1. Sign language phonology – theoretical perspectives

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1. Introduction

In this chapter, we provide an overview of the 'phonology' of sign languages (admittedly biased toward our own work, but with ample discussion of, and references to work by many other researchers). In Section 2, we will first focus on presenting *constraints* on sign structure. In doing so we use our own model for the overall structure of signs as a frame of reference, although our objective is not to argue for it or imply that this is the only defensible proposal.[1] Then, in Section 3, turning to *rules,* we will argue that sign languages do not seem to display a type of phonological rules that is typical of spoken languages, namely rules that account for allomorphy. To explain this, we will distinguish between what we call *utterance phonology* and *grammatical phonology*. While sign languages certainly display utterance phonology, as we will show (effects of automatic assimilations, co-articulation, and reduction processes), we will argue that we do not find what we will call grammatical phonological rules which account for allomorphic alternations, although we will consider possible objections to this claim. While the point of establishing phonological structure in signs rests on the claim that signs consist of meaningless parts (like the consonants and vowels in spoken languages are meaningless parts), in Section 4, we discuss views that question the alleged 'meaningless' character of all phonological building blocks. Recognizing meaning-bearing units[2] will provide a possible explanation for why sign languages seem to disallow allomorphic rules. We will then propose that the lack of grammatical phonological rules that regulate allomorphy in sign phonology is compensated for by rules of a different kind (which might be called phonological). Such rules account for systematic form-meaning relationships internal to alleged 'monomorphemic' signs.[3] Section 5 presents some of our conclusions.

2. Basic units and constraints

Up until 1960, sign languages were not regarded as fully-fledged natural languages that possess morpho-syntactic structure and an independent level of phonological structure. Recognition of phonological compositionality, which was due to the groundbreaking work of William Stokoe (Stokoe 1960), suggested that sign languages display duality of patterning which had long been identified as a pivotal property of spoken languages (Martinet 1955; Hockett 1960). Stokoe proposed a transcription system for signs that replaced holistic drawings and verbal descriptions by a finite number of graphic symbols for what he perceived as separate meaningless parts or 'aspects' of the sign: the handshape, the movement of the hand, and the location in front of or on the body.[4] The ideas of Stokoe were further developed in the sense that other properties of signs were added to his list of major units. Also, the major units were subsequently decomposed into distinctive features. We will provide examples of such additional proposals in subsequent subsections.

While it is possible to recognize and transcribe phonetic properties of signs, it simply does not follow automatically that these distinctions have a reality in the mind of the signer in terms of storage in memory and language processing. Groundbreaking work on these issues was done by a research group at the Salk Institute during the 1970s, resulting in the Klima and Bellugi volume (1979), a must-read for sign language researchers. Performing recall experiments, they showed that percepts of signs in short-term memory are compositional. Importantly, they also showed that errors were in the direction of formational similarity and not meaning. Studying 'slips of the hands', they argued for the likelihood of compositionality in the articulatory phase (see Gutierrez & Baus, Chapter 3). Finally, they showed that American Sign Language (ASL) users can make judgments about what they considered well-formed or ill-formed for ASL, which supports formal compositionality in the lexicon.

We will now turn to our review of phonotactic constraints in sign languages. It is well known that spoken languages can differ quite dramatically in the constraints that specify the inventory of segments and the ways in which these segments can be combined, despite the fact that almost all constraints follow universal 'markedness' principles which regulate symmetry in inventories, sonority sequencing in syllable structure, and assimilation in sequences, and the general fact that 'more complex structures' imply the presence of 'less complex structures'. While the phonological form of sign languages is likewise subject to phonotactic constraints, there is much less evidence for cross-linguistic differences in this respect, although, arguably, there are currently not enough data from typological cross-linguistic studies to know to what extent different sign languages can differ.

Putting aside for the moment whether sign languages have units that formally or functionally can be compared to such notions as vowel, consonant, or syllable (see Section 4 for discussion), we would find evidence for *language-specific* (context-free[5]) constraints if sign languages differed in their inventories of handshape, movement, or locations. Context-sensitive constraints (assuming that the context does not have to be linear) would capture restrictions on the manner in which these major units can be combined to make up signs. While constraints of such kinds certainly exist, it seems to be the case that sign languages only display minor differences in terms of their inventories of the major units (as was already shown in Klima & Bellugi's (1979) comparison of ASL and Chinese Sign Language), as well as in the ways in which these units combine into signs. But, again, only few systematic typological studies have been done.[6] However, the sets of major units as found in sign languages do not seem to be random (just like vowel and consonant inventories are not random), and while this perhaps can be explained on the basis of phonetic principles of articulation and perception (as has also been argued for spoken languages), it would seem that an account in terms of smaller building blocks (features) provides insight into these inventories. Thus, even though perhaps most constraints appear to generalize over sign languages as a whole (rather than differentiating between them), they nonetheless, like in spoken languages, provide a window on the compositional structure of the major sign units in terms of features. Given a feature analysis, we can, for example, make distinctions between simpler and more complex units, which allows for implicational statements. As in the case of segmental inventories of spoken languages, the occurrence of more complex units implies the occurrence of simpler and more frequently occurring units, which are often called ‘unmarked’. Given the right set of features, simpler (and thus less marked) units have a simpler featural structure (see Battison 1978; Sandler 1996b).

(1) Examples of unmarked handshapes, locations, and movements[7]
  a. Handshapes: B (), S (), 1 ()
  b. Locations: Neutral space, Chest
  c. Movements: Downward path, End contact (hand touching a location)

Given that signers are able to judge whether or not a given handshape belongs to their language, we may conclude that they tap into featural co-occurrence constraints that capture the systematic structure of the handshape inventory of their language. This ability would not be so easily accounted for if we assumed that signers simply memorize a list of ‘atomic’ handshapes, although people are certainly capable of memorizing lists and of identifying an item that is not in the list as ‘unfamiliar’. The argument from well-formedness gains strength as we consider larger inventories such as the inventory of all signs. Hence, in addition to studies that establish featural co-occurrence constraints that define inventories of basic units such as handshapes, movements, and locations, we would also expect to find context-sensitive constraints that limit how the major units can be combined within the total inventory of signs. The examples in (2) show that not all locations allow for all handshapes, movements, and orientations, and vice versa. Again, while such constraints have been observed, there is still not enough evidence to suggest different sign languages differ systematically in this respect.

(2) Examples of context-sensitive constraints
  a. * Two-handed symmetrical sign:
     HS (both hands): pinky+index extended (), MOV: rotation, LOC: cheek
  b. * Two-handed asymmetrical sign:
     Weak hand: R-handshape (), strong hand: B (), ORI: palm of hand, MOV: tapping (end contact)
  c. * One-handed sign:
     HS: index+thumb extended (), MOV: flexing, ORI: back of hand, LOC: lower arm

It would appear that some observed constraints have a natural phonetic basis in that the non-occurring combinations either are virtually impossible to articulate or, while possible, seem phonetically ‘hard’, or even ‘painful’. However, this is not the case for the examples in (2).

There is a family of general phonotactic constraints on the internal make-up of, specifically, monomorphemic[8] signs in terms of the major units of signs. These various constraints all have in common that they demand *a single occurrence* of each major unit per sign. We first paraphrase these constraints in an informal manner in (3a–c) and then show how a more precise formulation motivates a feature composition of the major sign units.

(3) a. The one-handshape constraints (1H): Each sign has only one handshape (Mandel 1981)
b. The one-location constraint (1L): Each sign has only one major location (Battison 1978)
c. The one-movement constraint (1M): Each sign has only one movement (Sandler 2011)

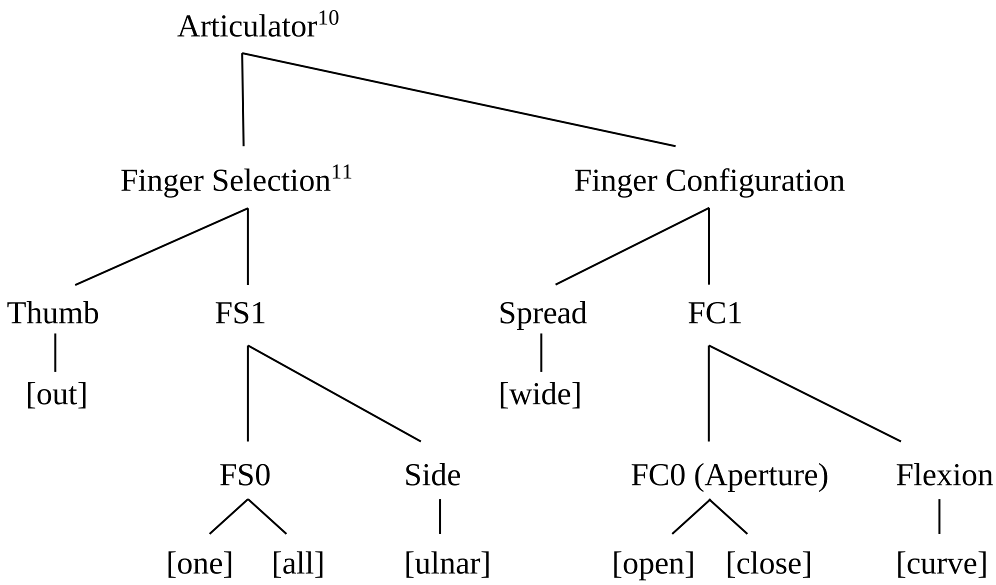
In subsequent sections, we will discuss and reformulate these constraints and show how they can be accounted for in a phonological model of sign structure, raising the question whether the domain of these constraints is the word (i.e., the whole sign), the morpheme, or the syllable.

We will now proceed with a technical account of each of the major units. In doing so, we incorporate the idea that the major units are not a list, but rather form a hierarchical structure. This idea, introduced in Sandler (1987), was inspired by models of 'feature geometry' for spoken language (Clements 1985).

2.1. Handshape

Handshape is not holistic (as in Stokoe's original model), but rather internally complex, acknowledging a *selected finger unit* and a so-called *finger position unit*. The selected finger unit refers to the fingers that are 'foregrounded' (selected), as opposed to the 'backgrounded' (non-selected) ones (see Mandel 1981: 81–84). Mostly, foregrounded fingers are the fingers that are in a specific configuration, while backgrounded fingers are folded.[9] Both *Finger Selection* and *Finger Configuration* have a further finer substructure in terms of features that has been motivated in various studies (Sandler 1989; van der Hulst 1993, 1995; van der Kooij 2002); see the structure in (4).

(4)



Finger Selection is represented with various sets of features in different models. Some models have a feature for each finger (e.g., Sandler 1989; Corina & Sandler 1993; Uyechi 1994; Brentari 1998). The drawback of such proposals is that they overgenerate the set of attested handshapes for all sign languages that have been studied to date. In a more restricted model that is in accordance with the principles of *Dependency Phonology*, van der Hulst (1993, 1995) and van der Kooij (2002) have proposed a system of unary phonological primes to characterize handshapes. The Finger Selection node in (4) dominates two features, [one] and [all], which can occur by themselves or in combination. If combined, a head-dependency relationship between the two features is established (indicated by '|' in Table 1.1). This allows four possible structures, which, in conjunction with the specification of the side of the hand [ulnar] gives us eight possible sets of selected fingers. In combination with Finger Configuration, these features can capture all contrastive handshapes.

Table 1.1. Finger Selection specifications ('|' indicates head-dependency relationship)

<table>
<tr><th>Finger Selection</th><th>one</th><th>one
|
all</th><th>all
|
one</th><th>all</th></tr>
<tr><td></td><td>index</td><td>index and middle</td><td>index and middle and ring</td><td>all four</td></tr>
<tr><td>side: ulnar</td><td>pinky</td><td>index pinky</td><td>middle and ring and pinky</td><td></td></tr>
</table>

The phonetic interpretation of [one] is that one finger is selected. In principle, this could be any finger, but the default is the index finger. The default can be overridden by specifying the Side value [ulnar] 'pinky side'. This table does not give us a representation for the middle and ring finger occurring together or separately. Signs in which these two fingers occur together are not attested, and the two fingers occurring separately are used interchangeable (except in counting) in Sign Language of the Netherlands (NGT). The issue of separate occurrence of the middle fingers, which are rare at best, will not be discussed here.[12]

The position of the thumb is often predictable.[13] If Finger Configuration specifications for aperture are specified, its position is 'opposed to the selected fingers', as in 'closed baby-beak' (). In the initial posture of an opening movement, the thumb often restrains the selected fingers. The feature [out] must be specified, however, when the thumb is the only selected digit or when it co-occurs with other selected fingers, in which case configuration features apply to all selected fingers, including the thumb.

Finger Configuration features specify the 'position' of the selected fingers. The central (head) unit of Finger Configuration is taken to be *Aperture* as it is found to be the most frequent configuration of selected fingers. The aperture features [open] and [close] refer to the opposition relation between the selected fingers and the thumb. Unlike the combination of features in the Finger Selection node, resulting in different sets of selected fingers, combinations of the two aperture features do not encode intermediate degrees of opening, but rather are interpreted dynamically, as opening (closed to open) and closing (open to closed) movements. So-called *hand-internal movements* are, like all other movements, represented as a sequence of features resulting from a branching node (such as aperture). We take the difference between the simultaneous interpretation of [one] and [all] vs. the sequential interpretation of [open] and [close] to be a manifestation of the difference between the head and dependent status of Finger Selection and Finger Configuration, respectively.

For flexion of the fingers, we found a single feature [curve] to be sufficient. Handshapes that apparently have flexion of the base joint only are either analyzed as alloshapes of a handshape without base joint flection (as, possibly, in the ASL sign GROW, in which the palm of the whole flat hand or the palm side of the fingers is level with the (horizontal) top of the indicated referent), or as manifestations of path movements (as in the NGT sign COME-HERE). This implies that 'handshape' is not a phonological unit but rather an abbreviation for the visual manifestation of the Finger Selection and Finger Configuration features. The default option of [curve] means that all joints are bent to indicate a round shape. So-called 'claw' shapes, in which only the non-base joints are flexed, are treated as tensed versions of curved shapes or resulting from contact with the Place.

Finally, Width also has only one feature and is only used when the selected fingers need to be visually separated (abducted) so that they can be used as individual entities (in the signs WALK or FIVE) or when the selected fingers are spread apart to express the meaning of vastness (as in ROOM).

Our hypothesis is that the sets of selected fingers in combination with the configuration features in (4) can capture the contrastive handshapes in most or all sign languages (but see, for example, Nyst (2007)). This can only be established by comparing phonological analyses of various sign languages along the same lines. Some sign languages appear to have a more complex handshape inventory, mostly as a result of activating multiple finger selection or configuration features.[14] However, meaning can often be associated with these complex handshapes (e.g., in borrowings from Chinese fingerspelling or character signs (Fischer & Gong 2010), or the male-female paradigm in several Asian sign languages such as Japanese Sign Language (Peng 1974) and Taiwan Sign Language (Tsay & Myers 2009)). These complex handshapes could in principle be accommodated by complex (i.e., branching) head nodes, a solution that may be licensed by morphologically complex structures. The question of which phonetic properties of all occurring handshapes (and other properties of signs for that matter) fall under the purview of phonological specification is addressed in Section 4 below, where we argue that some phonetic properties are direct iconic projections from the sign's meaning.

As the examples in (5) demonstrate, the one-handshape-constraint must allow that certain *changes* in the handshape (hand-internal movements) are possible (such as opening, closing or bending), but these are restricted to movement of the joints of the selected fingers, as specified in the aperture node. The examples in (5) are from NGT and are illustrated in Figure 1.1.

(5) Handshape changes
   a. Aperture change: closing – NICE: index finger selected
   b. Aperture change: opening – SPRING: all fingers selected
   c. Aperture change: closing + curve – WANT: all fingers selected

NICE

SPRING

WANT

Figure 1.1. Hand internal movements apply to one set of selected fingers per sign (© NGT Global SignBank: Crasborn et al. 2019)

A more precise formulation of the 1H-constraint is therefore:

(6) The one-handshape constraint (revised): Each sign has only one selected finger specification (Mandel 1981)

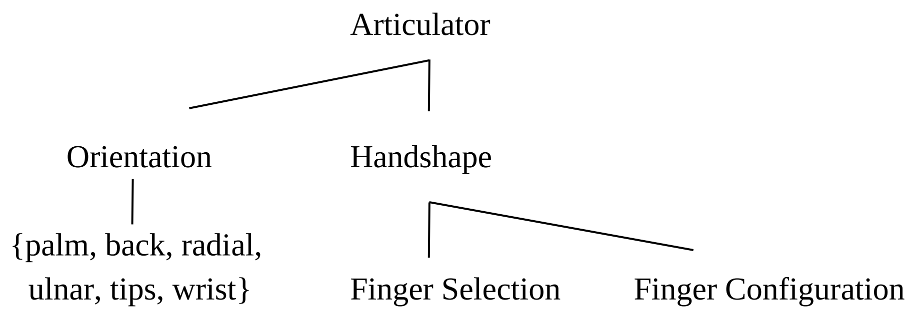
We will later discuss whether this is a constraint on the phonological complexity of morphemes or on syllables. If the notion of syllable is invoked (see Section 4), it is often observed that morphemes tend to be monosyllabic.

2.2. Orientation

Stokoe's notation introduced various symbols for specifying the orientation of the hand (mainly referring to the articulatory positions (rotation) of the lower arm). Later, researchers introduced orientation as a major sign unit that Stokoe found to be distinctive in some signs (the standard reference is Battison (1978); see van der Hulst (to appear) for details.). Several sign phonologists took orientation to be *the absolute direction* (in space) of the palm and/or the fingers. Whereas this may be a possible distinction, it was observed that often, there is much variation in the so-called absolute orientation (e.g., 'palm down' or 'fingertips contralateral') in actual signing. Moreover, the description in terms of absolute orientation cannot capture the similarity in underlying forms of various inflecting predicative signs (such as NGT VISIT). This has led to a proposal of describing orientation *in relative terms*, i.e., as the part of the hand that points in the direction of the end of the movement (the final setting) or towards the specified location (Crasborn & van der Kooij 1997).[15] Relative orientation specifies a part of the hand regardless of its specific configuration and includes palm side, back of the hand side, radial (thumb) side, ulnar (pinky) side, tips of selected fingers, and wrist side of the hand.[16]

Sandler (1989) has proposed to group orientation under a node 'hand configuration', which corresponds to what we called the articulator in (4). In (7), we rename the original articulator node as 'handshape' and use the label 'articulator' for the higher node, which dominates handshape and orientation.

(7)



The evidence for this grouping is based on assimilation phenomena, discussed in Sandler (1987), in lexicalized compounds in ASL and Israeli Sign Language (ISL), which show that either the orientation spreads by itself, or combined with the entire handshape. Since orientation can spread by itself, van der Hulst (1993) took this to be the dependent node (on the assumption that dependent nodes have greater 'mobility' than head nodes). We will assume that the orientation node can dominate a branching feature specification (e.g., prone and supine). A double specification for Orientation then characterizes an *orientation change*, as in, e.g., ASL DIE, in which the lower arm rotates.

2.3. Location

Location (or place) is one of the major components of signs. The phonetic-perceptual requirement for objects to move to be optimally visible leads to the fact that hands move during most (perhaps all) signs[17], which seems to contradict the one-location constraint in (3b), according to which each sign has one major location. To understand what the one-location constraint tries to capture, the notion of location needs to be broken down into a *major location unit* and a so-called *setting unit*. The major locations proposed by Battison (1978) (such as body, hand, arm, head, neck, and neutral space) are the 'areas' *within which* the hands move.

Based on the observation that movements of monomorphemic signs stay within these major locations, Sandler (1989) proposed *setting features* to specify more specific locations *within* the major place of articulation. Sets of setting features may represent the movements within major locations such as [high] and [low], as is illustrated by the NGT examples in (8); see Figure 1.2.

(8) Changes in setting values
  a. Head high>low: SERIOUS
  b. Chest high>low: HUMAN
  c. Space high>low: HOME

SERIOUS HUMAN HOME

Figure 1.2. Downward movement as change in setting values (high > low) in three major locations (Head, Chest and Space) (© NGT Global SignBank: Crasborn et al. 2019)

If we look more closely at the set of movements in relation to the various places of articulation, the one-location constraint appears to hold not only for the major locations that Battison identified: the head, the torso, and the nondominant hand. Rather, there is a slightly larger set of major locations including cheek, ear, etc., if we define (Major) Location to be a distinctive area rather than a spot within which the hand typically moves. Examples from NGT are given in (9) and illustrated in Figure 1.3.

(9) a. Cheek high>low: FATHER
  b. Ear high>low: DISOBEDIENT
  c. Nose high>low: SKILLFUL

FATHER DISOBEDIENT

SKILLFUL

Figure 1.3. Downward movement as change in setting values (high > low) in three distinctive locations (as areas) (© NGT Global SignBank: Crasborn et al. 2019)

We thus have to reformulate the one-place constraint:

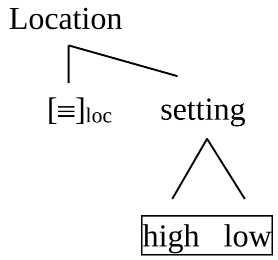
(10) The one-place constraint (revised): Each sign has only one (major) location specification

As a result of being interpreted both as spots, areas, or a combination of the two, location inventories that have been proposed vary in size. In several models that describe ASL, we find an abundance of location features (e.g., Liddell & Johnson 1989). This is due to the fact that every phonetic location that is touched or referred to by the articulator in any sign is deemed evidence for a location feature specification in these models. In our view, a set of location features is only achieved through analysis of the *contrastive* status of the location (as a distinctive property of the sign) and by unraveling phonetic predictability patterns and the role of iconicity (see van der Kooij 2002).

While Sandler (1989) proposed a set of setting features to specify more specific sublocations within the major place of articulation (e.g., [high], [low], [contact]), it would seem that a single setting specification must be used to indicate a specific point within the distinctive location, if this sublocation is not identifiable as a default sublocation. Examples of such cases occur when a specific meaning associated to that point or 'landmark' (eye, ear, temple, heart, etc.) is expressed. However, we will argue below that in such cases, meaning association in specific settings within the distinctive location calls for a morphological analysis in combination with phonetic prespecification of the specific setting. By interpreting location as a distinctive area in the lexical specification of a sign, the variation space of that sign is accounted for either with reference to the notion default setting or to an iconically-motivated choice that relates to the meaning of the sign (see Section 6). In the latter case, we propose that the specific meaning-bearing setting value is prespecified in the lexicon.

When *two* setting features are specified, this implies a *path movement*, a movement of the hand. By pairing up two setting values (high-low, contra-ipsi, proximal-distal, etc.), a path movement *within* the distinctive locations (as areas) can be formally described *without postulating a movement unit as such*. For example, a branching setting may be 'high-low', as illustrated in (11), referring to a sign that follows a downward path movement.

(11)



The formal specification of setting as a dependent of the head (location) accounts for the interpretation of the size of movement as relative to the size of the location. For instance, a downward path on the cheek may be smaller than a downward path in neutral space.

Given the distinction between major place and settings, the observed limitation on path movement could be stated as a restriction on setting specifications, as in (12):

(12) The one-(path)movement constraint: Each monomorphemic sign has only two setting specifications.

The one-movement constraint has not been formulated explicitly in the literature (but see Sandler (1999) for the idea). Meanwhile, it has certainly been noted that signs seem to require a movement in order to be perceived (cf. Sandler 1996a).

As just noted, the reduction of the movement constraint in (3c) to the setting constraint in (12) raises the question (or perhaps suspicion) as to whether path movement is an independent major unit or can be derived from settings. The main reason for granting movement the status of a formal unit is that path movements can have different properties involving the trajectory of the path, as we will see in the next section.[18]

2.4. Movement types

As discussed, a movement stemming from two setting specifications is called a *path movement.*[19] Other 'smaller' changes result from double specifications for orientation or aperture; these are *local movements* (13b).

(13) Types of movement:

- a. Path movement
- b. Local movement
  - i. Aperture change (hand-internal movement)
  - ii. Orientation change

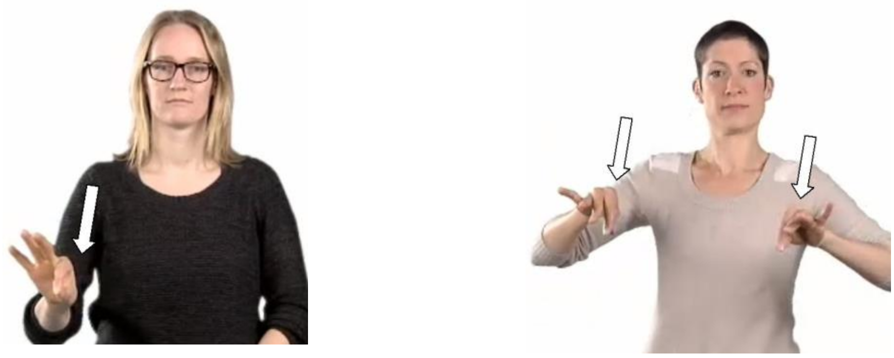
In lexical signs, local movements and path movements can occur independently, or combined, in which case both are executed simultaneously, meaning that their beginnings and ends occur at the same time.[20]

Many signs consist of one simple path (interpolations between two settings, high-low being the most frequent). But path movement trajectories can take different shapes; they can be straight, circular, curved, or zigzag. The circular and some of the curved movements are best analyzed in terms of *movement features*, i.e., [circle], [curve], which means that we need a unit in the sign structure where such features can be specified. Below, in (21) we will make a proposal with respect to where in the sign structure movement features are placed, which involves the introduction of a *manner node*.[21]

Path movements that are not simple interpolations between two settings can furthermore display what is sometimes called a *secondary movement*. For example, a path movement during which the hand makes small rotations or closing movements. These can be analyzed as repeated local movements (i.e., repeated aperture change and orientation changes) that can co-occur with a path movement, although they can also occur by themselves when there is no path movement and the hand is held in one position (Perlmutter 1992). In this case, the manner node will be specified with a feature such as [repeat]. Verbal descriptions of these repeated secondary movements include 'nodding', 'hooking', twisting', etc. (see Liddell & Johnson (1989) and van der Hulst (1993: § 2.2.2) for more discussion).[22]

2.5. Two-handed signs

Given that we refer to the hand as the articulator, it is remarkable that sign languages have access to *two* manual articulators. While, one might expect that the choice of one or the other hand could be contrastive, there is no evidence for this.[23] Signers will typically use their preference hand to sign, but can easily switch to the other hand when this is necessary or convenient, without any change in lexical meaning. However, many signs are specified in the lexicon as being made with two hands; the proportion of one- and two-handed signs can vary from sign language to sign language, but can be as high as 50% (Battison 1978). We note that the choice between using one hand or two is only 'weakly' contrastive; an example from NGT is given in Figure 1.4.



CHOOSE SOCK

Figure 1.4. Example of a minimal pair: a one- vs. two-handed sign in NGT (© NGT Global SignBank: Crasborn et al. 2019)

In the class of two-handed signs, we find that the possibility for the two hands being different or doing different things is severely constrained. Two general co-occurrence constraints have been proposed for two-handed signs (Battison 1978; Napoli & Wu 2003; Eccarius & Brentari 2007; Morgan & Mayberry 2012):

(14) a. **The symmetry condition**: In two-handed signs in which both hands act as active articulators, both hands have the same handshape, the same (or opposite) orientation, the same movement (synchronic or asynchronic, called *alternating*), and the same location. Two NGT examples are provided in Figure 1.5a.

b. **The dominance condition**: In two-handed signs in which one hand (the passive or weak hand) is the location for the other (active or strong) hand, the location hand either has the same handshape as the active hand or is selected from a small set of 'unmarked' handshapes. Two NGT examples are provided in Figure 1.5b.

a.

SAME

JUDGE$_{\text{VERB}}$

b.

GREEN

POLITICS

Figure 1.5. Two symmetrical signs (the sign on the right has alternating movement) and two asymmetrical signs (the sign on the left has similar handshapes) (© NGT Global SignBank: Crasborn et al. 2019)

Two-handed signs thus come in two broad types. For signs in which both hands act as active articulators, called *symmetrical*, one might simply adopt the feature '[2-handed]' and, when relevant, [alternating], while signs in which the hand acts as a location, called *asymmetrical*, require [hand] to be one of the location features (cf. Sandler 1989).

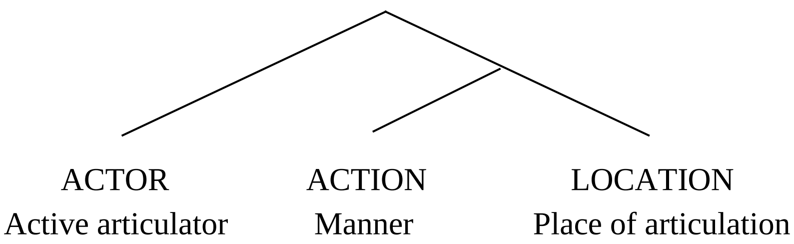
The *specific relation* between the two hands may also be a relevant property (van der Kooij 2002). The relation between the hands is captured by the orientation features of the strong hand. The orientation is interpreted with respect to the weak hand as the location in asymmetrical signs and with respect to same part of the hand as indicated by the orientation feature in symmetrical signs. For some two-handed signs, specific *hand interaction features* may be required such as [crossed], [below] or [above], in relation to the other hand, and so on. If such specifications are required, we must identify a separate node for the weak hand (albeit for different reasons than those given in van der Hulst (1996)[24]) and the spatial arrangement of the two hands appears to be always motivated.

3. Signs as single segments

Stokoe's suggestion was that the major units of signs are comparable to phonemes, which led him to say that a big difference between spoken and sign languages is that in the former, phonemes occur sequentially, while sign phonemes ('cheremes' in his terminology) occur simultaneously. However, van der Hulst (1993) points out that the major units compare more closely to what in spoken phonology are called class nodes (which are subunits of 'phonemes'), such as Manner, Place, or Laryngeal (see Clements 1985). If this is the right analogy, this implies that monomorphemic signs are 'monosegmental', i.e., contain the equivalent of a single phoneme in spoken language (see Channon (2002) for a similar view). In this section, departing from a general characterization of articulation that generalizes over both spoken and sign language, we will argue that signs are indeed phonologically analogous to single segments ('phonemes') in spoken languages.

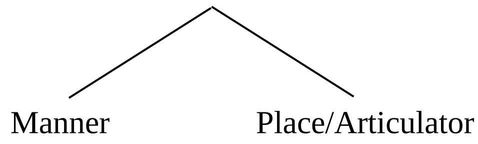
From a production point of view, we can say that the articulation of a single segment in both spoken and sign language involves an action by an actor at some location (15).

(15)



In spoken language, there is a close correlation between articulator choice and choice of location, which results in the fact that models for spoken segments adopt only one node that is called either 'articulator node' or 'place node'.[25] As a result, phonologists have come to use 'articulator' and 'place' terminology almost interchangeably, referring to a /k/ as either 'velar' (= place) or 'dorsal' (= articulator) without discrimination. The point is that having *both* an articulator and a place/location specification, while required in the actual production of speech, introduces a significant amount of redundancy, due to the fact that many theoretical combinations are either anatomically impossible or so hard that they do not occur, such as a coronal pharyngeal (impossible), or a labial alveolar (difficult). In practice, then, *phonological* models of speech segments reduce the structure in (15) to that in (16).[26]

(16)



For sign language, however, we need the full structure in (15), because the articulator can have many different shapes and moreover moves relatively easily with respect to all places.[27] Indeed, the distinction between actor and location can be found in *all* sign models.

Returning to the notion of relative orientation, we can now identify this specification as providing a subdivision of the hand into at least six sub-articulators, being the six sides of the hand that may account for minimal pairs in various sign languages (17).[28]

(17) Sub-articulators of the hand:

- Palm
- Back
- Tip
- Wrist side
- Ulnar side
- Radial side

Adopting the structure in (15) as the structure of signs, we have provided a natural place for features that specify the shape of non-interpolation movement. Since ‘manner’ specifies the relation between the articulator and the place, this node could just as well be labeled ‘movement’, but we will maintain the label ‘Manner’; see (21).

In conclusion, from the analogy that has been developed in this section, the structure of (monomorphemic) signs *as a whole* is that of a single segment (or single ‘phoneme’). This means that the various constraints that we have discussed (see (3a–c), (6), (10), (12)) are constraints on segments. These constraints then, indirectly, bear on morphemes if we adopt a morpheme structure constraint which says that morphemes consist of a single segment; we will turn to the notion of ‘syllable’ in the next section.

While Stokoe’s original claim that sign language differs from spoken language in lacking sequential structure was based on the simultaneity of the units of handshape, movement, and location, this would now appear to be a non-starter, since the corresponding class nodes in spoken segments are also simultaneous. The real striking difference between the two modalities is rather that ‘monomorphemic’ signs (i.e., morphemes) lack sequential segmental structure in being monosegmental, as opposed to most morphemes in spoken languages, which consist of multiple segments. This conclusion stands in apparent contrast to proposals that we will discuss in the next section which argue for a sequential skeletal structure for signs. In our own proposal in (21), we will incorporate a ‘skeletal structure’, albeit of a reduced form.

The question is now how it is possible that there are no multisegmental monomorphemic signs. Surely, such a state of affairs is unheard of for any spoken language.[29] The obvious answer is that there are many more possible sign segments than there are possible spoken language phonemes, which results from the four facts listed in (18), the first two of which were already mentioned (cf. Meier (2000) for discussion of a similar point):

(18) a. In signs, as shown, articulator and place are independent parts that can cross-classify fairly freely.
b. The hand can take many different shapes.
c. In signs, the articulator has six different sub-articulators.
d. In signs, the manner can take many different forms, due to the magnitude of the movement.

With respect to (18d), we suggest that, broadly speaking, the manner features relate to three aspects of the sign: path shape, temporal alignment, and spatial alignment. In (19), we propose a tentative set of manner features:

(19) A set of potential manner features
a. Path shape:
1. [arc] (taking 'straight' to be the default)
2. [circle]
b. Temporal alignment properties
3. [repetition]
4. [alternation]
5. [bidirectional]/[reverse]
6. [contact]
c. Spatial alignment properties; hand arrangement
7. above
8. in front of
9. interlocked/inside/interwoven

We can conclude that the array of phonological distinctions for sign segments is many times larger than for speech segments, so much so that it is possible to represent perhaps all 'necessary' morphemes in terms of single segments.

A question that relates to the issue discussed here is how many morphemes a (sign) language needs? There is no general answer to this question. The age of the language and properties of the surrounding culture play a role here. Yet, there is perhaps one reason for believing that sign languages can function adequately with fewer morphemes: due to the influence of gestural elements (also iconically-based), morphemes can be modified for use in a given context in many ways. In this sense, sign morphemes are perhaps comparable to consonantal roots in Semitic languages, which represent a 'semantic field' rather than a specific individual word meaning.

4. What about syllable structure?

Limiting ourselves to alleged monomorphemic signs, it would seem to follow from the monosegmental hypothesis that signs cannot have syllable structure. After all, syllable structure in spoken language presupposes combinations of segments that occur in a specific linear order. Moreover, in spoken languages, syllabic organization is based on an alternation between two very different kinds of segments, namely consonants and vowels, which, in sequence, form a mandibular open/close rhythm (which perhaps ultimately underlies the production and recognition of syllabic units). As Sandler (2008) points out, there is no mandibular cycle in sign, or anything remotely like it.

There are of course signs that have a linear sequence of segments, but such segment sequences result from *concatenative* morphological operations, which, except for compounding, are not typical in sign languages. Sequences of segments also occur in fingerspelled words. When compound structures become opaque, and effectively simplex morphemes (Liddell & Johnson 1986), or when fingerspelled words are compressed and become, as such, conventionalized morphemes (Wager 2012), morphemes that consist of a sequence of segments can arise.

Putting those cases aside for the moment, our claim that monomorphemic signs have no syllable structure, and thus no sequential phonotactic organization, simply because there is no segment *sequencing*, is seemingly at odds with many other claims in the literature. After Stokoe's groundbreaking work, which stressed the simultaneity of the units that constitute a sign, later researchers (e.g., Supalla & Newport 1978; Newkirk 1981; Liddell 1984; Liddell & Johnson 1989) argued that it was necessary to be able to make reference to the beginning and end point of (the movement of) signs, for example for inflectional purposes (I-GIVE-YOU as opposed to YOU-GIVE-ME), or to express assimilations involving a switch in the beginning and end point of the movement (see Sandler (1989) and van der Hulst (1993) for a discussion of the arguments). Without *formally* recognizing the beginning and end point in the linguistic representation, it would be impossible to formulate morphological or phonological rules that refer to these entities. These considerations led to the adoption of structural *timing units*, forming a *skeleton* to which the content units (class nodes, features) of the sign associate in an autosegmental fashion (as explicitly proposed in Sandler (1986)). Most researchers (Johnson & Liddell 1984; Liddell & Johnson 1989; Sandler 1989, 1993; Perlmutter 1992; Corina 1996; Brentari 1998, 1999) proposed a skeleton that not only represented the initial location and final location, but also an intermediary movement unit M, as shown in (20).

(20) L M L

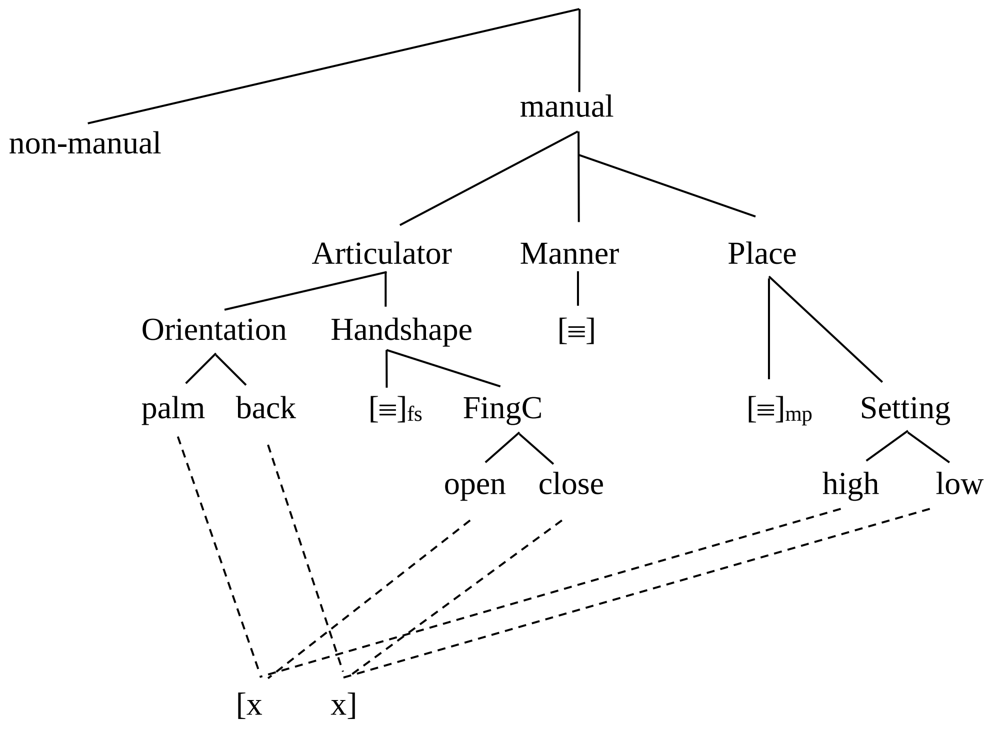
Several researchers then supported the M unit by assigning a central perceptual status to this unit (see Perlmutter (1992), Corina & Sandler (1993), Sandler (1993), and Brentari (1998) for relevant discussions). Given (20), it was almost 'inevitable' to draw an analogy between the

PMP sequence and a CVC-syllable in spoken language (see Chinchor 1978; Coulter 1982). Pursuing these earlier ideas, Perlmutter (1992) explicitly compares the M to the vowel (or nucleus) in spoken language and even adds a 'moraic' layer to the representation.

As we illustrated in (11), in the model that we have formulated, the presence of a path movement follows from a sign having two setting specifications. Since we have located the 'movement' features within the segmental *content* of the sign, i.e., in the manner class node, we maintain the claim, made in van der Hulst (1993), that the 'M' unit does not belong in the skeleton.

However, in the representation of path movements, the setting points must be linearized even for monomorphemic signs, because a movement can go from [high] to [low] or vice versa. We therefore do need a skeleton 'tier' that is separate from the setting features. Moreover, linearization is not only necessary for setting features, but also for the features that specify local movements, i.e., orientation changes and aperture changes. Van der Hulst (1993) thus proposes a sign skeleton with two positions ('x'), to which the various features that need to be linearized are associated, as in (21).

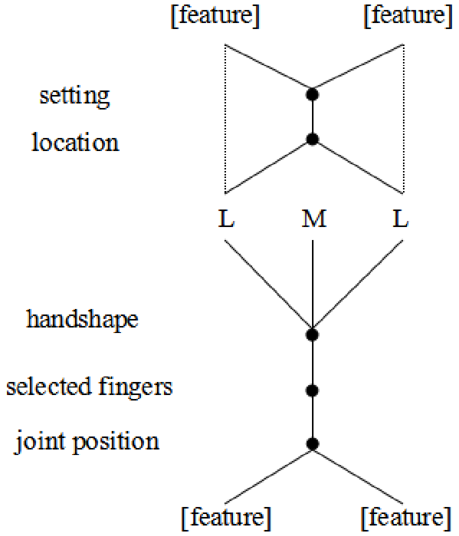
(21)



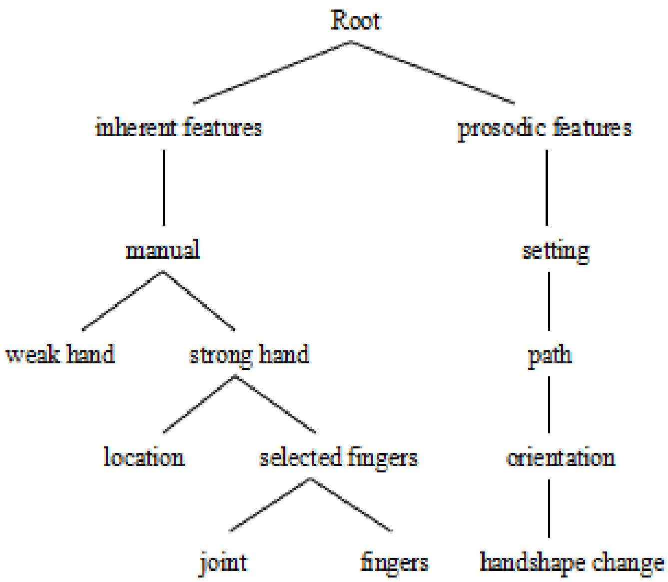
Wilbur (1985) proposes a model that concurs with the dependency model by establishing linearization of features on different tiers (such as the location tier, orientation tier, etc.), each of which forms a syllable, and in which the different syllables are unified under one node.

This dependency model differs in various ways from Sandler's hand-tier model (Sandler 1987) and Brentari's prosodic model (Brentari 1998). The former adopts the M unit and associates feature content units to the position in the LML skeleton. The latter accepts the bipositional skeleton, but separates all static features and all dynamic features (called prosodic) under separate nodes in the structure. In (22), we provide representations of these two models.

(22) a. Sandler's hand-tier model (Sandler 1987; also see Sandler & Lillo-Martin 2006: 132–181)



b. Brentari's prosodic model (Brentari 1998: 26)



Sign researchers (e.g., Padden & Perlmutter 1987) have observed that when a sign has several dynamic properties, such as a path movement and an orientation or aperture change, the beginning and end point of each movement component are synchronized. This is precisely what the model in (21) predicts. The skeletal positions can also play a morphological role and function as the units to which inflection features associate (see Sandler (1987) for other processes that affect the skeleton.).

We thus come to the apparently 'odd' conclusion that whereas signs lack 'suprasegmental' sequencing, they do possess intrasegmental sequencing. If sequencing is the hallmark of syllable structure, we could also say that in sign structure, the syllable is inside the segment, rather than being superimposed on it.

We think we can perhaps explain this difference with reference to a crucial difference between *auditory* and *visual perception*. Visual perception of signs, even if these have dynamic and apparently sequential properties, is more 'instantaneous' than the perception of auditory speech input, which is necessarily stretched out in time (see Brentari (2002) and Emmorey (2002)). The latter reaches the ear bit by bit (albeit as a continuous stream), and it seems plausible to assume that the auditory system first and foremost imposes a linear organization on speech percepts, perhaps based on the rhythmicity that results from the motoric actions of the articulatory system, before it partitions the sequential chunks into simultaneous smaller properties (i.e., features). In contrast, visual percepts capture the entire signs as a whole and would first of all deliver a partitioning into simultaneous layers which, then, takes precedence over the linear sequencing of the dynamic aspects at (some of) these layers. Adopting a terminology proposed in Goldsmith (1976), we can represent the difference in terms of the notions of *vertical* and *horizontal slicing* of the signal. When comparing sign and speech, these occur in different dependency relations, as illustrated in (23).

(23)

SPEECH	SIGNING
vertical (syntagmatic)	horizontal (paradigmatic)
|	|
horizontal (paradigmatic)	vertical (syntagmatic)

Thus, an incoming speech signal is first spliced into vertical slices, which gives rise to a linear sequence of segments. Horizontal slicing then partitions segments into co-temporal feature classes and features. In the perception of sign language, however, the horizontal slicing takes precedence, which gives rise to the simultaneous class nodes that we call Handshape, Movement, and Place. Then, a subsequent vertical slicing of each of these can give rise to a linear organization that is captured by branching nodes (for Aperture and Orientation and Setting) and a bi-positional skeleton.[30]

The position outlined in this section does not deny the importance of the notion of syllable and thus does not invalidate arguments in favor of this unit, even when these have been formulated with respect to models that recognize an M-unit (Sandler, Perlmutter) or a prosodic node in the feature structure (Brentari). The arguments that Brentari and Fenlon (Chapter 4) provide for syllable structure, in our view, carry over to the model in (21). In acquisition, the emergence of the bipositional skeleton introduces the phase of syllabic babbling. Degrees of 'sonority' and of 'weight' can also be formulated. The bipositional skeleton with its associated features provides a basis for distinctions between types of syllables, depending on how many feature pairs are associated with the two positions.

5. Rules

5.1. Grammatical phonology and utterance phonology

For spoken languages, various proposals have been made to differentiate the class of phonological rules into different types (see van der Hulst (2016) for a general review). We believe that the major division in types of phonological rules is that between rules that belong to the grammar that delivers *linguistic expressions* (accounting for allomorphy at the word level and for form variation in words that depends on syntactic context) and rules that are part of the production system that delivers *actual utterances* **(**applying across the board with reference to phonological representations of any size and thus including both word and phrasal phonology); these latter rules belong to phonetic implementation. We will refer to the two subsystems as *grammatical phonology* and *utterance phonology*, respectively.[31] With this division, *all* rules that deliver fully predictable properties would belong to the utterance phonology, so that the grammatical phonology only deals with allomorphic alternations due to rules that range from highly restricted (in terms of lexical diacritics or morphological context) to rules that apply fairly regularly (but not 'automatically'). Many regular grammatical rules (such as vowel harmony rules) can be seen as repairs to cases in which a phonotactic constraint is violated in a morphologically complex word. Others are fully idiosyncratic with respect to certain morphological constructions; here one can think of rules that deal with alternations, such as in *electric ~ electricity*, where /k/ alternates with /s/ in a morphologically restricted context. In this view, the grammatical phonology is seen as 'digital', 'categorical', or 'discrete', while the utterance phonology is 'analog' and 'continuous'. In our view, all phonological processes that are automatic belong to the utterance phonology, including processes that are called allophonic rules. Indeed, allophonic rules (despite their formulation in textbooks or exercises) are actually often subject to speech rate and stylistic factors. For example, aspiration in English varies depending, among other things, on the strength of the following stressed vowel.

The literature on phonological processes in sign language is rich, but in our view, all reported processes belong to the utterance phonology, that is, the phonetic implementation system. We believe that the evidence for grammatical phonological rules in sign languages is very limited, if not absent. Utterance rules account for the most natural realization of phonological units, given their simultaneous and sequential context in actual utterances. Sign languages thus display co-articulatory or assimilation processes, but, unlike in the case of spoken languages, there is little evidence for such processes to have developed into language-specific allomorphic rules that obligatorily apply in specific contexts (and that are no longer fully automatic). Co-articulation within morphologically complex forms occurs in cases of sequential morphology (specifically compounding), but also in non-concatenative morphology, when, for example, the movement of a sign is modified to create a derived word. Co-articulation within monomorphemic signs affects the way in which the (simultaneous) major units are realized. A given handshape, say *fist*, will have slightly different positions for the thumb depending on which part of the hand makes contact with the place (Cheek 2001; van der Kooij

2002; Mauk, Lindblom & Meier 2008). Another example of a process that occurs in actual signing concerns two-handed signs. Frequently (under conditions that are reported in several studies), a two-handed sign can be articulated with one hand, typically the strong hand ('weak drop'; see Padden & Perlmutter (1987) for ASL, van der Kooij (2001) for NGT). It can also happen that the weak hand after being part of a two-handed sign stays in place while a following sign is articulated ('weak freeze' or 'weak hand hold', see Kimmelman et al. (2016)). The case of compounding deserves special attention. Liddell & Johnson (1986) and Sandler (1987) have described various processes that affect compounds, such as deletion of initial or final 'holds', spreading of handshape, etc. These processes, however, have the characteristics of utterance rules and never have acquired the status of obligatory rules that automatically must apply when a compound is formed. That said, the effect of such assimilations may lexicalize, i.e., grammaticalize into the lexical representation of compounds, which is why there is nothing to gain by accounting for the implied alternation between the free form and the form as it occurs in a compound in terms of a grammatical allomorphic rule.

In short, most if not all processes that sign phonologists have described seem to fall in the realm of utterance phonology and, more specifically, phonetic implementation; some examples are provided in (24).

(24) Examples of implementation processes
  a. Default implementations (default rules)
     e.g., no specification for location > [neutral space], Selected Fingers [one] > index finger
  b. Adaptations of handshapes and orientations to specific places and vice versa
     e.g., thumb position in S () vs. AS () depending on relative orientation ([radial] or [palm], respectively)
  c. Assimilation processes between units of signs in sequences (compounds/phrasal collocations) or weak freeze
  d. Reduction/deletion processes such as weak drop, or 'weak hand lowering'
  e. Epenthesis of non-lexical movements (Geraci 2009)
  f. Other phrasal processes, e.g., enhancement of movement for sentence position or focus (Crasborn & van der Kooij 2013)

An important point regarding implementation processes is that while, on the one hand, these processes can be grounded in articulatory or perceptual factors ('phonetics'), it is also possible that such processes are motivated by semantic factors, which lead the signer to add (sometimes called gestural) elements to signing that would appear to be iconically motivated. As reviewed in Goldin-Meadow & Brentari (2017), the co-occurrence of lexical phonological properties and gesture properties is particularly salient in sign languages. This means that the goal of isolating contrastive properties of signs involves abstraction not only from universal effects that are due to the physical and psychological state of the signer, idiolectal properties resulting from gender, age etc., co-articulation and stylistic factors, but also from gestural aspects. As they point out, this presupposes the possibility of identifying aspects that are due to gesture, which is not an easy task, assuming that indeed we are dealing with two separate systems. The authors also point out that, as for the three major units of signs, handshape seems to be the most categorical, i.e., least subject to gestural mutation, while location and movement would appear to be different in this regard.

5.2. Why do sign languages lack a grammatical phonology?

We now need to address the question as to why sign languages appear to lack grammatical phonological rules. But first, we take a look at some cases that have been claimed to be precisely of this type. One reviewer mentions the following two examples that could be considered as cases of allomorphy:

(i) Verb agreement realization in ASL & ISL (Meir 2002): agreement realization in ASL can be expressed by path features only (e.g., HELP), by orientation and path movement (e.g., ADVISE), or by orientation only (e.g., SAY-YES-TO, SAY-NO-TO).

(ii) Reciprocals in German Sign Language (DGS) (Pfau & Steinbach 2003): one- and two-handed signs have different forms for expressing the reciprocal. One-handed stems have a simultaneously realized reciprocal form, while balanced, two-handed stems have a sequential form for the reciprocal.

We would like to argue that the alternations in the cases in (i) can be treated as suppletive, even though the choice as such is phonologically motivated, that is, dependent on the phonological form of the base verb.[32] The case in (ii) is in our view implementational, since the expression of reciprocity simply must be sequential in two-handed signs.

But our point is not that sign language could not have grammatical phonology. Even if an occasional case can be made, the question still remains why there is so little of it. To gain insight in this observation, we first note that it has frequently been argued that the various types of phonological rules in spoken languages reflect stages in the 'life cycle' of phonological processes, the idea being that phonetic effects of universal phonetic implementation processes can be exaggerated (for whatever reason) and give rise to *language-specific* implementation rules, which (perhaps first being optional and then becoming obligatory), with further exaggeration, then fall within the scope of feature-specifications, so that they develop into what are traditionally called allophonic rules. Allophonic rules (perhaps only after becoming neutralizing) eventually become detached from their phonetic roots and give birth to non-automatic rules that account for allomorphy, which then may transition from general rules to rules that have a few or even many exceptions. This leads to a point where the rules can be analyzed as part of morphological operations. The question is thus why, in sign language phonology, processes that start out as phonetic implementation processes fail to transition into allomorphy rules. We attribute this 'failure' to what we believe to be a crucial difference between phonology in spoken and sign languages. In sign languages, the phonological form of morphemes and words that are stored in the lexicon is foremost a grammaticalization of the iconic motivation of signs, rather than of their phonetics. In contrast, phonological form, both static and dynamic, in spoken languages emerges from the grammaticalization of phonetic, implementational preferences and processes. While we do not deny that such processes and preferences are visible (!) in the phonological form of sign languages, we believe that semantic/iconic factors play an overriding role in the emergence of the phonological form of signs. This being so, sign languages resist rules that 'blindly' alter phonological properties of morphemes, that is, rules that are blind to the semantic value of these properties. The fact that many form elements in signs are meaning-bearing explains, in our view, the resistance in sign languages to develop allomorphy rules. These rules would, after all, render the semantic 'compositionality' of signs opaque by removing or mutating the meaning-bearing form elements. While, as mentioned, bits and pieces of the members of compounds may be deleted or assimilated, this perhaps is less damaging because, on the whole, the semantics of compounds are inherently less predictable (in all languages). The fact that such rules do not become general rules of the language is here claimed to be due to the semantic damage that they will do; this point is also made in Sandler (2017).

We conclude that the lack of grammatical phonology is both due to and compensated for by the semantic value of many, perhaps most phonological units. We elaborate this point in the next section, with reference to earlier work that paved the way for this viewpoint, which calls for a re-evaluation of what counts as a morphologically complex sign.[33]

6. Iconicity

6.1. Discrete iconicity and gradual iconicity

In early work on sign phonology, the obvious iconic motivation of many signs was downplayed or ignored, because it was important at the time to make the point that sign language, just like spoken language, has autonomous 'meaningless' structure in the form and thus duality of patterning (or double articulation), the existence of which was (implicitly) taken to be a defining characteristic of human natural languages (Martinet 1955; Hockett 1960). Early on, sign phonologists took exception to the 'denial' of iconicity; see Friedman (1977), Mandel (1977), and Boyes-Braem (1981). The question is now whether acceptance of iconically motivated properties of signs undermines the claim that sign languages have phonological structure, i.e., a 'dual articulation'.

In order to understand how iconicity contributes to the form of signs, we must distinguish between *discrete iconicity* and *gradual iconicity*. Discrete iconicity occurs in two types: recurrent and incidental. The iconic motivation of a specific form element is recurrent in the lexicon when a genuine phonological element is used with a semantic value in multiple signs. An example is the location on the side of the forehead, which is frequently associated with the meaning 'mental state or process'. This location is used in ASL signs such as THINK, UNDERSTAND, TEACH, DREAM, etc. A similar point about phonological units being meaning-bearing is made in Lepic et al. (2016) in a study about two-handed signs. The authors show that the fact of being two-handed corresponds to a small list of semantic properties well above chance, similar to the properties found for NGT two-handed signs (van der Kooij 2002).[34] In case a form element is iconically motivated but occurs only in one sign, we call it incidental; an example would be the location near the kidney for the NGT sign KIDNEY.

With the term 'gradual iconicity' we capture the fact that the specific articulation of a sign aspect is determined by the referential context by showing 'form copying' (similar to what Goldin-Meadow & Brentari (2017) describe as co-sign gesture). For example, the hand configuration feature [open] refers to the aperture between the thumb and the selected fingers. The exact degree of opening may be partly determined (aside from articulatory factors) by the size of the referent (e.g., a book or a piece of paper).

We will refer to KIDNEY cases and gradual iconicity as reference copying. In the next section, we propose that the three-way distinction between discrete recurrent iconicity, discrete incidental iconicity, and gradual iconicity is reflected in three different mechanisms in the phonology. We start with gradual iconicity, which is perhaps the least controversial in its treatment.

6.2. Gradual iconicity

Adaptation of the form of signs to specific sign acts can, in principle, not be recorded in the lexicon, unless one adopts an extreme form of exemplar-based phonology, according to which every instance of producing or perceiving a sign is added to the lexicon. While it is no doubt possible for signers to mentally record specific sign instances, we believe that this cannot replace the need for an abstract lexical representation that ties all the instances of use together, abstracting away from what differentiates them. We therefore take it to be uncontroversial that gradual iconicity arises in phonetic implementation. This implies that phonetic implementation itself can be dependent on iconicity. Signs can be adapted in use to formally represent properties of a (mental image of) a thing or action that is being referred to at a specific time and place of signing. This makes such gradual iconicity pragmatic in a sense. Gradual iconicity can also be found in spoken language, when speakers adapt the pronunciation of a word when they, for instance, say that the benefit of a tax bill for the middle class will be *huuuuuge* (see Okrent 2002).

6.3. Incidental discrete iconicity

Incidental iconic properties are an obligatory part of the lexical representation of a sign, i.e., these properties are conventionalized. However, we do not believe that such properties, while discrete, function as phonological units that can be used contrastively other than being meaning-bearing themselves. Adding the location for KIDNEY to a list of contrastive locations would be a mistake. Van der Kooij (2002) and van der Hulst & van der Kooij (2006) have proposed that such properties are designated as being *pre-specified* phonetic properties, which bleed what would otherwise be a default sublocation within a major location, assuming that such default sublocations need not be encoded in the lexical representation. We take detailed properties to arise in phonetic implementation. As an example, to illustrate the difference between phonetic pre-specification and default specification, we can compare the NGT signs SOLDIER and ALSO, which share the major location feature [chest]. In the latter sign, the thumb side of the hand touches the upper chest contralaterally, which we take to be the default sublocation because it is more 'natural' (i.e., easier) to touch the chest contralaterally. The former sign places the hand ipsilaterally, representing holding a riffle. The ipsilateral location, which does not follow the default rule, has to be pre-specified in the lexical representation of the sign SOLDIER. If all instances of phonetically pre-specified properties were accepted as distinctive features, the list of features would become very long, perhaps infinitely long. Moreover, when iconicity gets somehow lost, default sublocations may appear (e.g., the cheek as default sublocation of [side of head] when the motivation of the specific sublocations ear (from SLEEP) and mouth (from EAT) are bleached in the reduced ASL compound HOME). We here add the suggestion that iconically motivated phonetic properties, perhaps because they need to be pre-specified in the lexicon, can give rise to phonological elements that carry meaning if their use, by a form of analogical extension, becomes recurrent.

6.4. Recurrent discrete iconicity

In sign languages, *new* signs are overwhelmingly iconic (van der Kooij & Zwitserlood 2016): motivated form is projected from meaning (within the limits of what is anatomically feasible and 'painless'), and using form elements that can also occur as 'meaningless' form units, which means that they belong to the arsenal of phonological building blocks of the language. While recurrent iconic form elements can occur in the existing (sometimes called frozen) vocabulary (see Johnston & Schembri 1999; Brentari & Padden 2001), we would like to suggest that form elements are only recognized as being potentially meaning-bearing if they occur productively in newly created words and/or in morphological constructions. Thus, so-called *classifiers* (which are formal parts in that they are 'handshapes') qualify as such units (see Tang et al. (Chapter 7) and Zwitserlood (Chapter 8) for discussion of classifiers). However, we repeat that a condition on recognizing phonological units that can occur as meaning-bearing is that they can also occur as pure form units, i.e., non-meaning bearing. This is paralleled in spoken languages by cases in which a feature such as [nasal] functions on its own, as a morpheme (although without being iconic), while at the same time being used in many other circumstances as a distinctive form element.[35]

The question is now how we formally account for the grammatical mechanism that introduces meaning-bearing form elements in signs. A traditional understanding of morphological structure is that it involves an exhaustive partitioning of words into minimal meaning-bearing forms (called morphemes), such that the semantic value of the whole structure is the compositional result of the meaning of the parts and their mode of combination. However, this requirement may be too strict. We suggest here that meaning-bearing form elements (whether iconically motivated or not) can be regarded as morphemes, even if the sign form cannot be *exhaustively* parsed into meaning-bearing units.[36] If we then argue that the meaning-bearing form elements can also be treated as morphemes in frozen lexical items, most signs that are traditionally thought of as monomorphemic must be analyzed as morphologically complex (Zwitserlood 2001, 2003a,b, 2008).[37] Perhaps, typically, the reason that such frozen forms must be listed is that their meaning as a whole cannot be fully predicted from the parts, especially if some parts are meaningless. We need to acknowledge that since the meaning of such signs is in part unpredictable like in compounds, they need to be listed as such in the lexicon.

An alternative to the ‘radical’ morphological approach just sketched can be extracted from the proposals made in Boyes-Braem (1981), which are further developed in Taub (2001). Given that new formations display a systematic use of iconicity, Boyes-Braem (1981: 42ff.) proposes a derivational system in which properties of a mental image (which she calls a visual metaphor) that can be associated to a semantic concept are encoded by one of the independently needed phonological elements of the language (which she calls morpho-phonemic features, i.e., phonological features that can play a ‘morphological’ role). While this is an interesting proposal, it remains to be seen whether it ultimately differs from our radical morphological approach, but we refer to van der Kooij & Zwitserlood (in preparation) for further discussion of these issues.

It could perhaps be argued that the approaches advocated in this section imply the elimination of sign phonology, if meaning is assigned to building blocks that were formerly held to be meaningless. However, we think that it is more correct to speak of a *conflation* of phonology and morphology in the sense that the decomposition of signs intermingles phonological and morphological structure, rather than the former strictly preceding the latter.[38]

7. Concluding remarks

In this chapter, we have reviewed the emergence of sign phonology as a field of study beginning with the work of William Stokoe. We discussed further developments and presented our own model for a phonological organization of signs, including class nodes, features, and a bipositional template, all subject to phonotactic constraints. Other influential models were also discussed. While sign languages have traditionally been claimed to share most of their constraints, typological work, of which we need more, tentatively suggests that differences do occur, albeit in a much more modest way when compared to spoken languages. Turning to the dynamic side of phonology, and bearing in mind the distinction between grammatical and utterance phonology, we suggested that sign languages appear to lack grammatical phonological rules, i.e., allomorphy rules. We discussed the proposal that the monomorphemic structure of signs is mono-segmental, and this led us to re-evaluate claims about syllable structure in signs. We then considered the role of iconicity, drawing attention to the fact that features and class nodes are not always meaningless, a view that has implications for the traditional ‘phonological analysis’ of signs, leading to the idea that phonological and morphological structure are intermingled.

Acknowledgements

We are grateful to Shengyun Gu, Wendy Sandler, and the editors of this volume for careful reading of and comments on previous versions of this chapter.

Notes

1 We refer to several reviews of the sign phonology field which focus on reviewing different theoretical models: Corina & Sandler (1993) and van der Hulst (1993) for earlier models; see also Sandler (2012, 2017), Brentari (1995, 2011, 2012), and Fenlon, Cormier & Brentari (2018).

2 In Section 6.4, we will also address the question whether such meaning-bearing units should be identified as morphemes.

3 In Section 4, we will discuss different views on the status, or place in the grammar, of such rules.

4 For a history of the sign phonology field, see van der Hulst (to appear). Of particular interest is the fact that alongside Stokoe (1960), West (1960) develops a very similar proposal concerning the duality of signs, based on his study of the Plain Indian Sign Language.

5 With reference to signs, 'context-free' means that the constraint does not make reference to other major units, but instead only makes reference to the co-occurrence of features *within each major unit.*

6 An extensive comparative study of the phonology of 15 languages, based on a data base of 15,000 signs (1,000 for each language), is currently carried out in the SignTyp project, led by Harry van der Hulst and Rachel Channon; NSF grant BCS-1049510.

7 Here and in (2), we use 'technical terminology' that will be explained in following subsections, after which the reader might want to go back to re-inspect (1) and (2).

8 In Section 6, we discuss the notion 'monomorphemic' that is used here, arguing that many alleged monomorphemic signs may have to be analyzed in terms of containing at least one (possibly more) phonological building block that is meaningful.

9 This is a simplification because when the selected finger index and thumb make contact, the unselected finger are extended; see Sandler (1989) and van der Kooij (2002) for a detailed discussion.

10 Here we use a 'neutral term' for what others call 'handshape' or 'handconfiguration'.

11 Here we use an 'X-bar' notation to indicate that within Finger Selection and Finger Configuration FS0 (selected fingers) and FC0 (aperture) are the heads of a complex structure which contains two dependent units, one being the 'complement', the other 'the specifier'. See van der Hulst (1993, 1995) and van der Kooij (2002) for motivations for the choices being made here.

12 The 'insult gesture' ('the finger') occurs as a so-called *emblem*, that is, a stand-alone gesture that can be used (although should be avoided) by all members of certain cultures. It does not, as far as we know, occur in sign languages as part of regular signs; see Kendon (2004) for an account of gestures.

13 Such predictability is accounted for in allophonic rules, i.e., rules that account for non-distinctive variants of handshape units. Stokoe (1960) and Friedman (1976), for example, distinguish between the /A/ hand as a phonemic unit and various [A]-variants.

14 Eccarius (2008), who uses the model of Optimality Theory, proposes that a distinction is needed between primary and secondary selected fingers. In our model, more complex structures are possible

when licensed by the morphology. For instance, two sequential sets of selected fingers within one syllable are possible if they stem from letter signs (e.g., change from [all] to [one] in NGT #BLUE, to represent the first two letters of the Dutch word *blauw* ('blue'))

[15] This notion of relative orientation was called 'focus' in Friedman (1976), among others. The term 'leading edge' can also be found.

[16] Below in (21), we identify the relative orientations as sub-articulator features, encoding different parts of the articulator, the hand.

[17] This leads to the constraint that signs must have movement, which feeds into the idea that the movement unit is the nucleus of the sign syllable; see Section 4.

[18] See van der Hulst & Sandler (1994) for an extensive comparison of the two views, which comes out on the side of acknowledging a movement unit. In Section 2.4, while claiming that movement is implied by having two setting specifications, we will identify a major unit with the label 'manner', which takes on the role that Sandler (1996a) attributes to a movement unit, which in her model is structurally quite different from the location and handshape units. We do not deny the need for movement features, but we do deny a skeletal position to accommodate them; see Section 2.4.

[19] Below, we will distinguish between simple and complex path movement.

[20] An alleged exception to the simultaneous articulation of the two movement components is for instance the outlining of the rectangular shape in the NGT sign PURSE (which has a closing movement at the end of a path). Arguably, it is the outlining property that motivates this sequential articulation of the lateral path and the closing local movement. In current signing, however, we do observe simultaneous articulations of the two movement components in the sign PURSE, thus overruling the outlining of a rectangular shape.

[21] A potential alternative for characterizing other non-interpolation paths, like zigzag movements, would be to analyze them as *combinations* of two path movements, one being repeated and perpendicular to the main path. This approach, while perhaps feasible, cannot capture other ways in which the path movement can have special properties. This is why we adopt a manner feature analysis of these properties of non-interpolations path movements.

[22] There are, however, more types of possible secondary movements that do not lend themselves to such an analysis, including rubbing, scissoring, and pumping (e.g., the thumb in repeatedly clicking a ballpoint), which cannot readily be analyzed in a similar fashion. For such cases, we again need 'manner' features. However, we also think that an account of the whole array of secondary movements will most likely include reference to iconically motivated movements that occur in a small set of signs and which do not warrant an extension of the set of features.

[23] Spoken language articulation also has access to various articulators, notably the lips and the tongue (and various subpart of the tongue), which are often regarded as different articulators. In spoken language, articulators can be combined and the presence of each is contrastive, as in for example, the complex consonant /kp/, which in some languages contrasts with both /p/ and /k/.

[24] Van der Hulst (1996), who calls these two types of two-handed sign signs 'balanced' and 'unbalanced', respectively, argues that the weak hand deserves its own place in the structure in both types, which requires a branching structure of the Articulator node, with the weak hand being a dependent node. He further argues that the dependent status of the weak hand accounts for its underspecification. In balanced signs, the weak hand is fully underspecified (because it is identical to the strong hand), while the choice for unmarked handshapes in unbalanced signs likewise correlates with a very low degree of specification.

[25] For example, in articulator-based theories, there are usually four articulators (labial, coronal, dorsal, and radical), and to the extent that these articulators can reach more than one location, 'dependent'

features are specified under the articulator features that refer to different locations (such as [±anterior]) or to shapes of the articulator (such as [±distributed], [±retroflex], and [±lateral] as dependents of [coronal]). Other phonologists will, while using articulator features such as [coronal], [dorsal] etc., regard these as choices under a node labelled ‘Place’.

[26] The structure for spoken segments usually also includes a laryngeal node for phonation features for consonants, or tone features for vowels.

[27] The sign structure in (15) captures an insight offered in Stokoe (1991), who compares the articulation of a sign to a subject-predicate structure in which the hand (the ‘subject’) performs an action (‘the predicate’), which involves a movement toward or on a place. Stokoe suggests that this prototypical sign structure was a model for the emergence of the prototypical sentential syntactic structure: [subject/actor [verb/action [‘theme’]]].

[28] The sub-articulators correspond to the separate articulators [labial], [coronal], [dorsal], and [radical] in models for segments in spoken language models. The sub-articulator [coronal] can take different shapes, namely apical and laminal, retroflex and lateral. Such finer distinctions are not present in the sign geometry.

[29] In spoken languages, vowels can constitute a morpheme by themselves, as well as consonants; the latter case is typically restricted to bound morphemes. However, given the limits on inventory sizes (with an average of 34) (Maddieson 1984), the number of segments in spoken languages is far below the average number of morphemes that sign languages have (although we are not aware of any estimates for this average number).

[30] The picture for spoken language is slightly more complex, since, for example in a tone language, the tone layer is arguably horizontally sliced first. This results in the autosegmental nature of tone, as proposed in Goldsmith (1976).

[31] Our distinction between grammatical and utterance phonology relates to ‘lexical rules’ and ‘post-lexical rules’, following Kiparsky (1982). While utterance rules would certainly be post-lexical (and in fact, post-syntactic), grammatical rules can be lexical rules (referring to ‘words’) as well as phrasal rules that are grammatically conditioned.

[32] See Nevins (2011) for phonologically-motivated suppletion in spoken languages.

[33] There could be additional factors for why spoken languages are so characteristically rich in allomorphic variation. One such factor could be the stability in language transmission across generations, which impose allomorphy on the learner even though, as is well known, allomorphy is non-optimal from the viewpoint of one-to-one form-meaning relations. And indeed, learners are probably responsible for analogical levelling and extension, which eliminate such allomorphic variation or make it more general by extending it to more words. We speculate that learners of sign languages, perhaps being typically guided by a rather impoverished or more diverse input (because their primary learning environment, i.e., their caretakers, may not be native signers), have more freedom and opportunity to create optimal form-meaning relations which militate again allomorphy. Finally, a factor that stabilizes allomorphy in spoken languages may be the presence of alphabetic writing systems.

[34] We also refer to Meir et al. (2013) for a different kind of demonstration of the systematic role played by iconicity in the grammar of sign languages.

[35] Perhaps a closer analogue would be cases in which a feature is used ideophonically in a spoken language, when words occur in two variants that differ in meaning. We refer to Dingemanse (2012) and Dingemanse et al. (2015) for examples and systematic discussion.

[36] The case where parsing is non-exhaustive, thus leaving a residue that is called a cranberry morpheme (after the unit ‘cran’) is considered to be exceptional in morphological analysis of spoken languages.

[37] Perhaps the earliest proponent of this view is West (1960).

[38] In his later work, Stokoe developed the notion of 'semantic phonology', which, while not unrelated to the issues discussed here, has a different motivation; see endnote 27. Stokoe suggested that the basic structure of signs, as discussed here in Section 3, is based on a semantic subject-predicate structure.

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