Sign Language Phonology

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Summary

Sign language phonology is the abstract grammatical component where primitive structural units are combined to create an infinite number of meaningful utterances. Although the notion of phonology is traditionally based on sound systems, phonology also includes the equivalent component of the grammar in sign languages, because it is tied to the grammatical *organization*, and not to particular content. This definition of phonology helps us see that the term covers all phenomena organized by constituents such as the syllable, the phonological word, and the higher-level prosodic units, as well as the structural primitives such as features, timing units, and autosegmental tiers, and it does not matter if the content is vocal or manual. Therefore, the units of sign language phonology and their phonotactics provide opportunities to observe the interaction between phonology and other components of the grammar in a different communication channel, or modality. This comparison allows us to better understand how the modality of a language influences its phonological system.

Keywords

phonology, phonetics, gesture, lexicon, morphology

1 Communication Modality

Sign language phonology broadens the range of structures under consideration for phonological theory, getting us ever closer to understanding phonology in its most complete range of cases. As phonology is the level of the language that directly interfaces with the articulators, anatomical differences in turn have the potential to influence the phonological structure of languages across modalities. It is apparent with respect to production because the articulators involved in speaking and signing are different; the articulators in speech are the lips, teeth, tongue, throat, and larynx, and the articulators in signing are the hands, arms, head, body, and face. Besides this obvious difference, there are fundamental differences between these sets of articulators. First, sign language articulators are larger than those of spoken languages, and this has an effect on the rate at which words or signs are produced (Bellugi & Fischer, 1972; Klima and Bellugi, 1979; Grosjean, 1977). Bellugi and Fischer (1972) found that the rate of speaking measured as words per second was twice as high as the rate of signing measured as signs per second, and they attributed this result to the size of the articulators, as the arms and hands are much larger and therefore require more effort to move than those involved in speaking. Despite the slower rate of signing compared to speech, however, Bellugi and Fischer found that the proposition rate was similar across signed and spoken languages. They attributed this result to the use of simultaneous organization in sign languages, concluding that both modalities are equally efficient at conveying information, but do so in different ways: speech is more likely to use sequentially ordered units, while sign languages are more likely to layer morphological units simultaneously. Second, under typical signing conditions, the source articulators are entirely visible, while in speech the acoustic signal is an indirect cue to the underlying articulation. In the source-filter model (Fant, 1960), the vocal apparatus generates the sound (source), which is then modified by the shape of the vocal tract (filter); this model has been effective for explaining how listeners encode and decode speech. The signal in sign language may have less of a role in phonological explanation than it does in speech, because the source articulators are visible; in other words, the spoken language is more prone to reanalysis due to acoustics to production decoding. Third, sign language can transmit multiple visual events simultaneously, and there are two hands and arms involved in articulation; in contrast, speech is transmitted through the single stream of an acoustic signal (Meier 2002, 2012).

With regard to perception, the difference between central and peripheral vision is important for feature distribution (e.g., unmarked vs. marked handshapes) and is also related to paired articulators (e.g., one-handed vs. two-handed forms). In sign languages, the addressee must look at the person signing to them, and signers focus their gaze on the face, neck, and upper torso, and it is in these areas that visual acuity is greatest (Siple, 1978). In ASL and BSL (see Battison, 1978; Eccarius & Brentari, 2007; Fenlon et al., 2014), marked handshapes (i.e., handshapes that are perceptually very difficult to identify) appear to be more frequent in areas where visual acuity is greatest. For example, in BSL, according to BSL Signbank at the time of writing, out of a possible 376 signs using a marked handshape, 286 (76%) of these are produced on the head and neck locations. In addition, when comparing the frequency of one- vs. two-handed forms, such as BROTHER and PAPER, in which both hands are the same (Figure 2), one might expect signs produced in areas in the central vision to be one-handed, since less information is required for a sign to be recognized. Indeed, in BSL, 81.7% (517/633) of signs produced centrally in the head and neck locations are one-handed (e.g., NAME, Figure 2), compared to 59.9% (169/282) of signs produced in the trunk and arm locations. The increased frequency of two-handed forms in areas overlapping with the peripheral vision may be explained with reference to sign recognition; there is more information available to the addressee to identify the sign in peripheral areas when it is two-handed and contains identical information than when it is one-handed. This observation, together with the distribution of marked and unmarked handshapes with respect to location, suggests that constraints on the distribution of features may have their origins in perception, as suggested by Siple (1978) and Battison (1978).

In addition, it has been noted in Brentari (2002) that humans can temporally resolve auditory stimuli when they are separated by an interval of only two milliseconds (Green, 1971; Kohlrausch et al., 1992), while the visual system is much slower and requires at least 20 milliseconds to resolve visual stimuli presented sequentially (Chase & Jenner, 1993). The advantage of temporal processing therefore goes to audition. In contrast, simultaneous processing benefits vision over audition. The effect of speed-of-light transmission on the perception of objects is that vision can take advantage of light waves reflected from the target object together with secondary reflection from other objects in the environment onto the target object (i.e., visual "echo" waves). The combination of the two, perceived simultaneously, enhances the three-dimensional quality of the target object (Bregman, 1990) and allows a three-dimensional image to be perceived quickly due to properties of the signal (the same echo phenomenon in audition is much slower).

Given these differences in production and perception across modalities, one might expect words in signed and spoken languages to exploit the advantages available to their respective systems.

2 Phonological Units in the Core Lexicon

Because of the modality differences between signed and spoken languages, we might expect to see differences between the two types of languages in the organization of phonological units. In this section, the distribution of features across the lexicon, in syllables, and in words is described. Because phonological distributions in both spoken and sign languages change based on the origins and morphological structure of words, it is useful to view the lexicon as multi-componential. A multi-componential model allows words or signs with different origins and morphological structure to have different phonotactics; Itô and Mester (1995a, 1995b) developed this type of model for spoken Japanese, and it has subsequently been applied to a number of different sign languages (Johnston & Schembri, 1999; Brentari & Padden, 2001; Cormier et al., 2012; see Figure 1). Specifically, the sign language lexicon is divided into the following components: the *core lexicon*, the *non-core lexicon* (both comprising the *native lexicon*), and the *non-native lexicon*. Much of the work on phonological theory concerning sign languages has been based on the core lexicon, where the sublexical elements are considered to be phonological—i.e., they can create contrast and be implicated in rules, and they may have no meaning in themselves. Signs from the non-core lexicon, sometimes called the spatial lexicon, are made up of elements that can be both morphological and phonological—i.e., polymorphemic classifier constructions or constructed action forms where the whole body functions as an articulator (Cormier et al., 2012). The non-native lexicon includes signs borrowed from other sign languages and signs that use letters of the manual alphabet, known as fingerspelling. Fingerspelled sequences represent a form of borrowing in which different configurations of the hand are each associated with a letter from the corresponding spoken language's alphabet in order to spell out a word. Importantly, in some cases signs from the non-core and the non-native lexicon show weaker adherence to the phonological constraints than the signs in the core lexicon (Aronoff et al., 2003; Eccarius & Brentari, 2007; Eccarius, 2008). These components can also have different handshape inventories. We refer to signs from other components of the lexicon in Section 3 when we consider the relationship between signs from the non-core lexicon and gesture, a prominent and current area of inquiry, and Section 4, which is about fingerspelling.

<COMP: INSERT FIGURE 1 NEAR HERE>

2.1 Features

It is widely acknowledged in the sign language literature that the manual parameters of handshape, place of articulation (POA, or location), movement, and orientation play a significant role at the phonological level in a similar way to the spoken language properties of place of articulation, manner, and voicing. Non-manual behaviors of the face and body are also part of the phonology (see e.g., Pfau & Quer, 2010), but here we focus on manual parameters. In the BSL sign DANGER, the parameters specified are the W hand for *handshape*, the ipsilateral side of the forehead for *place of articulation*, and a short repeated movement contacting the forehead for *movement*. The *Orientation*, which is interpreted here as the relationship between the active hand and the place of articulation, is the radial side of the hand (i.e., the part of the hand that contacts the place of articulation). Justification for the feature units within each parameter stems from their ability to show contrasts. For example, the BSL sign GAY differs from BSL UNSURE along the handshape dimension alone (BSL GAY has only an extended thumb with all fingers closed while BSL UNSURE has an extended thumb with all fingers extended). In Figure 2, pairs of contrasts along each parameter in BSL are provided.

<COMP: INSERT FIGURE 2 NEAR HERE>

Within the core lexicon, the parameters of handshape, location, movement, and orientation typically have no iconic motivation for the handshape in the signs PAPER or DANGER; these are arbitrary sub-lexical elements that are contrastive in BSL, and are important because they create minimal pairs and are implicated in phonological rules). Several phonological models have been proposed to account for a sign's underlying representation and the organization of these parameters (Liddell & Johnson, 1989; Sandler, 1989; van der Hulst, 1993; van der Kooij, 2002). To better illustrate the hierarchical structure of these features, an overview of the general organization of the sign according to the Prosodic Model is provided (see Figure 3).

<COMP: INSERT FIGURE 3 NEAR HERE>

The Prosodic Model follows Dependency Theory (Anderson & Ewen, 1987; van der Hulst, 1993) in that each node is maximally binary branching, and each branching structure has a head (which is more elaborate) and a dependent (which is less elaborate). A description will be provided of how the parameters of handshape, POA, movement, and orientation are grouped into the Inherent and Prosodic branches of structure within the Prosodic Model. These features all combine to form a lexeme at the root node, in contrast to spoken languages, where they would combine to form a segmental unit—a consonant or vowel.

2.1.1 Handshape, Location, and Orientation

A closer look at the Inherent Features structure within the Prosodic Model is provided in Figure 4. The Inherent Features structure branches into the parameters of handshape and place of articulation (location or POA); each will be discussed in turn.

These features are typically specified only once per lexeme, not once per segment or once per syllable as in spoken language. This is a fact that is—if not explicitly stated—implied in many models of sign language phonology. Parallels can be drawn with tone in tonal languages and features that harmonize across a lexeme (e.g., vowels), but it appears that fewer features are associated with the domain of the word in spoken languages than in signed languages; this is a fundamental difference between signed and spoken language phonology. Importantly, all sign languages that have been subject to serious inquiry have been noted to operate in this way; the extent to which tone and vowel harmony are attested cross-linguistically in spoken languages does not approach a similar scale by comparison.

Beginning at the topmost node, the handshape parameter is located within the Articulator branch of structure (Brentari, 1998; van der Hulst, 1993), which is first specified for whether the sign is produced by the arms and hands or by the body or face. The manual node then branches into the dominant (H1) and non-dominant (H2) hands. If the sign is two-handed, it will have both H1 and H2 features. If it is one-handed, it will only have H1 features. These features include which fingers are active (selected), how many are selected (quantity), and whether they are straight, bent, flat, or curved (joints). It is at the level of specific terminal features that the minimal units of contrast can be identified. For example, BSL GAY and BSL UNSURE in Figure 2 differ according to features of selected fingers: GAY is specified only for the thumb (i.e., no finger features), while UNSURE is specified for the thumb and (all) fingers at the quantity node.

As with handshape, POA is represented within the Inherent Features structure. Beginning at the top, the POA branch is divided into three-dimensional planes: horizontal (y-plane), vertical (x- plane), and mid-sagittal (z-plane). Signs occurring along the vertical plane may also be specified for one of the major locations on the body: the head, the torso, the arm, or the non-dominant hand. Within each of the eight major locations, eight further POA values are specified. The POA in signed and spoken languages is the passive articulator (van der Hulst, 1993). Its organization reflects the generalization that there are four major body regions (the body, the head, the torso, and the arm) and that each region has eight place distinctions. For example, the eight POA values for the head which are thought to be contrastive in ASL are: top of the head, forehead, eye, cheek/nose, upper lip, mouth, chin, and under the chin. The model describes eight distinctions in each of the major locations, but the values may well be language-specific, differing from sign language to sign language.

Orientation is traditionally regarded as a minor parameter, since there are fewer minimal pairs based on orientation alone (Brentari, 2012). Earlier descriptions of orientation (e.g., Stokoe et al., 1965; Battison, 1978) were often based on the direction of the palm and the fingertips (e.g., in BSL UNSURE, the palm is facing leftwards and the fingertips are facing forwards). Brentari (1998) and Crasborn and van der Kooij (1997) treat orientation as a relationship between an active handpart and the POA. From this perspective, the orientation in BSL UNSURE would be expressed as the relation between the ulnar side of the dominant hand (i.e., handpart) toward the palm of the non-dominant hand (i.e., the POA).

<COMP: INSERT FIGURE 4 NEAR HERE>

2.1.2 Movement

Returning to Figure 3, one can see that the root lexeme branches into both Inherent Features and Prosodic Features. Figure 5 provides a detailed representation of the organization of the Prosodic Features tree, which includes the features of movement. Movements are, by their very nature, the dynamic elements of signs, and thus their values change throughout the sign—e.g., [open] > [closed] aperture features; [ipsilateral] > [contralateral] setting features. These dynamic elements contrast with the features of Handshape and POA within the Inherent Features branch; according to the phonotactics of ASL and BSL, the fingers and POA do not change within a monomorphemic sign, while the aperture and setting features are allowed to change (Mandel, 1981; Sandler, 1989; Brentari, 1990).

<COMP: INSERT FIGURE 5 NEAR HERE>

Movements are dynamic acts with a trajectory, a beginning, and an end; their phonological representation will vary depending on the body part used to articulate the movement (see Figure 6 for examples from ASL). The hierarchy of movement class nodes starts at the top with the more proximal joints (e.g., the shoulder) because they typically articulate larger movements, and the more distal joints (e.g., the fingers) at the bottom because they typically articulate smaller movements. In Brentari (1998), it was argued that the larger the movement, the higher the sonority (see Section 2.2), due to increased effort and higher visual salience. In some signs, it is also possible to have two simultaneous types of movements articulated together. The movement change in ASL UNDERSTAND is a change in aperture. The movement change in ASL HAPPEN is a change in orientation articulated by the radial-ulnar (forearm) joint. The elbow articulates a path movement in ASL SEE, and the shoulder articulates a setting movement in ASL WE. ASL THROW has both a path movement and an aperture change.

<COMP: INSERT FIGURE 6 NEAR HERE>

While much has been made of the simultaneous nature of sign languages, it is uncontroversial that signs are comprised of sequential elements. This sequentiality is represented through timing slots projected within the prosodic structure (shown as X-slots in Figure 5). Path features, such as [direction] in SEE generate two timing slots; all other features generate one timing slot, such as [−open] and [open] in UNDERSTAND. Inherent Features do not generate timing slots at all; only movement features do this within the Prosodic Model. When two movement components are articulated simultaneously, as in ASL THROW, they align with one another, and only two timing slots are projected onto the timing tier (see ASL THROW in Figure 6). Timing slots typically do not create minimal pairs (i.e., duration is not contrastive in sign languages) but can play an important role in morphological operations; e.g., when some signs are modified for intensity in both ASL and BSL, the first segment is lengthened—e.g., the initial segment of the ASL UNDERSTAND in Figure 6 can be copied, creating a geminate initial hold word initially (i.e., X > XX/ #__), obtaining a more intense meaning—“totally understand!” or “got it!”

2.2 The Syllable and the Phonological Word

Section 1 demonstrated how modality forms the basis of the content and organization of phonological features. This section examines how modality affects the way signs are grouped into a constituent of higher prosodic structures, such as syllable and prosodic word (see also Sandler & Lillo-Martin, 2006 and Sandler, 2012 for a discussion of the prosodic system).

The movement features already described play an important role in the sign language syllable, with movement being described as analogous to vowels. Parallels between the two can be seen when one considers that vowels and movements are perceptually the most salient feature within a word or a sign and that movement is what makes signs visible, just as vowels make words audible. In fact, researchers have proposed that larger, more visually salient movements are more sonorous than smaller, less visually salient movements. For example, wiggling the fingers is less sonorant than twisting of the radial/ulnar joint (forearm), which is less sonorous than a path movement (Sandler, 1993; Corina, 1992; Brentari, 1993; Perlmutter, 1992). The criteria for counting syllables in sign languages are outlined in Figure 7.

<COMP: INSERT FIGURE 7 NEAR HERE>

Several arguments can be made to demonstrate that movement plays a central organizing role at the phonological level, forming a unit similar to the syllable nucleus in spoken languages. First, single fingerspelled letters (located in the non-native lexicon in Figure 1) and number signs produced in isolation have been observed to add an epenthetic movement in some sign languages when used as an independent word (Brentari, 1990; Jantunen, 2007; Geraci, 2009). Brentari (1990) suggests that, as in spoken languages, where an operation of vowel epenthesis ensures syllable well-formedness, movement is inserted where necessary to ensure that the signed output is a well-formed syllable. Second, the repetition of movement appears as a rhythmic sequential unit produced by deaf infants at a similar milestone to vocal babbling observed in hearing children (Pettito & Marentette, 1991). Third, morphological modifications to signs are often permitted on the basis of their movement properties, phenomena that are associated with sonority and syllable weight. In spoken and signed languages, there is a positive correlation of energy output with sonority and syllable weight (Gordon, 2006, Gordon et al., 2008). Sonority and syllable weight are typically calculated sequentially in spoken languages—from one segment to the next for sonority, and the concatenation of morae for syllable weight. In sign languages, they are typically calculated across the simultaneous components of movement (Brentari, 1998). For example, some ASL signs are permitted to undergo modifications resulting in derived nominal forms, but only if they contain one movement element. The single path movement in SIT can be repeated to derive the nominal form such as CHAIR, but reduplication is prohibited in THROW, which contains both a path and aperture movement, as shown in Figure 4. These data can be explained if forms with one movement are treated as light syllables and those with two or more are treated as heavy, and suggests that sign syllables do not have the same internal structure as spoken language syllables.

It has been proposed that the organization of a syllable in speech stems from the opening and closing movement of the jaw, which acts as an oscillator in speech (MacNeilage, 2008;

MacNeilage & Davis, 1993). When one looks at sign languages, it is apparent that there is not a single oscillator linked to articulation. Signs can be produced by different joints of the arms and hands, as shown by the signs in Figure 6. On this basis, Meier (2012, 2012) concludes that the syllable in sign language is physically distinct from the syllable in spoken languages, since it clearly has a more varied articulatory basis.

Moving on to the phonological word, signs in many languages tend to be monosyllabic—that is, they tend to have a single sequential movement, such as the signs in Figure 6. In Stokoe et al. (1965), 83% of the lexical entries are composed of a single sequential movement using the syllable counting criteria in Figure 7. Evidence for this tendency towards monosyllabicity can also be seen in compounds, for example, THINK^SELF as shown in Figure 8, where the movements of the two signs making up the compound are not present in the compound. Only the single movement between the two signs is retained, which results in a monosyllabic form for the compound. Fingerspelled sequences that move from the non-native lexicon to the core lexicon over time (discussed in Section 4) are also modified towards monosyllabicity when possible. It is important to note, however, that 17% of the items in the Stokoe et al. (1965) dictionary are not monosyllabic; this provides evidence for the separate units of syllable and phonological word in the language. This one-to-one correspondence between meaning and phonological unit (i.e., syllable) represents a substantial difference between sign languages and spoken languages, especially when one considers that many monosyllabic words can be polymorphemic.

<COMP: INSERT FIGURE 8 NEAR HERE>

Also in phonological words, there is a tendency for some features within the parameters of handshape and POA to be specified once per lexeme. For handshape, this generalization is captured by the *Selected Fingers Constraint* (Mandel, 1981; Brentari, 1998), also known as the *Handshape Sequence Constraint* (Sandler, 1989; Sandler & Lillo-Martin, 2006), which specifies that a sign only has one set of selected fingers. For example, ASL THROW (Figure 6), despite having a handshape change, has the same number of selected (or extended) fingers at the beginning and end of its articulation. This constraint may be violated in compounds, but as they become more lexicalized they sometimes conform to this handshape constraint.

3 Phonology and Iconicity in the Non-Core Lexicon

In sign languages, classifier constructions are polycomponential and highly iconic, and they occupy the non-core native lexicon (see Figure 1). They are also very important in teasing apart the relationship between sign language and gesture (Emmorey, 2003; Liddell, 2003; Supalla, 2003; Schembri, 2003; Zwitserlood, 2012). When the field of sign language linguistics began as an area of serious inquiry in the 1960s, the focus was on making sure that sign languages were credited as linguistic systems, and as a result the formal, hierarchical properties of these systems received more attention in the literature than their iconic aspects (see Goldin-Meadow & Brentari, in press. It was not until the 1990s that researchers began to seriously reconsider the relationship between sign language and gesture (Emmorey, 1999; Liddell, 2003; Liddell, 1990; Brennan, 1992).

Given this interest in the question of the relationship between language and gesture, there have been several studies analyzing classifier constructions produced by deaf signers and classifier-like constructions produced by gesturers (without voice) and comparing them with the productions of signers who have a set of classifier handshapes in their sign language. Two types of handshapes that figure prominently in these studies are those that represent objects, either partially or wholly (entity or object classifiers), or how objects are handled (handling classifiers); both are shown in Figure 9.

<COMP: INSERT FIGURE 9 NEAR HERE>

From the point of view of function, entity and handling constructions classifier constructions in sign languages have much in common with “observer” and “character” viewpoint gestures respectively (Cormier et al., 2012). Observer viewpoint gestures that accompany discourse in the role of narrator typically appear similar to whole entity classifiers (object handshapes), while character viewpoint gestures that accompany discourse in the role of a character in the narrative assume handling classifier handshapes.

This similarity between silent gesture and sign language in form and function raises an interesting question from a phonological perspective regarding the extent to which constructions within this component demonstrate evidence of phonological patterning not seen in gesture. Goldin-Meadow et al. (1996) compared ASL signers with American English gesturers (without speech), and Schembri et al. (2005) compared Taiwanese and Auslan signers with Australian gesturers (without speech) while describing the same set events of concerning the motion and location of objects. These studies showed fewer differences between signers’ and gesturers’ use of movement and space (location), and more differences in the use of handshape. Brentari et al (2012, in press) compared the productions of silent gesturers and signers in several countries, including Italy, the United States, China, and Nicaragua, using a task similar to those of Goldin-Meadow et al. (1996) and Schembri et al. (2005), and found that the features used in silent gesture and sign languages differ as well. Signers show more complexity in finger selection, particularly in object handshapes, while gesturers demonstrate more complexity in joint features. These studies show the differences between sign languages systems and silent gesture in handshape.

The results from such experimental studies allow several conclusions to be drawn regarding the nature of entity and handling classifiers and their relationship with gesture. Schembri et al. (2005) suggest that classifier constructions are blends of a linguistically specified handshape along with gestural elements of location and possibly movement, thus providing evidence for the analysis of these constructions as both language and gesture. Additionally, regarding handling constructions at least, both gesturers and signers can perceive some handshapes categorically, but gesturers retain their ability to encode some handshapes in a continuous fashion (Sevcikova, 2013), while signers lose this ability. Brentari et al. (2012) and Brentari et al. (in press) take this further to indicate that these iconic forms undergo phonologization to better fit into the overall phonological system—pruning some features (joint features in handling handshapes) and elaborating in others (finger features in object handshapes) in order to better conform to the phonotactics of the phonology as a whole.

4 Fingerspelling: Phonology in the Non-Native Lexicon

The non-native lexicon (see Figure 1) includes forms borrowed from other sign languages and forms that include at least one letter of the manual alphabet via fingerspelling. This section focuses on fingerspelling, which at first glance seems easy to describe: There are a limited number of 26 units (Figure 10 for ASL; Figure 11 for BSL), and these are strung together sequentially, one unit after another. Note that the 26 letters of the English script are represented in one-handed forms in ASL and in two-handed forms in BSL and the related languages Australian Sign Language (Auslan) and New Zealand Sign Language (NZSL).[1]

<COMP: INSERT FIGURES 10 AND 11 NEAR HERE>

Since fingerspelling in ASL and BSL is a representation of English orthography, fingerspelling is often thought to be solely a language-contact phenomenon. It can also provide a window into the structure of signs more broadly. The letters are not merely beads on a string. Even though the two sign languages express the letters of the English alphabet in one- vs. two-handed systems, in both ASL and BSL the individual units are influenced by the precise timing and configurations of adjacent forms in systematic ways. The most widely held view of how fingerspelling functions is captured by the Dynamic model (Wilcox, 1992), where fingerspelling is composed of not only postures (or holds), which are the typical handshapes (and orientations) that are seen on fingerspelling charts (e.g., Figure 9), but also of transitions between the postures. The coordination of the holds and the transitions is regulated at least in part by the signer's biomechanical system of articulator coordination, in a fashion that has been used to describe spoken language production in models such as Articulatory Phonology (Browman & Goldstein, 1992). These claims have been made specifically for one-handed fingerspelling systems. Two-handed systems appear to be coordinated in similar ways (Cormier et al., 2008)

Here only two phenomena associated with fingerspelled forms that are relevant for[1] word-level phonotactics are addressed. Several researchers have proposed that as fingerspelled words are nativized into the ASL lexicon as loanwords, they are restructured according to the phonotactics of the core lexicon (Battison, 1978; Akamatsu, 1985). Brentari and Padden (2001) propose how this is done for ASL, and Cormier et al. (2008) have proposed similar strategies for BSL and related languages, which involve reducing the number of movements towards monosyllabicity, and to retain and in some cases even enhance the most visually salient movements features as represented in Figure 5. The partially nativized forms for #CLUB (BSL) and #SURE (ASL) are shown in Figure 12. The -U- unit has been deleted from both forms, and others have been enhanced or deleted.

<COMP: INSERT FIGURE 12 NEAR HERE>

Coarticulation and variation are also quite widespread in fingerspelling. Fingerspelled letters may have several variants, based on factors such as the letters on either side. A form from the manual alphabet that has pinky finger extension, such as -I-, -Y-, or -J-, can influence adjacent target letters bidirectionally, so that a form such as B-U-I-L-D could have pinky extension on the -U- or -L- , preceding or following the -I- (e.g., coarticulation to the -L- would change **C** > **h** / P___).The variants triggered by adjacent contexts can be viewed as coarticulation (Keane, 2014; Keane & Brentari, 2016), and analyzing the linguistic contexts can shed light on variation in these forms. Dissimilation occurs as well; for example, there are two variants of the letter -E- in ASL fingerspelling, a closed and an open variant (Figure 13). Prescriptively the closed -E- has been thought to be the citation form, but variation is systematic: there are more closed -E-s at word edges (that is, the more canonical variant is preserved in highly prominent positions), and there are more open -E-s when they immediately precede handshapes that are completely closed, such as the sequence E-S. The open -E- serves to enhance the movement between the -E- and the following letter through dissimilation, thereby increasing the visual salience of this change in aperture.

<COMP: INSERT FIGURE 13 NEAR HERE>

Coarticulation also occurs in two-handed fingerspelling. The letter -B- in BSL, Auslan, and NZSL has two variants: one as shown in Figure 11 where both hands have the O-handshape A, and another (not shown) where both hands have the F-handshape O. Cresdee and Johnston (2014) studied these two variants in Auslan to test a (perhaps prescriptive) claim made by Auslan teachers that the F-hand variant is preferred by deaf signers and that the O-hand variant is incorrect. Out of 453 tokens of the fingerspelled letter -B- in the Auslan Corpus (deaf signers), Cresdee and Johnston found that the F-hand variant only accounted for 3% of their tokens, while the most common variant (in 74% of cases) was actually a combination of the O- and F-hand variants where one hand had the F-handshape O and the other hand a thumb and index finger variant of -O- M. This was likely due to coarticulation, because the index finger and thumb of the -F- of the dominant hand triggered assimilation on the nondominant hand; that is, the selected fingers are the same in both handshape, and it is only the nonselected fingers that differ in their open or closed positions.

5 Redefining the Range of Phonological Systems

Sign language phonology complements and expands our understanding of phonology, which has been largely based on spoken languages. The work concerns sign language and gesture, which is becoming increasingly important in understanding human language. Spoken languages clearly include both speech and the gestures that accompany them as co-speech gesture. Numerous researchers have made this claim in psychology, most notably Goldin-Meadow (2003) and McNeill (1992), and they have described many ways in which gestures contribute to the meaning of our utterances. For example, Krahmer and Swerts (2007) have opened up a field of inquiry describing ways that beat gestures, which co-occur with the prominent syllable of a phonological phrase, can influence how we perceive the *vocal* prominence of the prominent syllable. Assuming this body of work continues to gain support, analyses of spoken languages, particularly spoken language prosody, will routinely include properties of the face and body and will be bi-modal. The insights from work on sign languages where the body is a site for phonological operations such as the syllable will potentially be of great use in that work. The sign language syllable, in particular, offers tools for how to think about the componentiality of gesture in this new area of inquiry that couples gesture with speech in considering the totality of spoken language.

The study of sign language phonology also broadens the range of extant phonological systems. In the attempt to construct theories that can handle both, Hale and Reiss (2008) have gone so far as to propose that the work of describing "substance-free" phonology is the primary task of phonologists. Although that goal is distant, there is optimistim. As Stephen Anderson (1989:803) wrote, "[Phonology] is a domain of human cognition where we probably know more in detail about the specific principles operative within a particular cognitive subsystem than anywhere else, and about the specific representations that play a part in such knowledge." Sign languages are much more than a couple of extra data points on the landscape of possible phonological systems, or a new, quirky set of facts that stretch current theory. They are a set of languages with long histories which have generated solutions to building efficient and effective phonological systems with some materials that are the same as those of speech (i.e., the same mind or brain) and some different ones (i.e., the articulators). It is the resilient creativity in response to our human need to communicate that gave rise to the range of phonological structures in sign languages. Working on how signed and spoken languages can genuinely be handled by the same phonological tools brings ever closer the goal of understanding phonology in its most complete range of cases.

Further Reading

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

This text delivers a good basic overview of the subject area as well as a description of phonological processes observed in fingerspelled loan signs.

Brentari, D. (1998). *A prosodic model of sign language phonology*. Cambridge, MA: MIT Press.

This text provides a detailed description of the Prosodic Model, which is used throughout this article, as well as background on sign language phonology.

Brentari, D., & Padden, C. (2001). Native and foreign vocabulary in American Sign Language: A lexicon with multiple origins. In D. Brentari (Ed.), *Foreign vocabulary in sign languages* (pp. 87-119). Mahwah, NJ: Lawrence Erlbaum Associates.

This text gives a more in-depth description of the differences in the phonology of the lexical components discussed here.

Liddell, S. K., & Johnson, R. E. (1989). American Sign Language: The phonological base. *Sign Language Studies, 64*, 195–278.

This paper introduces the Hold-Movement model, the first model to employ features and segments in sign languages. ~~Section 3.1~~.

Pettito, L., & Marentette, P. (1991). Babbling in the manual mode: Evidence for the ontogeny of language. *Science, 25*, 1493–1496.

This is the first study arguing for the syllable in infants.

Sandler, W., & Lillo-Martin, D. (2006). *Sign language and linguistic universals*. Cambridge: Cambridge University Press.

This text provides a detailed description of the Hand Tier Model as well as additional background on sign language phonology.

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Stokoe, W. (1960). *Sign language structure: An outline of the visual communication system of the American Deaf*. Studies in Linguistics Occasional Paper 8. Buffalo, NY: University of Buffalo.

This is the first text that argues for a meaningless, sub-lexical level of structure in a sign language.

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Figure 1: Sign language lexicon (adapted from Brentari and Padden, 2001).

Figure 2: Sign pairs with handshape, location movement and orientation contrasts in BSL.

Figure 3: Overview of the Prosodic Model.

Figure 4: Inherent Features Structure with representations for the minimal pair GAY and UNSURE in BSL (cf. Brentari, 1998). Both signs have the thumb selected, but UNSURE also includes the feature [all].

Figure 5: Prosodic Features representation within the Prosodic Model (cf. Brentari 1998). The dominance of the class nodes in the PF branch of the feature tree is based on their degree of visual saliency (sonority).

Figure 6: Different types of movement in ASL as represented within the Prosodic Model. (Reprinted with permission by Mouton de Gruyter, from Brentari, 2012, Figure 3.3.)

Figure 7: Syllable Counting Criteria (Brentari, 1998).

Syllable Counting Criteria: The number of syllables in a sequence of signs equals	
a.	When several shorter (e.g., secondary) movements co-occur with a single (e.g., path) movement of longer duration, the longer movement is the one to

b.	When two or more movements occur at exactly the same time, it counts as one syllable, e.g., ASL THROW is one syllable containing an aperture change and

Figure 8. The compound THINK^SELF (“decide for oneself,” right), made up of the sign THINK (left) and SELF (middle). The movements of THINK and SELF are not present in the compound, which consists of a single movement between the two original signs. (Printed with permission from MIT Press, from Brentari, 1998, Figure 3.2.)

Figure 9: Entity construction and handling construction (pictures from Cormier et al., 2012).

Figure 10. The ASL manual alphabet.

Figure 11. The BSL manual alphabet.

Figure 12. Partially lexicalized forms in BSL #CLUB and ASL #SURE. (Reprinted with permission from John Benjamins Publishing Company, Amsterdam/Philadelphia, in Cormier et al., 2008 [www.benjamins.com].)

Figure 13. Closed -E- (left) and open -E- (right).

[1] There is a single one-handed form in BSL fingerspelling, namely -C-.