The Challenge of Sign Language Phonology

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Abstract

Comparing phonology in spoken language and sign language reveals that core properties, such as features, feature categories, the syllable, and constraints on form, exist in both naturally occurring language modalities. But apparent ubiquity can be deceptive. The features themselves are quintessentially different, and key properties, such as linearity and arbitrariness, although universal, occur in inverse proportions to their counterparts, simultaneity and iconicity, in the two modalities. Phonology does not appear full blown in a new sign language, but it does gradually emerge, accruing linguistic structure over time. Sign languages suggest that the phonological component of the language faculty is a product of the ways in which the physical system, cognitive structure, and language use among people interact over time.

1. INTRODUCTION TO PHONOLOGY IN ANOTHER MODALITY

Only humans have language, and we have two kinds: spoken and signed. Sign languages arise spontaneously wherever there is a group of deaf people who have opportunities to communicate with one another. Deaf children acquire sign languages from deaf signing parents without instruction on the same timetable as hearing children acquire spoken languages (Newport & Meier 1985, Meier 1991, Lillo-Martin 2009). Sign languages are relevant to phonological theory precisely because they are naturally occurring languages that are not conveyed through sound, but rather are characterized by a level of structure that is comparable to phonology, which I elaborate in this review.

Sign languages are particularly relevant in the current academic climate, in which a growing body of research is seeking to revise or replace influential paradigms of modern phonology. In the generative phonology tradition, important aspects of phonology are deemed to be universal and innately specified: features and types of rules and interactions (Chomsky & Halle 1968) or constraints and ranking procedures (Prince & Smolensky 2004). In recent years, researchers from diverse perspectives have increasingly called into question both the claim that there are true phonological universals and the claim that innateness is the best explanation of observed phonological generalizations (Blevins 2004, Evans & Levinson 2009). Linguists from different theoretical viewpoints have proposed that language use (Bybee 2001, Pierrehumbert 2001) and formal diachronic and organizational factors (Blevins 2004, Wedel 2006, Mielke 2008) account for phonological structure. More generally, both computational and laboratory approaches support the role of culture, in the sense of transmission across generations, in shaping phonology (de Boer & Zuidema 2010, Verhoef et al. 2014, Carr et al. 2016). Diachronic, usage-based, and cultural approaches, although different in theoretical and methodological respects, all stand in opposition to synchronic approaches, which typically attribute widespread generalizations to innateness. Browman & Goldstein (1992) propose an intricate model of articulatory organization to account for much of phonology as commonly conceived, challenging percepts such as phonological features. The assumption that the relation between phonological elements and meaning is by nature arbitrary is also challenged by mounting evidence that iconic relations between form and meaning are a resource exploited by language (Perniss et al. 2010, Dingemanse et al. 2015).

Jackendoff (2011, p. 5) frames these issues, correctly in my view, in terms of selecting the better theoretical paradigm for research:

> [T]o the extent that a theory of language permits a graceful integration with a plausible picture of the structure and function of the rest of the mind/brain, it places fewer demands on the genome, and therefore it is a better theory.

Sign language, a product of the mind that is like spoken language in some respects and unlike it in others, offers an extraordinary opportunity to address these issues, for three reasons. First, the study of sign languages helps to isolate and more clearly define types of organization that are directly attributable to the physical system underlying phonology. Second, doing so reveals those properties that are universal regardless of modality. Third, due to their youth, sign languages bring critical empirical evidence to bear on the claim that phonology is an emergent system in which culture and diachronic processes play a role.

What do we mean when we say that sign languages have phonology? In his slim, seminal volume, *Sign Language Structure*, Stokoe (1960) showed that the signs of the American Sign Language (ASL) lexicon constitute a finite list of discrete, contrastive, formational visual units—likened to phonemes—that create a large vocabulary of meaningful signs or words. Later research

showed that the constraints on the combination of these elements and the processes that alter them, such as assimilation, deletion, reduplication, and lengthening, are comparable in kind, if not in detail, to those of spoken language.

If this were the whole story, it would be a very short story with a single lesson: Sign language phonology is like spoken language phonology. It is possible to interpret some of the literature that way, and Chomsky (2007) does just that. Referring to the phonological component of language as a secondary "externalization" of the primary, computational system, he writes, "We have learned from the study of sign language . . . that the externalization of language is independent of modality" (Chomsky 2007, p. 22). One implication of this statement is that phonology, and its relation to other levels of structure, is essentially the same in the two modalities. If so, although the details of sign language phonology might be as interesting as those of spoken languages, they would not offer more insight into the nature of the phonological system than those of any spoken language.
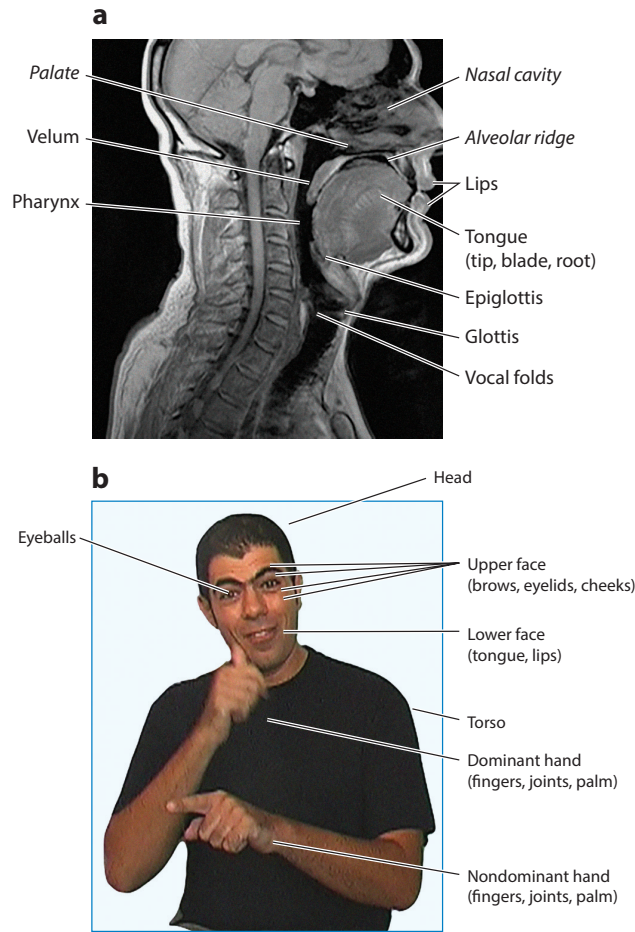
If phonology is grounded in phonetics (Browman & Goldstein 1992, Archangeli & Pulleyblank 1994), is it possible for essentially the same phonological system to result from two such different physical channels? **Figure 1** compares the articulatory apparatus of speech with that of sign.[1] Although the total number of articulatory structures in the two modalities is roughly comparable, any similarity ends there. One striking difference is in perceptibility. We need an MRI to view the articulators of spoken language, whereas those of sign language are there for all to see. Unlike speech articulation, in sign there is little or no difference between the configurations of the articulators and the overall perceptual effect—the input and output, in Browman & Goldstein's (1992) terms.

Another difference between speech and sign is the relation between articulatory configuration and linguistic function. The configuration of the vocal tract at a given moment during speech may articulate one sound (or parts of two or three, in cases of coarticulation) and a single pitch. In the sign language configuration in **Figure 1b**, taken from Israeli Sign Language (ISL), we see much more. In the shape and orientation of the hands, we see elements that constitute words. In the configurations resulting from the combinations of these elements, we see two lexical items simultaneously (WHITE, signed with the dominant hand, and THERE, signed with the nondominant hand). The raised brows and nonneutral head position signal the occurrence of these signs in a dependent clause, and squinted eyes signal that this information is shared between interlocutors. The compositional, simultaneous structure of the signals of face and head belongs to the prosodic/intonational system of sign languages. Space prohibits further elaboration of this rich component, but see, for example, Nespor & Sandler (1999), Wilbur & Patchke (1999), Wilbur (1999, 2000), Sandler & Lillo-Martin (2006, chapters 15, 23), Sandler (2010a and references cited there), Sandler (2012a), and Dachkovsky et al. (2013). **Figure 1b** shows that the articulators manifest phonological, lexical, intonational, and discourse level information simultaneously.

Section 2 provides a general overview of the "phonetic" parameters of signs (at the lexical level) and systematic constraints on their organization across sign languages. The exposition reveals structural similarities between the two types of systems that transcend the very different channels of transmission. But a closer look reveals that two opposing pairs of phonological properties of both modalities are found in glaringly inverse proportions: linearity/simultaneity (Sections 2.1 and 2.4) and arbitrariness/iconicity (Section 3).

A characteristic particular to sign languages is their youth. Whereas spoken languages are many thousands of years old, or descended from old languages, extant sign languages are at most two or three centuries of age (Kyle & Woll 1984). In fact, sign languages can emerge at any time under

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[1]Here, "sign" is the counterpart of "speech," "sign language" of "language," and "signed language" of "spoken language."

a

Palate

Velum

Pharynx

Nasal cavity

Alveolar ridge

Lips

Tongue
(tip, blade, root)

Epiglottis

Glottis

Vocal folds

b

Head

Eyeballs

Upper face
(brows, eyelids, cheeks)

Lower face
(tongue, lips)

Torso

Dominant hand
(fingers, joints, palm)

Nondominant hand
(fingers, joints, palm)

Figure 1

Articulatory apparatus for (*a*) spoken language (italicized items are static) and (*b*) sign language. Magnetic resonance image in panel *a* reproduced with permission from Didier Demolin, Thierry Metens, and John Kingston.

the right conditions, such as when deaf children with no common language first come together in a school, or in insulated villages in which there is a genetic basis for deafness. When sign languages do arise de novo, they offer an opportunity to witness what spoken languages could never show us directly: how linguistic structure emerges at all levels, including the level of phonology (the topic of Section 4).

If phonological systems do not spring forth full blown in sign languages, and if their properties can be linked to both the physical channel and cultural factors such as interaction among people over time, then the same may be true of spoken languages. At the same time, the very existence of a phonological level of structure with shared properties in two such different modalities implies a common kind of cognitive organization. Section 5 concludes by tying these threads together and focusing some of the challenges that sign language phonology presents for future research.

Most of the research reported in this review was conducted on the unrelated sign languages American Sign Language (ASL) and ISL. Although there are differences across sign languages (see, e.g., Channon & van der Hulst 2011b), observations noted here that do not refer to a specific sign language are understood as characterizing sign languages in general.

2. SOUNDLESS PHONOLOGY

Single signs made in isolation, such as dictionary citations or responses to a question, may appear to be holistic, pictorial gestures. For example, the sign BALL is likely to be made by the two hands held opposite one another in cupped shapes, as if holding a round object. This casual observation prevented linguists from seeking a lower level of formational units, a phonological level, and, in fact, any linguistic structure in sign languages at all. But in 1960, William Stokoe, an English instructor at Gallaudet College (now Gallaudet University) for deaf students in Washington, DC, published a monograph that changed this misperception. Using structuralist methods of phonemic analysis, Stokoe and colleagues (Stokoe 1960, Stokoe et al. 1965) demonstrated that the signs of ASL comprise three basic formational parameters—hand configuration, location, and movement—and that signs can be distinguished from one another by substituting a specification in any one of these categories for another specification in the same category. **Figure 2** shows minimal pairs of signs along each of these parameters, using ISL as an example. Stokoe developed a notation system with a finite list of feature-like units within each major category.
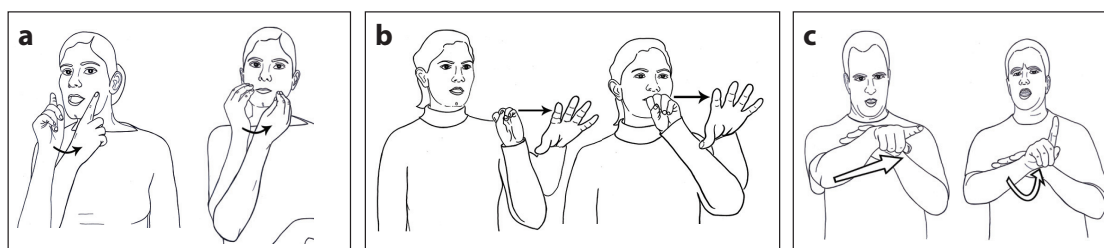
Figure 2

Minimal pairs in Israeli Sign Language. (*a*) MOTHER and NOON, distinguished by hand configuration features. (*b*) SEND and TATTLE, distinguished by location (place of articulation) features. (*c*) ESCAPE/FLEE and BETRAY, distinguished by movement features.

2.1. Simultaneity and Sequentiality

According to Stokoe, the major phonological categories are organized simultaneously in sign language, not sequentially like spoken language segments. In fact, so much information is presented simultaneously that signers need to see only about 35% of a sign to identify it, compared with 83% of a spoken word needed by speakers (Grosjean 1980, Emmorey & Corina 1990). That is why it is possible to interpret the signs WHITE and THERE from a still picture in **Figure 1***b*.

But linguists noticed that it is necessary to isolate the beginning, the middle, and the end of an ASL sign, in particular for stating certain morphological processes, leading them to posit some degree of sequential structure. For example, specific segments have to be isolated in order to capture reduction phenomena in lexicalized compounds in ASL (Klima & Bellugi 1979), as I show in Section 2.4, below. A morphological process by which verb signs move from one point to another in space, to agree with spatial loci established for subjects and objects, alters the beginning and ending segments of a sign separately (Padden 1988, Meir 2002). Motivated by phenomena

like these, Liddell (1984) and Liddell & Johnson (1986, 1989) proposed that all signs have linear temporal structure and should be represented as sequences of holds (Hs) and movements (Ms), comparable to consonants and vowels, where each H or M segment consists of a bundle of features for handshape, orientation of the palm, place of articulation, and type of movement. Liddell saw the movement segment as parallel to a syllable nucleus (see Section 2.4), and compared a typical HMH sign with CVC (consonant–vowel–consonant).

By listing all features as bundles associated with H or M segments, however, the strictly linear model contains much redundancy and represents linearity at the expense of simultaneity. Very often, only one feature differentiates the beginning and ending segments, such as the specific setting on a given place of articulation (e.g., [ipsilateral] versus [contralateral] with respect to the mouth in MOTHER), and all other features are identical. This structure is in stark contrast with a spoken English word with CVC structure, such as *fit* [fɪt], in which nearly all of the features of each segment differ from those of the other segments (see Sandler & Lillo-Martin 2006, chapter 16). By redundantly listing all features of each sequential segment, the MH model obscures the fact that most monomorphemic signs are characterized by a single grouping of selected fingers (Mandel 1981) and a single major place of articulation (Battison 1978), both very salient feature categories, thereby giving the impression of simultaneity adopted by Stokoe in the first place.
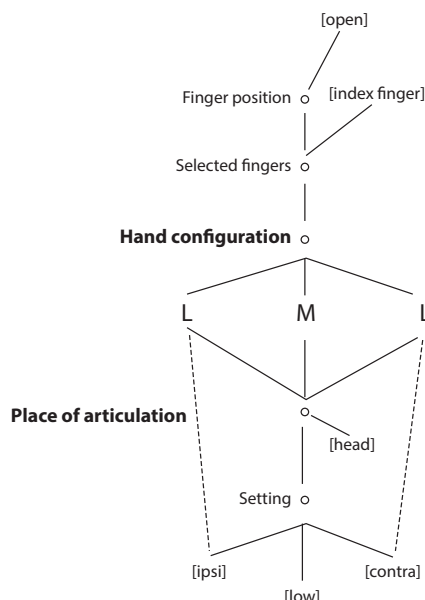
In fact, there is both simultaneity and sequentiality in the structure of a sign; it is all a matter of proportion. The theories of autosegmental phonology (Goldsmith 1976) and feature geometry (Clements 1985) informed a different model of sign structure that aimed to capture the right proportions more directly. The hand tier (HT) model (Sandler 1986, 1987, 1989) proposed that a single specification for both hand configuration and the major place of articulation (location) is multiply associated with the timing tier, consisting of location and movement (LM) timing slots: canonically, LML. The hold category was abandoned due to the observation that Hs are not underlying but rather are inserted by phrasal boundary lengthening (Sandler 1986, Perlmutter 1992, Nespor & Sandler 1999). **Figure 3** exemplifies the general organization of the HT model with a schematic representation of MOTHER. Following autosegmental/nonlinear representations of tone, the hand configuration category is represented above the LM tier.[2] In the rest of this review, I adopt the HT model for illustration.

The amount of underlying sequential structure is minimal, however, and the parallel with spoken language segments should not be taken at face value. There are virtually no clusters of locations or movements in a sign language syllable, and phonological alternations occur only when morphemes are linearly concatenated, which, apart from compounds, is rare (Aronoff et al. 2005). It is not surprising, therefore, that some researchers propose models without sequential structure in the underlying form of signs, and represent these as a single segment, root node, or syllable (e.g., van der Hulst 1993, Wilbur 1993, Channon & van der Hulst 2011a).

2.2. Constraints

The organization of features of the hand configuration, location, and movement categories is subject to constraints. For example, only one group of fingers may be selected for a monomorphemic sign, and all selected fingers must have the same shape (e.g., open or closed; Mandel 1981) (**Figure 2**). The fingers that are not selected are also constrained; they must be in a position

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[2]The hand configuration category is far more complex than tone, and a three-dimensional mobile would allow a more faithful representation. The hand configuration and location categories are organized in complex hierarchies that need not concern us here (see Sandler 1989).

[open]

Finger position ○   [index finger]

Selected fingers ○

Hand configuration ○

L   M   L

Place of articulation ○
[head]

Setting ○

[ipsi]   [contra]
[low]

Figure 3

Schematic representation of the Israeli Sign Language sign for MOTHER. Abbreviations: L, location; M, movement.

that is perceptually distinct from that of the selected fingers (Corina 1993). These constraints are widespread across sign languages, but they are sometimes violated when shapes are borrowed from the finger-spelling alphabet (Brentari 1998, 2011; Sandler 2012b). The exceptions show that the constraints are not required by the anatomy of the hand but rather are part of phonological organization.

As noted above, the articulating hand configuration moves with respect to one major body area: the head, the torso, or the nondominant hand/arm (Battison 1978). To avoid redundancy, those feature categories that spread throughout a sign are represented autosegmentally as multiply associated, reflecting the simultaneous impression conveyed by signs. Yet to distinguish places of articulation within a sign, the signer needs more specific features within the major place category, known as setting features, such as [high], [contralateral], or [proximal]. In an articulator-based geometry (Clements 1985) in which, for example, articulators such as the tongue tip or lips are dominated by the larger supralaryngeal class, sign language feature categories belonging to larger articulators dominate those of the smaller categories that constitute them. For example, the selected fingers category dominates the finger position (shape) category, as position is a refinement of the general selected finger category and all fingers must be in the same position. Similarly, place dominates setting. The schematic hierarchy shown in **Figure 3** is supported both by morpheme structure constraints and by assimilation facts (Sandler 1987, 1989).

One subcategory patterns in ways that are particularly informative regarding the phonology of sign languages: the nondominant hand. Following the patterning of this articulator reveals phonological patterning, constraints on the system, and the existence of a syllable unit in sign language.

2.3. The Nondominant Hand

In principle, the anomaly of having two anatomically identical articulators, the two hands, could result in a highly anomalous phonological structure compared with spoken language—a kind of double phonology in which the hands operate independently. We know that this is potentially possible from the way the nondominant hand patterns at higher meaningful levels of structure above the lexical item.

For example, the nondominant hand can provide topic continuity at the level of discourse by maintaining the configuration of a sign for a discourse topic in the signing space, while the dominant hand continues to provide the relevant commentary (e.g., Brentari & Goldsmith 1993, Miller 1994, Liddell 2003, Nilssen 2007, Napoli & Sutton-Spence 2010, Sandler 2012c), as shown in **Figure 1*b***. The nondominant hand is configured as an index (translated as THERE) and establishes a locus in space for the topic of the sentence, a white car (CAR WHITE in ISL), remaining in the signing space until the comment part of the utterance is signed by the dominant hand.

Another example of the independence of the nondominant hand in the morphosyntax is found in a subsystem known as classifier constructions. In these constructions, the nondominant hand may represent a separate morpheme from that represented by the dominant hand (Supalla 1986), and the two hands can move independently, representing, for example, a dog tagging along behind its owner (Aronoff et al. 2003; see also Johnston & Schembri 1999, Emmorey 2003, Sandler & Lillo-Martin 2006, Risler 2007, Meir & Sandler 2008).

I do not describe here levels of structure like these that are beyond phonology. I mention them to emphasize that the nondominant hand acts independently at higher levels. The considerably more constrained form of lexical signs is not due to phonetic restrictions such as bimanual coordination, but rather to phonological organization (Sandler 1993a, 2006), to which I turn now.

About half of the signs in any sign language are one-handed; the other half are made with two hands. According to Battison's constraints, the nondominant hand in lexical signs can be either (*a*) a copy of the dominant hand articulator, with the same hand configuration, moving in the same or mirror locations, or (*b*) a place of articulation, like the head or the torso, configured in an unmarked handshape, remaining static while the dominant hand moves on or near it (Battison 1978).[3] I refer to the type of sign in which h2 (the nondominant hand) is a copy of h1 (the dominant hand) as a symmetrical sign, and to the type of sign in which h2 is a place of articulation as an h2-place sign.

The phonological structure of lexical two-handed signs, then, is severely constrained in movement, location, and hand configuration, as reflected in all phonological models (Blevins 1993, Sandler 1993a, van der Hulst 1996). In the HT model, the nondominant hand is subordinate to more general categories (either hand configuration or place of articulation) that are independently required for phonology, and it is affected by rules and other features of these higher-level categories.

To capture these facts, the nondominant hand, h2, is represented in the tree shown in **Figure 4** as dominated by either the hand configuration node (in symmetrical signs) or the place node (in h2-place signs). **Figure 4*a*,*b*** shows the ASL symmetrical sign DRESS, in which h2 is part of hand configuration, and the ASL sign MARRY, in which h2 is a place of articulation, with representations. I omit the details of representation because of space constraints (see Sandler 1993a, 2006, and Crasborn 2011 for an overview).

The idea that h2 belongs to these higher-level categories (instead of requiring a category of its own) is supported by the form of lexicalized compounds. Compounding, first described

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[3]This characterization is somewhat simplified but holds for the vast majority of two-handed signs.
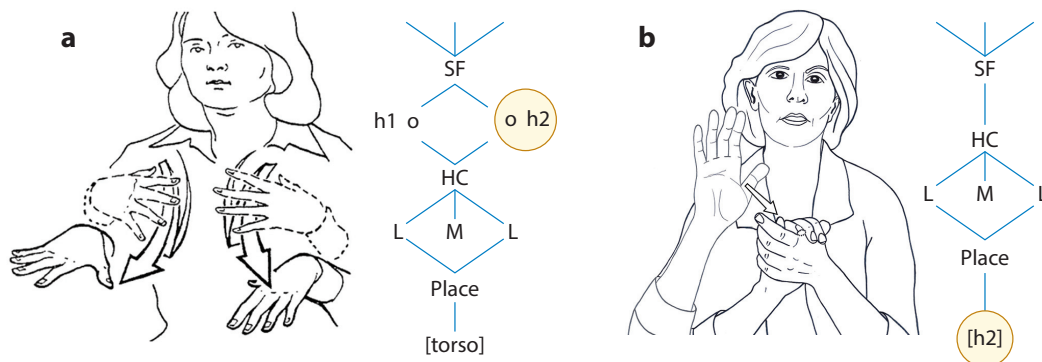
Figure 4

Two types of two-handed signs, with representations. (*a*) Symmetrical sign for American Sign Language (ASL) DRESS. (*b*) h2-place sign for ASL MARRY. Abbreviations: h1, dominant hand; h2, nondominant hand; HC, hand configuration; L, location; M, movement; SF, selected fingers. Illustration in panel *a* reproduced with permission from Ursula Bellugi.

for ASL by Klima & Bellugi (1979), is productive in sign languages. As in spoken languages, some compounds become lexicalized, undergoing semantic drift and, often, phonological changes, including regressive hand configuration assimilation and reduction (Liddell & Johnson 1986; Sandler 1987, 1989).
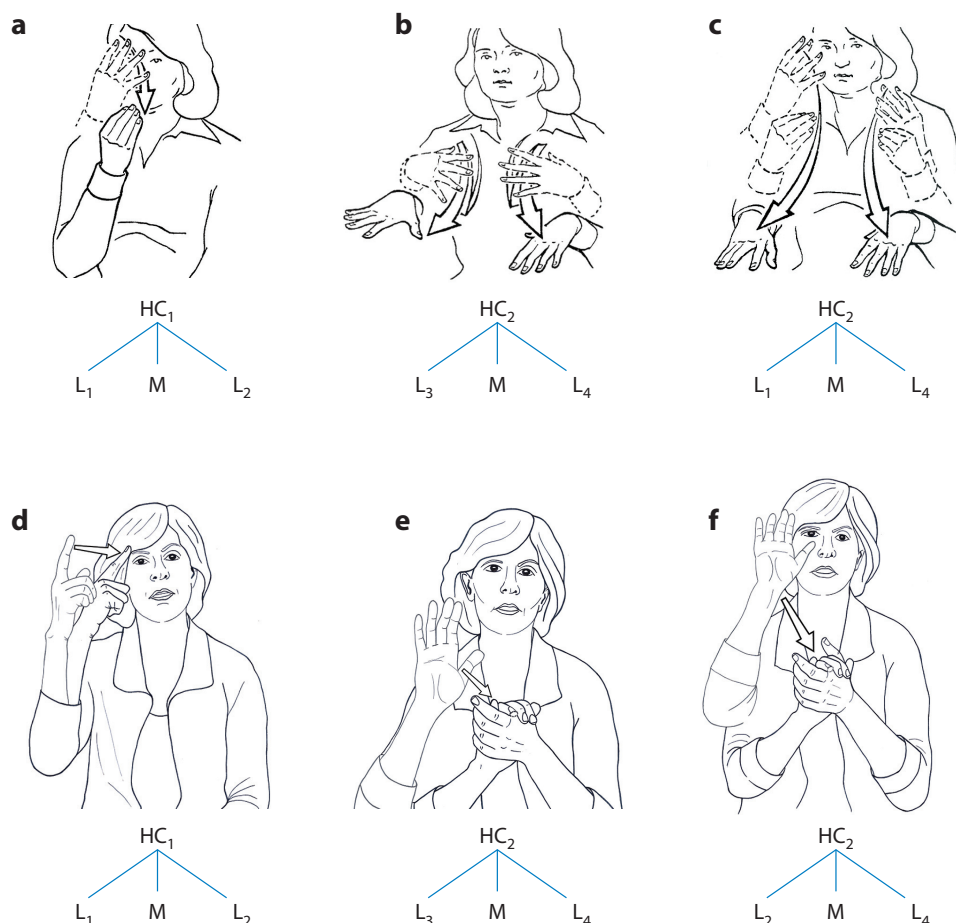
Hand configuration assimilation reveals the category membership of h2. If the hand configuration category assimilates in a two-handed symmetrical sign such as SLEEP^DRESS = NIGHTGOWN, then both hands assimilate. If hand configuration assimilates in an h2-place sign such as THINK^MARRY = BELIEVE, then only h1 assimilates, and h2 remains a static place of articulation throughout.[4] The compounds are shown in **Figure 5**.[5] Despite the existence of two anatomically identical articulators, then, no anomalous doubling of categories takes place in the phonology of the lexicon. As discussed in Section 2.4, below, the concatenation of signs in lexicalized compounds provides evidence for the syllable in sign language. I return to the nondominant hand in the context of iconicity in Section 3.

2.4. The Sign Language Syllable

Most phonological models propose that sign languages have syllables, and that movements are syllabic (Coulter 1982). A syllable comprises either one movement or two simultaneous movements— for example, a path movement from one location to another with co-occurring change in the position of the fingers, as in SEND or TATTLE in **Figure 2b**. An internal movement—a change in finger position or in the orientation of the hand—is sufficient to constitute a syllable by itself (Sandler 1989, Perlmutter 1992). In these cases, the sign has the form of only an L segment, with

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[4]Although the nondominant hand as a place of articulation in OVERSLEEP does not move in the articulation of the sign, it does spread in a sense, appearing from the beginning of the compound. See van der Hulst (1993) for a representation of h2 that accommodates this overlap in compounds. Nespor & Sandler (1999) argue that the domain for this spreading (at least in ISL) is not the compound or prosodic word, but the phonological phrase.

[5]Note that the pattern of reduction in the compound NIGHTGOWN is slightly different from that in BELIEVE, as explained in Section 2.4 and footnote 10.

Figure 5

Reduction of two American Sign Language compounds: truncation and hand configuration assimilation. (*a–c*) SLEEP^DRESS =
NIGHTGOWN, where the second member is a symmetrical sign. (*d–f*) THINK^MARRY+BELIEVE, where the second member is an h2-place
sign. Abbreviations: h2, nondominant hand; HC, hand configuration; L, location; M, movement. Illustrations in panels *a–c* reproduced
with permission from Ursula Bellugi.

branching hand configuration or orientation features. The ISL sign SEND (**Figure 2b**) and the
ASL sign SLEEP (**Figure 5a**), have a combination of a path movement and an internal movement.
When the two occur simultaneously, they constitute a single syllable, and the two together are
argued to be more sonorous than a path movement alone (Sandler 1993b). If two movements oc-
cur sequentially, typically in complex signs such as (unreduced) compounds, the sign is disyllabic.
Brentari (1990, 1998) demonstrated that syllables can be distinguished from morphemes and each
from words in ASL, although the three often appear to be isomorphic. One reason to attribute
syllable status to movements is that all signs must have movements to be well formed, even though
the movement typically carries very little information in uninflected signs. Movement features

can be contrastive, as in **Figure 2c**,[6] but the movement is often just a straight path. Unlike words without vowels, most signs would be quite intelligible without movement, as WHITE and THERE are in **Figure 1b**. But whereas hand configuration and location are immediately and simultaneously available in a sign, movement takes longer to identify and coincides with lexical recognition (Emmorey & Corina 1990), suggesting that it may facilitate perception. We infer that, like a spoken syllable nucleus, movement contributes the visual equivalent of sonority (Brentari 1990, 1998; Perlmutter 1992; Sandler 1993b; Wilbur 1993).

Another argument for the syllable in ASL apart from well-formedness comes from constraints and processes that require a syllable unit for their formulation. For example, reduction in lexicalized compounds is subject to a monosyllable constraint, the optimal form of the prosodic word (Sandler 1999). The compounds NIGHTGOWN and BELIEVE (**Figure 5**) become monosyllabic by deletion of one location and of one movement from each, leaving a single movement between two locations in the reduced compounds.[7]

The process of reduplication of compounds under various inflections provides more evidence for the syllable. A reduced, monosyllabic (LML) compound such as NIGHTGOWN or BELIEVE undergoes total reduplication (Sandler 1987, 1989).[8] Crucially, however, if the compound does not reduce, instead retaining both movements of its member signs ($L_1ML_2+L_3ML_4$), then, under reduplicative morphology, only the second part reduplicates (L_3ML_4).

The lexicalized ASL compound SLEEP^SUNRISE = OVERSLEEP is such an unreduced compound.[9] The first member, SLEEP, is the same as that of NIGHTGOWN; however, unlike NIGHTGOWN, OVERSLEEP is disyllabic, as the movements are sequential rather than simultaneous. Under reduplication, the first LML syllable (SLEEP) is signed once, and only the second LML syllable (SUNRISE) reduplicates. Both compounds are shown in **Figure 6**. This pattern suggests that the domain for reduplication in ASL is the final LML syllable.[10]

This pattern cannot be explained on the basis of meaning; in fact, it has the effect of obscuring the meaning of the individual members of the compound in both cases. Reference to the syllable as the domain of reduplication is a phonological fact, supporting the existence of the phonological category, syllable.

The distinction between prosodic elements, which create syllabicity at the lexical level, and inherent elements, important in the theory of Jakobson et al. (1952), is considered a critical bifurcation of sign language phonological structure, according to a third model of sign language phonology, the prosodic model (Brentari 1998). Prosodic features at the level of the sign are viewed as forming a coherent category because, for example, they may be substituted for one

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[6]See Wilbur (1993, 2008), Brentari (1998), Sandler (1996, 2011), and Mak & Tang (2011) for phonological properties of movement in different sign languages.

[7]Lexicalized compounds in ISL truncate and assimilate in the same way (Sandler 2012b).

[8]I am grateful to Ursula Bellugi for sharing the compound data collected at her lab at the Salk Institute, upon which this analysis (Sandler 1989) was based.

[9]The nondominant hand as a place of articulation in OVERSLEEP also spreads in a sense, appearing from the beginning of the compound. See van der Hulst (1993) for a different representation of h2 that accommodates this overlap in compounds.

[10]Note that the patterns of reduction in the compounds NIGHTGOWN and BELIEVE in **Figure 5** above are slightly different. NIGHTGOWN retains L_1 from its first member, SLEEP, whereas BELIEVE retains L_2 from THINK. Sandler (1993b) argues that this is due to the optimal "sonority cycle" in ASL: Those locations in which the hand contacts the place of articulation (e.g., the first L of SLEEP and the last L of DRESS in **Figure 4**) are less sonorous than those that do not, so that retention of contacting locations results in the optimal sonority distance between locations and movement. For treatments of relative sonority in sign language syllables, see also Perlmutter (1992) and Brentari (1998). The existence and internal structure of the syllable in sign languages are among the properties that led Berent (2013) to conclude that both spoken and signed languages are the product of an innate phonological mind.
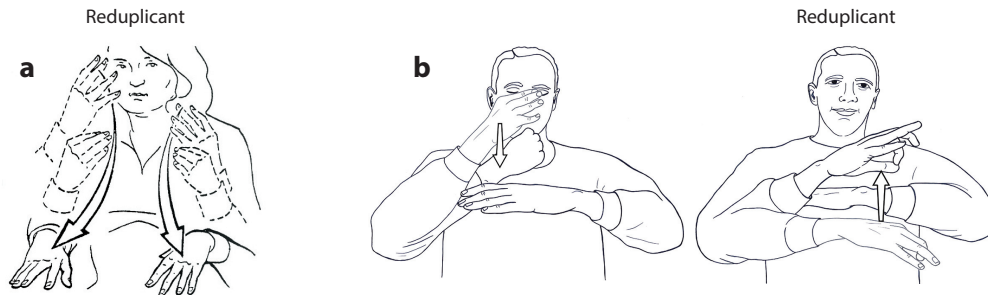
Figure 6

Reduplicants of the monosyllabic compound NIGHTGOWN and the disyllabic compound (SLEEP^SUNRISE) OVERSLEEP. Reduplication affects the final syllable.

another under certain circumstances, changing the degree of sonority in a syllable (Brentari 1998).[11]

2.5. Sign Language Phonology: Interim Summary

Other models have been proposed, each capturing generalizations about sign language phonology, and discrepancies among these models have not been resolved. What matters is that all models support the claim that there is a sublexical level of structure in sign languages, with its own formational units, constraints, and processes. These units are unlike those of other levels of linguistic organization, in terms of formational properties and the types of processes that affect them. They constitute a coherent level of structure: phonology. The fact that sign languages have phonology tells us that meaningful signals in communicative interaction among humans must have a level of structure that is not governed by meaning but by form. In this, Hockett (1960) was right: Duality of patterning—the existence of meaningless and meaningful levels of structure—is a design feature of all human language (de Boer et al. 2012).

However, a sign language is not merely one interesting language among many, like Walbiri or Igbo. Sign languages have properties in common that are different from those of spoken language, showing how profoundly the physical channel of language and conditions of interaction and transmission determine form in both modalities. As discussed above, the degree of simultaneity in sign languages (Vermeerbergen et al. 2007) is very different from that of any spoken language (Ladd 2014). **Figure 1***b* and the discussion in the text show that even more simultaneity is layered on by the intonational system.

Although there is an internal phonological level of structure in signs, organized according to formational criteria, it has become increasingly clear that meaning and phonology are not mutually exclusive in sign languages. Iconicity permeates all levels of structure in these visual languages, including the phonology.

3. ICONICITY: MEANINGFUL PHONOLOGICAL UNITS

Iconicity in language refers to a relationship or resemblance between form and meaning. The term "form" can refer to phonological elements that make up the sign, as well as to the way linguistic

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[11]The prosodic model, proposing and supporting a new bifurcation of major categories, is influenced by the other models described here, as well as by the dependency model of sign language phonology, which introduces unary features, head-dependency relationships among features, and other universal categorization principles (van der Hulst 1993).

elements are organized with respect to each other. The term "meaning" refers to lexical meaning as well as to more abstract and grammatical functions, such as plurality, anteriority, and others. de Saussure (1983) stressed the arbitrary relation between form and meaning as a central (but not mandatory) characteristic of language, which is why Stokoe's demonstration that signs have a meaningless level of structure was so important, and why some researchers in the field tended to steer clear of iconicity for so long. Yet Stokoe did not share this squeamishness. I clearly recall a keynote talk (at the Theoretical Issues in Sign Language Research conference at Gallaudet University, 1998) in which Stokoe referred to iconicity in sign language as "that bugaboo of little minds."

Iconicity is pervasive in sign languages at all meaningful levels of structure, lexical, morphological, syntactic, and pragmatic, as one might expect in a language that represents the world through visual images (e.g., Taub 2001, Aronoff et al. 2005, Perniss et al. 2010, Meir et al. 2013, Padden et al. 2013). Because phonology deals mainly with the formational level within the lexeme, as discussed above, its components might be expected to be determined by form alone and not by meaning. With Stokoe's admonition in mind, let us see what iconicity can mean at the phonological level, returning to the nondominant hand in lexical signs.

Consider again the sign BALL. It is very likely that BALL will be two-handed in any sign language because it conveys the dimensions of an object. Signs like EMPTY, DEPEND, MEET, NEGOTIATE, and RAIN are also likely to be two-handed. According to a study that compared signs for 200 concepts in three unrelated sign languages, 30% were two-handed for the same concepts in all three sign languages, whereas random distribution would yield an overlap of only 13% (Lepic et al. 2016).

For example, the signs for DISCUSS in both ISL and Al-Sayyid Bedouin Sign Language (ABSL) are two-handed (**Figure 7**). In each language, the signs obey phonological constraints on symmetrical signs: The two hands have the same configuration and move in the same way. However, both two-handedness and the specific alternating movement pattern (first one hand and then the other) are motivated by iconicity—representing the alternate exchange of information between two participants.

Lepic et al. (2016) propose that four kinds of relations predict two-handedness well above chance in any sign language lexicon, namely (*a*) interaction, (*b*) (relative) location, (*c*) external dimensions, and (*d*) internal composition, all subsumed under the general notion of plurality. Interaction is exemplified by DISCUSS in **Figure 7**, and external dimensions motivate BALL. Relative location between entities motivates signs such as ASL SUNRISE (**Figure 6*b***), in which the relation between the hands is motivated by the perceived relation between the sun and the horizon. In
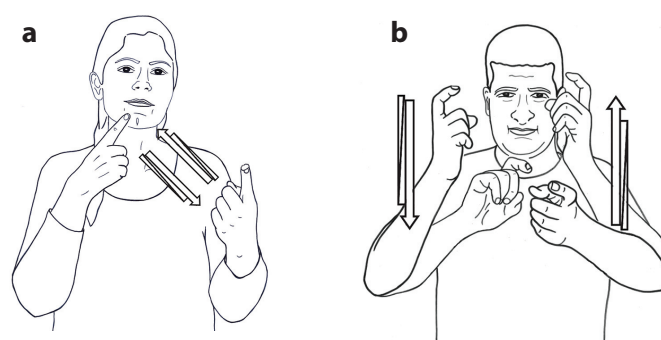
Figure 7

Iconically motivated use of the two hands and alternating movement in signs for DISCUSS in (*a*) Israeli Sign Language and (*b*) Al-Sayyid Bedouin Sign Language.

many sign languages, signs such as HOUSE represent the two component sides of a slanting roof. In all cases, the elements, although motivated, are organized phonologically. The signs are morphologically simple because if one hand is removed what is left has no morphological status. h2 is a meaning-bearing phonological element.

This discussion has been limited to iconicity only as manifested by the nondominant hand in lexical signs, for reasons of coherence and space. However, many other authors have investigated different aspects of the iconic relationship between meaning and phonological form in signs (e.g., Boyes-Braem 1981, Johnston & Schembri 1999, Fernald & Napoli 2000, Taub 2001, van der Kooij 2002, Wilbur 2008, Meir 2010, Strickland et al. 2015). In the ASL sign THINK (**Figure 5d**), the head as a place of articulation is motivated as the seat of mental processes (similarly, DREAM, IMAGINE, etc.). In the ISL sign TATTLE (**Figure 2b**), the mouth place of articulation is motivated as the location of speech (similarly, SAY, ASK, etc.). Although in all cases motivated elements are discrete in citation form, there is evidence that they can be altered in gradient fashion analogically with exigencies of the discourse. For example, the hand configuration of the ISL lexical sign for RAKE can undergo crumpling to iconically indicate a rake that has been bent (Fuks 2014).

Spoken languages also have iconicity at the phonological level (Bloomfield 1933, Ultan 1978, Ohala 1996, Klamer 2001). Ladd (2014) argues on the basis of spoken languages that elements need not be meaningless in order to be considered phonological. For example, Hamano (1986) found that, in Japanese mimetics, phonological features of the first consonant of an adverbial mimetic make a predictable semantic contribution: [−voice] conveys 'small/light/fine,' whereas [+voice] conveys 'big/heavy/coarse.' In laboratory studies (Perlman et al. 2015, Edmiston et al. 2016), participants created meaningful categories with spontaneous iconic vocalizations, passed down from one "generation" to another. Nevertheless, other experiments show that it is much more difficult to create correspondence between form and meaning with auditory than with visual signals (Fay et al. 2015). As a result, such phenomena in spoken languages are much less widespread than in sign languages, and the relation between form and meaning is less direct and more language specific. The types of iconic relation between form and meaning that occur across sign languages, exemplified here with the nondominant hand, seem more directly to reflect general properties of human cognition (Strickland et al. 2015). Language does what it can with what it's got.

4. PHONOLOGY EMERGES

What does a language do when it is first born? How and when in the course of emergence does a language require a phonology? Is the system innate, or does it emerge because of properties of the physical system and diachronic factors? From an evolutionary perspective, must phonology have arisen before other levels of structure could have taken form? Or would it have been possible to have holistic words or phrasal units first? In computer simulations (de Boer & Zuidema 2010), a combinatorial level of structure evolves even in the absence of meaning, and laboratory experiments show the emergence of combinatorial form from holistic signals that are referential (Verhoef et al. 2014) and iconic (Roberts et al. 2015). Sign languages alone can contribute empirical data to the discussion of these issues because only sign languages arise de novo in the wild, allowing linguists to document the phenomenon of language emergence.

My colleagues and I have been studying generations of signers of ABSL, a language that began to emerge about 80 years ago in a small village in the Negev Desert of present-day Israel, Al-Sayyid (Sandler et al. 2005). Its origin has been traced to a single family with a recessive genetic trait, into which four deaf siblings were born. Because of consanguineous marriage patterns and large numbers of children per household, deafness and sign language spread quickly throughout the community, which now numbers about 4,000 people, of whom about 130–150 are deaf (Kisch

2008)—some 50 times the proportion of deaf to hearing individuals in the general society. In this village, hearing people sign as well, with varying degrees of proficiency, depending on whether or not there are deaf people in the immediate household.

Deaf people in Al-Sayyid converse freely about all topics related to day-to-day life, as well as about things removed from the here and now, such as dreams, folk remedies no longer in use, social security, fertility, wedding planning, and much more. Across the community, ABSL functions as a full language. In this idyllic environment for language acquisition and interaction, and armed as we were with prevailing views about innate linguistic competence and about rapid emergence of sign language structuring in a school setting in Nicaragua (Kegl et al. 1999), we arrived with expectations. We expected ABSL to be as systematic and complex as more established sign languages, firmly supported by a scaffold of robust phonological structure. What we found was quite different, but no less exciting (see Sandler et al. 2014 for an overview).

At the phonological level, we found a significantly greater degree of variation in pronunciation of the same sign than in more established sign languages (Israel & Sandler 2011). Our investigation indicated that this variation included not only low-level differences that might be considered phonetic but also differences across major category boundaries, such as the number of fingers selected and the major place of articulation, which tend to be contrastive in established sign languages (Sandler et al. 2011).

Figure 8 shows two exemplars of the sign DOG, one articulated near the torso, the other near the face—two major places of articulation that are contrastive in other sign languages (compare with ISL SEND and TATTLE in **Figure 2b**). The type of finger movement differs as well between the two signers. In **Figure 8a**, the finger position changes from partly open to partly closed (and is reduplicated), whereas in **Figure 8b**, the fingers repeatedly articulate a quick, slight bending motion, giving a trilled appearance. What is important in the ABSL sign is the iconic image of the barking mouth of a dog, and not the place or position feature specifications of the sign.

We were able to identify the kernels of phonological structuring. For example, signing within households, which we termed "familylects," shows more regularity of structure than is evident across the community. As signs become more conventionalized with more use, internal formational elements begin to undergo alternation, irrespective of (or even in contradiction to) the meaning of the sign.
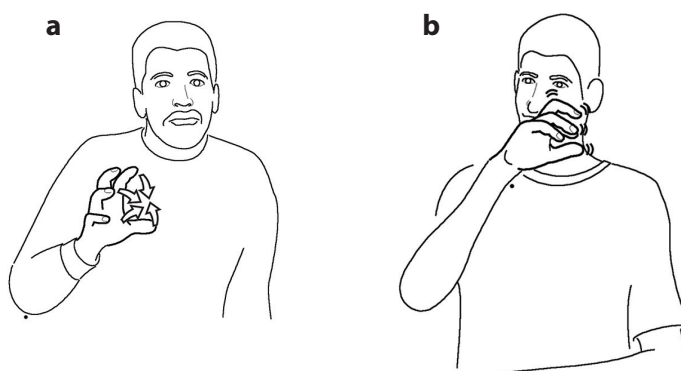
Figure 8

The sign for DOG in Al-Sayyid Bedouin Sign Language, produced at different major places of articulation and with different types of internal movement.

The compound form of the sign for EGG, which is conventionalized across the community, has a particular form in one household with five deaf children and a deaf mother. The form of EGG, in this familylect only, is characterized by countericonic handshape assimilation. We found other instances, among the youngest (third-generation) signers in our sample, of countericonic productions of signs, changing in the direction of ease of articulation. In addition, where older signers produced signs that had no movement element, anomalous in more established sign languages, younger signers added (meaningless) path movement to the same signs, creating the syllable nuclei necessary for well-formedness in more established sign languages (Sandler 2011).

We hypothesized that only with repeated use, conventionalization, and automaticity is attention diverted from the form–meaning correspondence, allowing structural forces within the sign to take over and forge a formal system. Our findings led us to conclude that a language can be fully functional before systematic phonology has crystallized (Sandler et al. 2011), suggesting that culture contributes to the emergence of phonology.

5. CONCLUSION: RISING TO THE CHALLENGE

Does phonological structure have universal properties? Is it explained by diachronic factors related to human interaction? By general cognition? By the details of physical organization? Comparing spoken with signed languages provides some answers and shows that these different approaches are not mutually exclusive (Sandler 2010b, Anderson 2016). Sign language shows that we can only hope to understand phonology through interdisciplinary investigation encompassing all of these approaches.

In both spoken and signed languages, a phonological level exists, characterized by contrastive features, hierarchically organized feature categories, syllables, and structural elements that are linear, all organized around form rather than meaning. These properties suggest a common cognitive system in some sense. However, ubiquity can be deceptive if it prevents us from looking further to understand the nature of this commonality, as well as the nature of the differences.

A closer look also shows that some shared phonological properties are found in strongly inverse proportions in the two modalities—simultaneity/linearity and iconicity/arbitrariness. Because there is little sequentiality within a sign, there are fewer opportunities for rules triggered by adjacency of segments, akin to common processes such as palatization or nasal assimilation, to arise. Yet, when signs concatenate, as in lexicalized compounds, systematic assimilation and truncation can occur (**Figures 5** and **6**). The character of alternations that can occur and the interactions among them, then, are strongly influenced by the degree of linearity that each modality permits. In addition to the production factors discussed here, differences in visual versus auditory perception, together with memory capacities, also shape phonological form in each modality (Brentari 2002, Emmorey 2002, Meier 2002).

Clearly, the inventory of phonological features and feature categories is not universal. Because these are tied to articulatory systems in both modalities, the importance of phonetics in shaping phonology becomes clearer through a comparison of the two. The notion that features and feature categories are innate in one modality is hard to reconcile with the fact that they are emergent in another modality (Mielke 2008).

As for iconicity, in spoken languages there is less of it, and it is less transparent and more language specific than in sign languages, whereas iconicity is pervasive in sign languages at all levels of structure. Comparison with sign languages, in which the proportions of iconicity and arbitrariness are reversed, prompts us to investigate not only why sign language phonology is so iconic but also why evolution selected spoken language, in which the phonology is so arbitrary.

Finally, sign languages teach us that phonology is not necessarily in place from the moment that a language arises. Instead, people seem to have a more holistic and, in sign languages, a more iconic image in mind in the earliest stages, such as the barking mouth of a dog in ABSL (**Figure 8**). Phonology crystallizes as a language is used by more people across more generations, demonstrating that culture plays a role in the formation of a phonological system.

But culture cannot explain everything. The system that crystallizes has particular properties, so that if phonological structure is not innate, it is, in some ways, inevitable. This type of structuring is due to particular kinds of interactions among the physical system; cognitive factors such as iconic conceptualization, memory, and processing; and cultural factors related to usage and transmission over time. Our goal should be to grasp the content of each of these components and the specific nature of their interaction. Only by pursuing this goal in both modalities can we fully understand the phonological component of the language faculty.

DISCLOSURE STATEMENT

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Errata

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