THE CHALLENGE OF SIGN LANGUAGE PHONOLOGY

Wendy Sandler

University of Haifa

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, while 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. Taken together, 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 over time, interact.

Key words. sign language, phonology, simultaneity, iconicity, duality of
patterning, language emergence

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, and deaf children acquire sign

languages from deaf signing parents without instruction on the same timetable as spoken languages (Newport & Meier 1985, Meier 1991). They are relevant to phonological theory precisely because they are naturally occurring languages that are not conveyed through sound, but are characterized by a level of structure that is comparable to phonology, which I will elaborate here.

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 & Smolensky2004). 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). From different theoretical viewpoints, linguists propose 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, Kirby, de Boer 2014; Carr, Smith, Cornish, Kirby 2016). Diachronic, usage-based, and cultural approaches, though 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, Thompson, Vigliocco 2010; Dingemanse, Blasi, Lupyan, Christiansen, Monaghan 2015).

Jackendoff frames these issues, correctly in my view, in terms of selecting the better theoretical paradigm for research.

> "…to 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." (Jackendoff 2011,
>
> p.5).

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. The first reason for this is that 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*, William Stokoe (1960) showed that the signs of the American Sign Language (ASL) lexicon are comprised of 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, in a recent article, Chomsky 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, while 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]

---
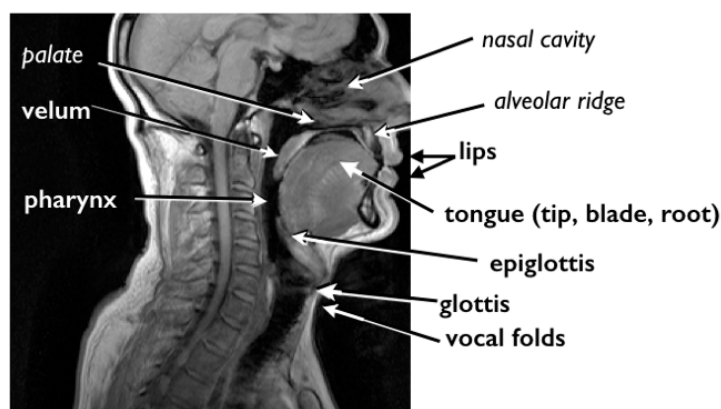
[1] Here, the term 'sign' is comparable to 'speech'; 'sign language' to 'language'; and 'signed language' to 'spoken language'.
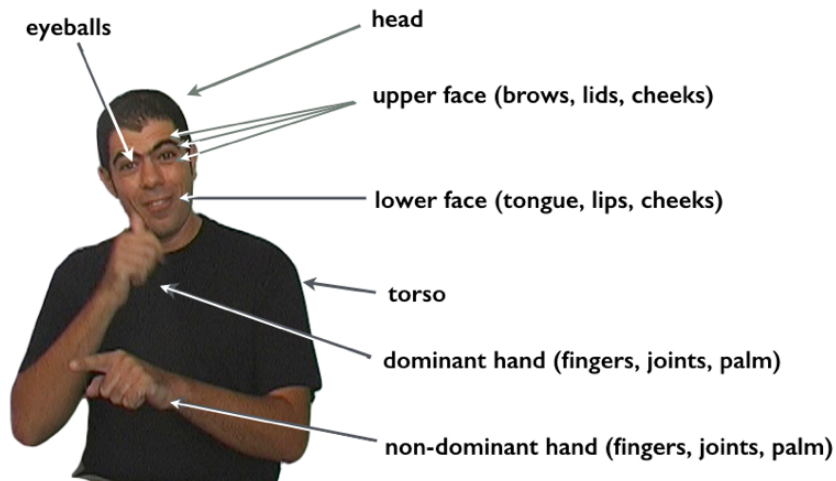
Figure 1. Articulatory apparatus. (a) Spoken language (italicized items are static). (b) Sign language (all articulators move.).

While the total number of articulatory structures in the two modalities is roughly comparable according to this figure, any similarity ends there.

One striking difference is in perceptibility. We need an MRI to view the articulators of spoken language, while those of sign language are out 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), we see much more. In the shape and orientation of the hands, we see elements that comprise words. In the configurations resulting from the combinations of these elements, we also see two lexical items simultaneously (WHITE, signed with the dominant hand, and THERE, signed with the non-dominant hand). The raised

brows and non-neutral 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 belong to the prosodic/intonational system of sign languages. Space prohibits further elaboration of this rich component, but see, e.g., 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, Healy, Sandler (2013). Figure 1 shows that the articulators provide phonological, lexical, intonational, and discourse level information simultaneously.

I begin in Section 2 with 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. While spoken languages are many thousands of years old, or descended from old languages, extant sign languages are at most two or three centuries in age (Kyle &Woll1984). In fact, sign languages can emerge at any time under 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 here was conducted on the unrelated sign languages of North America (ASL) and Israel (ISL). While there are differences across sign languages (see, e.g., Channon & Van der Hulst ed. 2011), observations 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 University) for deaf students in Washington, DC, published a monograph that changed this misperception. Using structuralist methods of phonemic analysis, Stokoe (Stokoe1960; Casterline, Stokoe, Croneberg 1965) demonstrated that the signs of American Sign Language (ASL) are comprised of 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 Israeli Sign Language (ISL) as an example. Stokoe developed a notation system with a finite list of feature-like units within each major category.
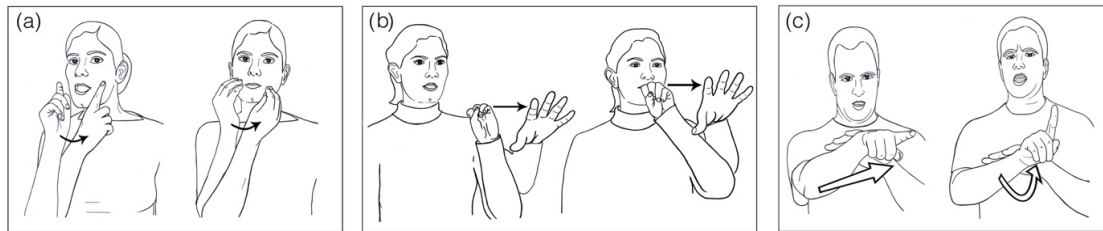

Figure 2. Minimal pairs in Israeli Sign Language. (a) MOTHER, NOON, distinguished by hand configuration features. (b) SEND, TATTLE, distinguished by location (place of articulation) features, (c) ESCAPE/FLEE, INSULT, distinguished by movement features.

2.1. Simultaneity and sequentiality

According to Stokoe, the major phonological categories are organized simultaneously in sign language, and not sequentially like spoken language segments. In fact, so much information is presented simultaneously that signers only need to see about 35 percent of a sign to identify it, compared with 83 percent 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 the still shot in Figure 1b.

But linguists began to notice 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 had to be isolated in order to capture reduction phenomena in lexicalized compounds in ASL (Klima & Bellulgi 1979), as I will show in 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 endpoints of a sign separately (Padden1988 [1983], Meir 2002).

Motivated by phenomena like these, Liddell (1984; 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 to CVC.

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] vs. [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 like *fit* [fIt], in which nearly all features of each segment are different 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, 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's 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 (HC) and the major Place of Articulation (Location) is multiply

associated to the timing tier, consisting of Location and Movement (LM) timing slots:

canonically, LML. The category Hold was abandoned due to the observation that

Holds are not underlying, but inserted by phrasal boundary lengthening (Sandler

1986, Perlmutter 1992, Nespor & Sandler 1999). The general organization of the HT

model is shown with a schematic representation of MOTHER in Figure 3 below.

Following autosegmental/nonlinear representations of tone, the HC category is

represented above the LM tier.[2] In the rest of this article, The HT model is adopted for
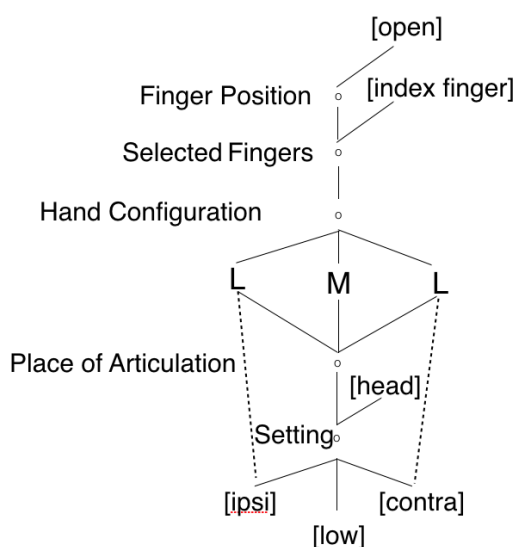
illustration.

Figure 3. Schematic representation of ISL sign, MOTHER.

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 of Movements in a sign language syllable, and

phonological alternations only occur when morphemes are linearly concatenated,

---

[2] The category of HC is far more complex than tone, and a 3-dimensional mobile
would allow a more faithful representation. The categories of Hand Configuration
and Location are organized in complex hierarchies that need not concern us here.

which, apart from compounds, is rare (Aronoff, Meir, Sandler 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., Wilbur 1993, Van der Hulst 1993, Channon & van der Hulst 2011).

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), as can be seen in the signs of Figure 2. The fingers that are not selected are also constrained; they must be in a position 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 are part of phonological organization.

As noted, the articulating HC moves with respect to one major body area, either the head, the torso, or the non-dominant 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, more specific features within the major place category are needed, such as [high], [contralateral], or [proximal], called setting features. Adopting 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, since 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 above 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 non-dominant 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 non-dominant hand

In principle, the anomaly of having two anatomically identical articulators, the two hands, could result in highly anomalous phonological structure compared to spoken language – a kind of double phonology in which the hands operate independently. We know that this is potentially possible from the way the non-dominant hand (h2) patterns at higher meaningful levels of structure above the lexical item.

For example, the non-dominant 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). We see this in Figure 1b above. The non-dominant 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 h2 in the morpho-syntax is found in a subsystem called classifier constructions. In these constructions, the non-dominant 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, Meir, Padden, Sandler 2003; see also Johnston & Schembri 1999; Emmorey ed. 2003; Sandler & Lillo-Martin 2006; Meir & Sandler 2008; Risler 2007).

I will not deal here with levels of structure like these that are beyond phonology. I mention them to emphasize that the non-dominant hand does act independently at the 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 we 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 non-dominant hand (h2) in lexical signs can be either (a) a copy of the dominant hand articulator, with the same Hand Configuration, moving in the same manner at the same or mirror Locations, or it can be (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] Here I call the type of sign in which h2 is a copy of h1 *symmetrical signs*, and the type in which h2 is a Place of Articulation *h2-place signs*.

_____

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

The phonological structure of lexical two-handed signs, then, is severely constrained, in Movement, Location, and Hand Configuration, as reflected in all phonological models (Sandler 1993a, van der Hulst 1996, Blevins 1993). In the HT model, the non-dominant hand is subordinate to more general categories (namely, either Hand Configuration or Place of Articulation) that are independently required for phonology, and it is affected by rules together with other features of these higher level categories.

To capture these facts, it is represented in the tree as dominated by either the Hand Configuration node (in symmetrical signs) or the Place node (in h2-place signs). Figures 4a and b show 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. In the interests of space and clarity, details of representation are omitted here (See Sandler 1993a, 2006; and Crasborn 2011 for an overview).
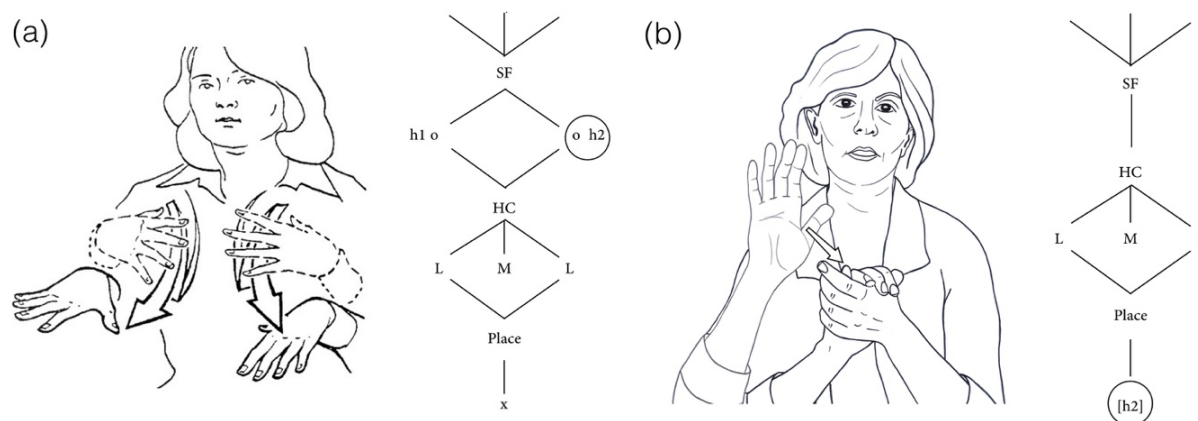

Figure 4. Two types of two-handed signs, with representations. (a) Symmetrical sign, ASL DRESS (figure reprinted with permission from Ursula Bellugi), (b) h2-place sign ASL MARRY.

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 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).

HC assimilation reveals the category membership of h2. If the HC category assimilates in a two-handed symmetrical sign like SLEEP^DRESS=NIGHTGOWN, then both hands assimilate. If HC assimilates in an h2-place sign like THINK^MARRY=BELIEVE, then only the dominant hand 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. We will see in Section 2.4 that the concatenation of signs in lexicalized compounds provides evidence for the syllable in sign language. We will later return to the non-dominant hand in the context of iconicity, in Section 3.

---

[4] Though the non-dominant 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 and BELIEVE is slightly different. This is explained in Section 2.4 and Note 9.
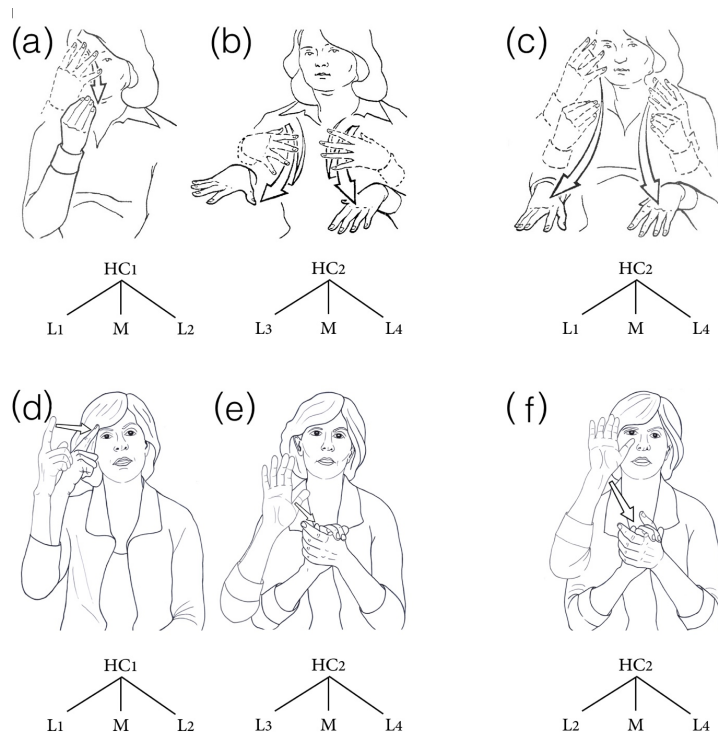
Figure 5. Reduction of two ASL compounds: truncation and hand configuration assimilation. (a-c) SLEEP^DRESS=NIGHTGOWN, second member a symmetrical sign, (d-f) THINK^MARRY+BELIEVE, second member an h2=place sign. SLEEP^DRESS=NIGHTGOWN is reprinted with permission from Ursula Bellugi.

2.4. The sign language syllable.

Most phonological models propose that sign languages have syllables, and that Movements are syllabic (Coulter 1982). A syllable is comprised of 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 branching Hand Configuration or orientation features. The sign MOTHER, represented in Figure 3, has 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 agued to be more sonorous than a path Movement alone (Sandler 1993b). If two

Movements occur sequentially, typically in complex signs such as 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 for attributing syllable status to Movements is that all signs must have Movements to be well-formed. This is the case even though the Movement typically carries very little information in uninflected signs. Movement features can be contrastive as in Figure 2c[6], but it 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 while the 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 Movement 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) both become monosyllabic by deletion of one Location from each and one Movement, leaving a single Movement between two locations[7]

The process of reduplication of compounds under various inflections provides more evidence for the syllable. A reduced, monosyllabic (LML) compound like

---

[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).

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, where the reduplicant is indicated with an arrow. This pattern suggests that the domain for reduplication in ASL is the final LML syllable.[10]

---

[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 non-dominant 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, while 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 Iris Berent (2013) to conclude in her book that spoken and signed languages are both the product of an innate phonological mind.
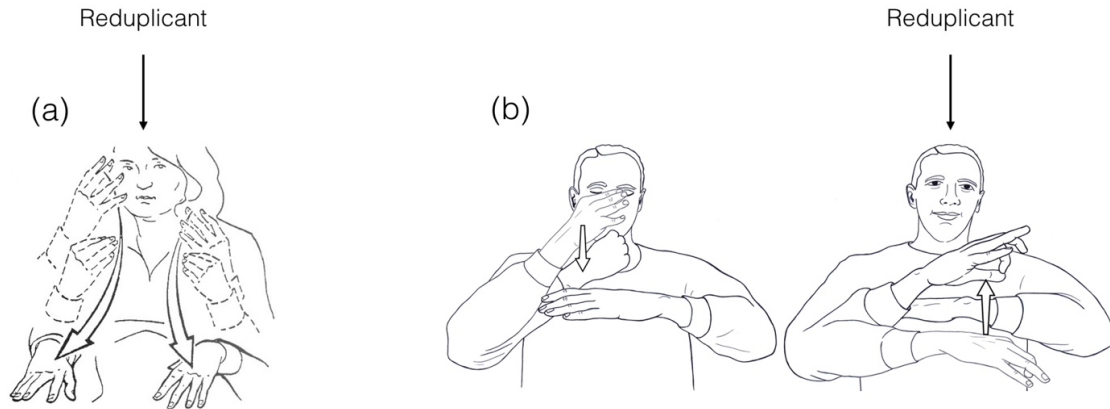
Figure 6. Reduplicants of monosyllabic compound NIGHTGOWN and disyllabic compound (SLEEP^SUNRISE) OVERSLEEP. Reduplication affects the final syllable.

This pattern cannot be explained on the basis of meaning, and, 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, Fant, Halle (1952), is seen as 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 another under certain circumstances, changing the degree of sonority in a syllable (see 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 them have not been resolved. What matters is

---

[11] The prosodic model is influenced by other models already mentioned, and by the Dependency Model of sign language phonology, which introduces unary features, head-dependency relationships among features, and other universal categorization principles (see Van der Hulst 1993).

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 comprise a coherent level of structure: phonology. The fact that sign languages do 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 (see de Boer, Sandler, Kirby, ed. 2012).

However, a sign language is not just one interesting language among many, like Walbiri or Igbo. Sign languages have properties in common with each other 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. We have already seen that the degree of simultaneity in sign languages (Vermeerbergen, Leeson, Crasborn ed. 2007) is very different from that of any spoken language (Ladd 2014). Figure 1b and the exposition following it 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. 'Form' can refer to phonological elements that comprise the sign, but also to the way linguistic elements are organized with respect to each other. 'Meaning' refers to lexical meaning as well as to more abstract and grammatical functions, such as plurality, anteriority and others. Saussure (1983) stressed the arbitrary relation between form and meaning as a central (though 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 in which Stokoe referred to iconicity in sign language as "that bugaboo of little minds" (Theoretical Issues in Sign Language Research, Gallaudet University, 1998).

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, Meir, Sandler 2005; Perniss, Thompson, Vigliocco 2010; Meir, Padden, Aronoff, Sandler 2013; Padden et al. 2013). Since phonology deals mainly with the formational level within the lexeme, as we have seen, 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 non-dominant 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, where random distribution would yield an overlap of only 13% (Lepic, Börstell, Belsitzman, Sandler 2016).

For example, the signs for DISCUSS in both ISL and ABSL are two-handed, shown in 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.
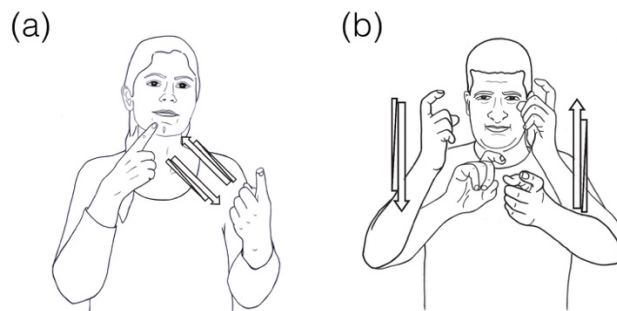

Figure 7. Iconically motivated use of non-dominant hand in signs for DISCUSS in (a) ISL and (b) ABSL.

The authors propose that four kinds of relations predict two-handedness well above chance in any sign language lexicon –(i) interaction, (ii) (relative) Location, (iii) external dimensions, and (iv) internal composition, all subsumed under the general notion of plurality, as they explain. Interaction is exemplified by DISCUSS in Figure 8, and external dimensions motivate BALL, as explained. Relative Location motivates signs such as ASL SUNRISE (the second sign in Figure 6d), in which the relations between the hands is motivated by the perceived relation between the sun and the horizon. Signs such as HOUSE in many sign languages represent the two component sides of a slanting roof. In all cases, the elements, though 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.

The present discussion has been limited to iconicity only as manifested by the non-dominant 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, van der Kooij 2002, Taub 2001, Meir 2010, Fernald & Napoli 2000, Wilbur 2008, 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 (2b), the mouth Place of Articulation is motivated as the Location of speech (similarly, SAY, ASK, etc.). While 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, Klamer2001), and 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', while [+voice] conveys 'big/heavy/coarse'. In laboratory studies (Perlman, Dale, Lupyan 2015, Edmiston, Perlman, Lupyan 2016), participants create meaningful categories with spontaneous iconic vocalizations, passed down from one 'generation' to another. Still, other experiments show that it is much more difficult to create correspondence

between form and meaning with auditory than with visual signals (Fay, Lister, Ellison, Goldin-Meadow 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 non-dominant 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 emergence of combinatorial form from holistic signals that are referential (Verhoef, Kirby, de Boer 2014), and iconic (Roberts, Lewandowski, Galantucci 2015). Sign languages alone can contribute empirical data to 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 a language that began to emerge about 80 years ago in a small village, Al-Sayyid Bedouin Sign Language (ABSL; Sandler, Meir, Padden, Aronoff 2005). Its origins are 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 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, Senghas, Coppola 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,Aronoff, Padden, Meir 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 differences across major category boundaries, such as the number of fingers selected or the major Place of Articulation, which tend to be contrastive in established sign languages (Sandler, Aronoff, Meir, Padden 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 above). The type of finger Movement is different as well between the two signers. In 8a, the finger position changes from partly open to partly closed (and is reduplicated), while in 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.
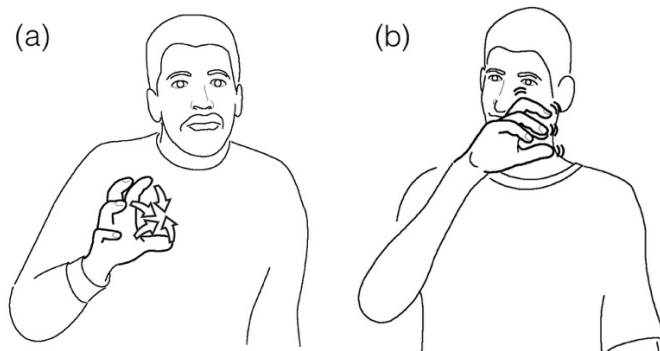

Figure 8. The sign DOG in ABSL produced at different major places of articulation and with different types of internal movement.

We were able to identify the kernels of phonological structuring. For example, signing within households, which we dubbed *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.

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 also found 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 hypothesize that only with repeated use, conventionalization, and automaticity is attention diverted from the form-meaning correspondence, allowing structural forces within the sign to takeover and to forge a formal system. Our findings led us to conclude that a language can be fully functional before systematic phonology has crystallized (Sandler, Aronoff, Meir, Padden 2011), suggesting that culture is a component in 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.

We have seen that 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 and 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. Since there is little sequentiality within the 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 production factors, discussed here, differences in visual vs. auditory perception, together with memory capacities, also shape phonological form in each modality (see Emmorey 2002, Brentari 2002, Meier 2002).

One obvious reality is that the inventory of phonological features and feature categories is not universal. Since these are tied to articulatory systems in both modalities, the importance of phonetics in shaping phonology becomes clearer by comparing 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 (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, while 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 further, not only why sign language phonology is so iconic, but 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' can't 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 interaction among the physical system, cognitive factors like 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.

Literature Cited
Anderson SR. 2016. Synchronic *vs*. diachronic explanation and the nature of the language faculty. *Annu. Rev. of Linguistics*. 2:11-31.
Archangeli DB., Pulleyblank DG. 1994. *Grounded Phonology*, Vol. 25. MIT Press
Aronoff M, Meir I, Padden C, Sandler W. 2003. Classifier complexes and morphology in two sign languages. In *Perspectives on Classifier*

Constructions in Sign Languages, ed. K Emmorey, pp. 53-84. Mahwah, NJ: Lawrence Erlbaum Associates.

Aronoff M, Meir I, Sandler W. 2005. The paradox of sign language morphology. *Language*. 81(2): 301–34.

Battison R. 1978. *Lexical Borrowing in American Sign Language*. Silver Spring: Linstok Press.

Berent I. 2013. *The Phonological Mind.* Cambridge UK: Cambridge University Press.

Blevins J. 1993. The nature of constraints on the nondominant hand in ASL. See Coulter 1993, pp. 43-62.

Blevins J. 2004. *Evolutionary Phonology: The Emergence of Sound Patterns.* Cambridge: Cambridge University Press.

Bloomfield L. 1933. *Language*. New York: Holt.

Boyes-Braem PK. 1981. *Features of the handshape in American Sign Language*. PhD thesis, Univ. Calif., Berkeley, CA.

Brentari D. 1990. *Theoretical foundations of American sign language phonology*. PhD thesis, Univ. Chic., Chicago, IL.

Brentari D. 1998. *A Prosodic Model of Sign Language Phonology*. Cambridge, MA: MIT Press.

Brentari D. 2002. Modality differences in sign language phonology and morphophonemics. See Meier, Cormier, Quinto-Pozos 2002, pp. 35-64.

Brentari D. 2011. Handshape in sign language phonology. See Van Oostendorp, Ewen, Hume, Rice 2011,pp. 195–222.

Brentari D, Goldsmith JA. 1993. Secondary licensing and the non-dominant hand. See Coulter 1993, pp. 17–41.

Browman C, Goldstein L. 1992. Articulatory phonology: An overview. *Phonetica. 49*:155-180.

Bybee J. 2001. *Phonology and Language Use*. Cambridge UK: Cambridge University Press.

Carr JW, Smith K, Cornish H, Kirby S. 2016. The cultural evolution of structured languages in an open-ended, continuous world. *Cognitive Science*.

Channon R, Van der Hulst H. 2011. Are dynamic features required in signs?. See Channon, Van der Hulst 2011,p.229.

Channon R, Van der Hulst H, Ed.2011. *Formational Units in Sign Languages*, Vol. 3. Berlin/Boston/Nijmegen: Walter De Gruyter, Ishara Press.

Chomsky N. 2007. Of minds and language. *Biolinguistics*. *1*:9-27.

Chomsky N, Halle M. 1968. *The Sound Pattern of English*. New York: Harper & Row.

Clements GN. 1985. The geometry of phonological features. *Phonology Yearb*. 2:225–252.

Corina D. 1993. To branch or not to branch: Underspecification in ASL handshape contours. See Coulter 1993, pp. 63–94.

Coulter G. 1982. On the nature of ASL as a monosyllabic language. In*Annu. Meet.of the Linguistic Society of Am*. San Diego, CA.

Coulter G, ed. 1993. *Phonetics and Phonology: Current Issues in ASL Phonology*, Vol. 3. San Diego, CA: Academic Press.

Crasborn OA. 2011. The other hand in sign language phonology. SeeVan Oostendorp, Ewen, Hume, Rice 2011, pp. 223-240.

Dachkovsky S, Healy C, Sandler W. 2013. Visual intonation in two sign languages. *Phonology*. 30(2):211-52.

De Boer B, Sandler W, Kirby S. 2012. New perspectives on duality of patterning. In *Special Issue of Language and Cognition*, Vol. 4(4), ed. B De Boer, W Sandler, S Kirby, pp. 251-59.

De Boer B, Zuidema W. 2010. Multi-agent simulations of the evolution of combinatorial phonology. *Adaptive Behav.*18(2):141–54

De Saussure F. 1983. *Course in General Linguistics*, trans. *R Harris*. London: Duckworth.

Dingemanse M, Blasi DE, Lupyan G, Christiansen MH, Monaghan P. 2015. Arbitrariness, iconicity and systematicity in language. *Trends in Cognitive Sciences*. 19(10):603-615.

Edmiston P, Perlman M, Lupyan G. 2016. The fidelity of iterated vocal imitation. In *Evolang 11 Conference*, New Orleans.

Emmorey K. 2002. *Language, Cognition, and the Brain: Insights from Sign Language Research*. Mahwah, NJ*:* Lawrence Erlbaum Associates.

Emmorey K, ed. 2003. *Perspectives on Classifier Constructions in Sign Language*. Mahwah, NJ: Lawrence Erlbaum Associates.

Emmorey K, Corina D. 1990. Lexical recognition in sign language: Effects of phonetic structure and morphology. *Percept.&Mot. Skills*. 71(3f):1227–52.

Evans N, Levinson SC. 2009. The myth of language universals: Language diversity and its importance for cognitive science. *Behavioral & Brain Sciences*. 32(5):429–48.

Fay N, Lister CJ, Ellison TM, Goldin-Meadow S. 2015. Creating a communication system from scratch: Gesture beats vocalization hands down. *Language by Mouth and by Hand.* p.168.

Fernald TB, Napoli DJ. 2000. Exploitation of morphological possibilities in signed languages: Comparison of American Sign Language with English. *Sign Lang. & Linguistics*. 3(1):3-58.

Fuks O. 2014. Gradient and categorical: Handshape's two semiotic dimensions in Israeli Sign Language. *J. of Pragmat*. 60:207-225.

Goldsmith JA. 1976. *Autosegmental phonology*. PhD thesis, Massachusetts Institute of Technology, Cambridge, MA.

Grosjean F. 1980. Spoken word recognition processes and the gating paradigm.*Percept.& Psychophysics*. 28(4):267–83.

Hamano SS. 1986. *The sound-symbolic system of Japanese*. PhD thesis,Univ. Fla, Gainesville, FL.

Hockett C. 1960. The origin of speech. *Scientific American*. 203:88–96.

Israel A, Sandler W. 2011. Phonological category resolution in a new sign language: A comparative study of handshapes. See Channon, Van der Hulst 2011, pp. 177-202.

Jackendoff R. 2011. What is the human language faculty?: Two views. *Language.* 87(3):586-624

Jakobson R, Fant G, Halle M. 1952.*Preliminaries to Speech Analysis:The Distinctive Features and their Correlates*. Cambridge, MA: MIT Press

Johnston T, Schembri A. 1999. On defining lexeme in a signed language. *Sign Lang. & Linguistics.* 2(2):115-85.

Kegl J, Senghas A, Coppola M. 1999. Creation through contact: Sign language emergence and sign language change in Nicaragua. In *Language Creation and Language Change: Creolization, Diachrony, and Development*, ed. M DeGraff, pp. 197–237. Cambridge, MA: MIT Press.

Kisch S. 2008. The social construction of deafness in a Bedouin community in the Negev. *Medical Anthropology*. 27(3):283–313.

Klamer M. 2001. Expressives and iconicity in the lexicon. *Typological Studies in Language.* 44:165-82.

Klima ES, Bellugi U. 1979. *The Signs of Language*. Cambridge, MA: Harvard University Press.

Kyle JG, Woll B. 1984. *Sign Language: The Study of Deaf People and their Language*. Cambridge, UK: Cambridge University Press.

LaddDR. 2014. *Simultaneous Structure in Phonology.* Oxford: Oxford University Press

Lepic R, Börstell C, Belsitzman G, Sandler W. 2016. Taking meaning in hand: Iconic motivations in two-handed signs. *Sign Lang.& Linguistics*.19(1)

Liddell SK. 1984. THINK and B E L IEVE: Sequentiality in American Sign Language. *Language.* 60: 372–92.

Liddell SK. 2003. *Grammar, Gesture, and Meaning in American Sign Language*. Cambridge University Press.

Liddell SK, Johnson RE. 1986. American Sign Language compound formation processes, lexicalization, and phonological remnants. *Nat. Lang.& Linguistic Theory*. 8:445–513.

Liddell SK, Johnson RE. 1989. American Sign Language: The phonological base. *Sign Lang. Stud.*64(1): 195–277.

Mak J, Tang G. 2011. Movement types, repetition, and feature organization in Hong Kong Sign Language. See Channon, Van der Hulst 2011, pp. 315-37.

Mandel M. 1981. *Phonotactics and morphophonology in American Sign Language*. PhD thesis, Univ. Calif., Berkeley, CA.

Meier RP. 1991. Language acquisition by deaf children. *American Scientist*. 79(1):60-70.

Meier RP. 2002. Why different, why the same? Explaining effects and non-effects of modality upon linguistic structure in sign and speech. See Meier, Cormier, Quinto-Pozos 2002, pp. 1-25.

Meier RP, Cormier K, Quinto-Pozos D, ed. 2002. *Modality and Structure in Signed and Spoken Languages.* Cambridge, UK: Cambridge University Press.

Meir I. 2002. A cross-modality perspective on verb agreement. *Nat. Lang.& Linguistic Theory*. 20(2):413-50.

Meir I. 2010. Iconicity and metaphor: Constraints on metaphorical use of iconic forms. *Language.* 86(4):865-96.

Meir I, Padden C, Aronoff M, Sandler W. 2013. Competing iconicities in the structure of languages. *Cognitive Linguistics*. 24(2):309-43.

Meir I, Sandler W. 2008. *A Language in Space: The Story of Israeli Sign Language*. Mahwah, NJ: Lawrence Erlbaum Associates.

Mielke J. 2008. *The Emergence of Distinctive Features.*Oxford: Oxford University Press.

Miller C. 1994. Simultaneous constructions in Quebec Sign Language. In *Word-order Issues in Sign Language, Working Papers,* ed. M Brennan, G Turner, pp. 89-112. Durham: International Sign Linguistics Association.

Napoli DJ, Sutton-Spence R. 2010. Limitations on simultaneity in sign language. *Language.*86(3):647-62.

Nespor M, Sandler W. 1999. Prosody in Israeli Sign Language. *Lang.& Speech*. 42(2-3):143-76.

Newport EL, Meier RP. 1985. The acquisition of American Sign Language. In *The Cross-Linguistic Study of Language Acquisition*, ed. DI Slobin, pp. 881–938. Hillsdale, NJ: Lawrence Erlbaum Associates.

Nilssen A. 2007. The non-dominant hand in a Swedish Sign Language discourse. In *Amsterdam Studies in the Theory and History of Linguistic Science.*series 4(281):163.

Ohala, John. 1996. The frequency code underlies the sound symbolic use of voice pitch. In *Sound Symbolism*, ed. L Hinton, J Nichols, JJ Ohala, pp. 325-47. Cambridge University Press.

Padden C. 1988. *Interaction of Morphology and Syntax in American Sign Language: Outstanding Dissertations in Linguistics*. New York: Garland. (Originally distributed as: PhD thesis, Univ. Calif., San Diego, CA.)

Padden CA, Meir I, Hwang SO, Lepic R, Seegers S, Sampson T. 2013. Patterned iconicity in sign language lexicons. *Gesture*. 13(3):287-308.

Perlman M, Dale R, Lupyan G. 2015. Iconicity can ground the creation of vocal symbols. *Royal Society Open Science.*2(8):150-52.

Perlmutter DM. 1992. Sonority and syllable structure in American Sign Language. *Linguistic Inquiry*. 23(3):407–42.

Perniss P, Thompson R, Vigliocco G. 2010. Iconicity as a general property of language: Evidence from spoken and signed languages. *Frontiers in psychology*. 1:227.

Pierrehumbert J. 2001. Exemplar dynamics: Word frequency, lenition, and contrast. In *Frequency and the Emergence of Linguistic Structure*, ed. J Bybee, P Hopper, pp. 137-57. Amsterdam: John Benjamins.

Prince A, Smolensky P. 2004. *Optimality Theory: Constraint Interaction in Generative Gramma*r. Oxford, UK: Blackwell.

Risler A. 2007. A cognitive linguistic view of simultaneity in process signs in French Sign Language. In *Amsterdam Studies in the Theory and History of Linguistic Science.*series 4(281):73.

Roberts G, Lewandowski J, Galantucci B. 2015. How communication changes when we cannot mime the world: Experimental evidence for the effect of iconicity on combinatoriality. *Cognition*. 141:52-66.

Sandler W. 1986. The spreading hand autosegment of American Sign Language. *Sign Lang. Stud.*50(1):1-28.

Sandler W. 1987. Assimilation and feature hierarchy ASL. In *Chicago Linguistics Society Parasession on Autosegmental Phonology,* ed. A Bosch, B Need, E Schiller, pp. 266-78.

Sandler W. 1989. *Phonological Representation of the Sign: Linearity and Nonlinearity in American Sign Language*. Dordrecht: Foris.

Sandler W. 1993a. Hand in hand: The roles of the nondominant hand in sign language phonology. *Linguistic Rev.* 10(4):337-390.

Sandler W. 1993b. A sonority cycle in American Sign Language. *Phonology.*10(2):243-79.

Sandler W. 1999. Cliticization and prosodic words in a sign language. In *Studies on the Phonological Word*, ed. T Hall, U Kleinhenz, p. 223. Amsterdam: Benjamins.

Sandler W. 2006. Phonology, phonetics, and the nondominant hand. In *Papers in Laboratory Phonology: Varieties of Phonological Competence*, ed. L Goldstein, DH Whalen, C Best, pp. 185–212. Berlin: Walter de Gruyter.

Sandler W. 2010a. Prosody and syntax in sign language. In *Transactions of the Philological Society*. 108(3):298-328.

Sandler W. 2010b. The uniformity and diversity of language: Evidence from sign language. Response to Evans and Levinson. *Lingua.* 120(12):2727-32.

Sandler W. 2011. The phonology of movement in sign language. In *Blackwell companion to phonology*, ed. M Van Oostendorp, C Ewen, K Rice, E Hume, pp. 577-603. Oxford: Wiley-Blackwell.

Sandler W. 2012a. Visual prosody. In *Sign Language: An International Handbook*, Vol. 37, ed. R Pfau, M Steinbach, B Woll, pp. 55-76. Berlin: Walter de Gruyter.

Sandler W. 2012b. The phonological organization of sign languages. *Lang. & Linguistics Compass*. 6(3):162-82.

Sandler W. 2012c. Dedicated gestures and the emergence of sign language. *Gesture.*12(3):265-307.

Sandler W, Aronoff M, Meir I, Padden C. 2011. The gradual emergence of phonological form in a new language. *Nat. Lang. & Linguistic Theory*. 29(2):503–43.

Sandler W, Aronoff M, Padden C, Meir I. 2014. Language emergence: Al-Sayyid Bedouin Sign Language. In *The Cambridge Handbook of Linguistic Anthropology*, ed. J Sindell, P Kockelman, N Enfield, pp. 250-84. Cambridge: Cambridge University Press.

Sandler W, Lillo-Martin D. 2006. *Sign Language and Linguistic Universals*. Cambridge, UK: Cambridge University Press.

Sandler W, Meir I, Padden C, Aronoff M. 2005. The emergence of grammar: Systematic structure in a new language. *Proc. of the Natl. Academy of Sciences of the U. S. A.* 102(7):2661-65.

Stokoe WC. 1960. Sign language structure: An outline of the visual communication systems of the American deaf. In *Studies in Linguistics: Occasional Papers*. Buffalo: University of Buffalo.

Stokoe WC, Casterline DC, Croneberg CG. 1965. *A Dictionary of American Sign Language on Linguistic Principles*. Washington, DC: Gallaudet College Press. [Reprinted in 1976 by Linstok Press.]

Strickland B, Geraci C, Chemla E, Schlenker P, Kelepir M, Pfau R. 2015. Event representations constrain the structure of language: Sign language as a window into universally accessible linguistic biases. *Proc. of the Natl. Academy of Sciences.* 112(19):5968–73

Supalla T. 1986. The classifier system in American Sign Language. In *Noun Classes and Categorization*, ed. C Craig, pp. 181–214. Philadelphia: John Benjamins.

Taub SF. 2001. *Language from the Body: Iconicity and Metaphor in American Sign Language*. Cambridge: Cambridge University Press.

Ultan R. 1978. Size-sound symbolism. In *Universals of Human Language*,Vol. 2,ed. J Greenberg, C Ferguson, E Moravchik, pp. 525-68. Stanford University Press.

Van der Hulst H. 1993. Units in the analysis of signs.*Phonology*.10(2):209–41.

Van der Hulst H. 1996. On the other hand. *Lingua*. 98(1):121-43

Van der Kooij E. 2002. *Phonological categories in sign Language of the Netherlands: The role of phonetic implementation and iconicity*. PhD thesis, Leiden Univ., Utrecht, Netherlands.

Van Oostendorp M, Ewen CJ, Hume EV, Rice K, ed. 2011. *The Blackwell Companion to Phonology, 5 Volume Set* (Vol. 2). Oxford: Wiley-Blackwell.

Verhoef T, Kirby S, De Boer B. 2014. Emergence of combinatorial structure and economy through iterated learning with continuous acoustic signals. *Journal of Phonetics.* 43C:57-68.

Vermeerbergen M, Leeson L, Crasborn OA, ed. 2007.*Simultaneity in Signed Languages, Form and Function.* Vol. 281. Amsterdam: John Benjamins Publishing.

Wedel AB. 2006. Exemplar models, evolution and language change. *The Linguistic Rev.* 23(3):247-74.

Wilbur RB. 1993. Syllables and segments: Hold the movement and move the holds. In *Current Issues in ASL Phonology*, Vol. 3, ed. GR Coulter, pp. 135–68. New York/San Francisco/London: Academic Press.

Wilbur RB. 1999. Stress in ASL: Empirical evidence and linguistic issues. Lang. and Speech. 42(2-3):229-250.

Wilbur RB. 2000. Phonological and prosodic layering of non-manuals in American Sign Language. In *The Signs of Language Revisited: An anthology to honor Ursula Bellugi and Edward Klima*, ed. K Emmorey, H Lane, pp. 215–44. Mahwah, NJ: Lawrence Erlbaum Associates.

Wilbur RB. 2008. Complex predicates involving events, time and aspect: Is this why sign languages look so similar? In *Theoretical Issues in Sign Lang. Res.,* ed. J Quer*, pp. 217-50.

Wilbur RB, Patchke C. 1999. Syntactic correlates of brow raise in ASL. *Sign Lang. & Linguistics*. 2:3–30.