable according to non-movement forearm posture (onset or coda) in conjunction with movement type (path, pivot) and direction and final holds. This system would eliminate referents located in space.

19. A fourth-generation native Deaf signer has informed me that this version of LEFT$_{\text{DIRECTION}}$ is not typical ASL but is a “hearing” version. Rather than a path movement, this sign is articulated with an oscillating compact pivot.
References

Anderson, Stephen R.

Baltaxe, Christiane A. M.

Battison, Robbin M.

Brentari, Diane

Chomsky, Noam

Chomsky, Noam and Morris Halle

FileMaker Pro 7.

Frishberg, Nancy

Hansen, Kathryn L.
2006 Recombinant features for the movements of American Sign Language. Doctoral dissertation, Purdue University.

Jakobson, Roman, C. Gunnar M. Fant, and Morris Halle

Johnson, Robert E. and Scott K. Liddell
Klima, Edward S. and Ursula Bellugi

Lane, Leonard G.

Liddell, Scott K.


Liddell, Scott K. and Johnson, Robert E.

Mandel, Mark A.

Padden, Carol A. and David M. Perlmutter

Pike, Kenneth L.

Sagey, Elizabeth

Sandler, Wendy
Stokoe, William C.

Trubetzkoy, Nikolai S.

Wilbur, Ronnie B.