1 Introduction

This chapter focuses on the notion of syllable in sign languages. Although there is now a consensus on the defining feature of a syllable in sign languages, i.e. that there must be a movement, the initial idea of having “syllables” in sign languages met with considerable resistance on its introduction in the early 1980s, in large part because sign languages are fundamentally monosyllabic languages (see Coulter 1982 on American Sign Language (ASL); similar evidence has been provided for Finnish Sign Language by Jantunen 2007). There was also a strong undercurrent that using concepts borrowed from spoken language linguistics for sign language phenomena would be problematic, if not inappropriate. However, I had an opportunity to ask my colleague Ray Kent, a speech researcher who was then editor of the Journal of Speech and Hearing Research, what he would require if I were to send his journal a paper on syllables in sign languages. He said he would look for evidence that the concept was linguistically meaningful and could be reliably measured, and his response will begin our tour on this topic. Actually, proving to spoken language researchers that there are syllables in sign languages on those two criteria was remarkably easy (Wilbur and Nolen 1986; Wilbur and Allen 1991). In contrast, the phonological representation of sub-syllabic structure has been under constant and lively debate. Accordingly, the presentation of evidence for the existence of syllables will be brief, and the bulk of the chapter will focus on describing the issues of disagreement and providing evidence for an answer to the question of the representation of syllables in sign languages.

2 Historical background

Early sign language research treated the sign as the unit of analysis. This is best observed in Stokoe (1960), where each sign was treated as a unit. Then, when this unit was analyzed further, it was observed that a sign was composed of a “simultaneous” bundle of aspects/primes/parameters, including the “big four”: handshape, location, movement, and orientation (Stokoe 1960; Friedman 1974, 1977; Battison 1978; Siple 1978; Klima and Bellugi 1979; Wilbur 1979; see also
Several studies suggested that there are syllables in ASL and that these syllables have internal “sequential” organization (Kegl and Wilbur 1976; Chinchor 1978, 1981; Newkirk 1979, 1980, 1981; Liddell 1984). Before addressing the question of internal organization of sign syllables, some clarification of the notion “syllable” in sign languages is necessary.

To better appreciate the status of a syllable in sign languages, we must consider the difference between a syllable and a sign. In many cases, the sign is a single syllable and the boundaries of the two, i.e. a syllable or a sign, coincide (Coulter 1982, 1990). Figure 56.1 is an example of a single-syllable sign.

In other signs, such as BABY in Figure 56.2, there are two syllables in a single sign. The sign BABY is a larger unit than ARRIVE (Figure 56.1). In still other signs, such as MOTHER (Figure 56.3), there are specifications for handshapes, locations, and hand orientations, but, critically, these signs do not have their own movement specifications.

Since every syllable must have a movement, the phonological specification for these lexical items is smaller than a syllable; it has been proposed that the epenthetic/transition movement to, or away from, the target location provides the prosodic feature needed to produce a full syllable (Wilbur 1985; Brentari 1990b, 1998; Geraci 2009).

We have so far sketched sign syllables by providing three groups of signs with different movement specifications, i.e. with single movement, with two movements,
and without lexical movement. We now consider the difference between a syllable and a morpheme in order to distinguish their functions. A morpheme is defined as the smallest possible unit of meaning. In Figures 56.1–3, each sign is also a single morpheme. In Figure 56.1, the morpheme and the syllable are the same size. In Figure 56.2, the morpheme is larger than the syllable (it has two syllables), and in Figure 56.3, the morpheme is smaller than the syllable (it is missing movement). A morpheme may also be as small as the feature specification for a single handshape, as in classifier constructions (see Chapter 9: Handshape in Sign Language Phonology), or location, as in verb agreement.

It should be noted that two-syllable lexical items are highly constrained with respect to their movement specifications: the movement in the second syllable is either the exact opposite (180° rotation) of the movement in the first syllable (as in BABY, Figure 56.2) or it is 90° rotated (Figure 56.4; note transitional movement inserted when the end of the first movement is not the starting position of the second movement) (Wilbur and Petersen 1997).

Clearly movement is central to syllable structure (see Chapter 24: The Phonology of Movement in Sign Language). The first attempt to break sign movement into smaller sequential pieces was Newkirk (1979, 1980, 1981). Considering rhythmic features of movement, he analyzed them into [onset] [movement] [offset]. Subsequently, a number of sequential and simultaneous proposals were offered. This brings us to the ongoing debate – what is the internal structure of a syllable with respect to sequentiality and simultaneity? In the following section, I provide an overview of what everyone does agree upon, i.e. that syllables in sign languages exist. In the subsequent section, I provide evidence of the behavior of syllables with respect to higher phonological organization. Finally, we dive inside the sign syllable and consider the evidence for the two theoretical options – sequential and simultaneous organization of syllable structure.
3 Sign syllables exist

Syllables have been reliably measured, and in conversational contexts they have roughly the same duration as spoken language syllables (Wilbur and Nolen 1986). As will become clear below, there has been no shortage of linguistic uses for the syllable in sign language (morpho-)phonology, hence it is linguistically meaningful. It is fair to say that sign language phonologists now take the notion of sign syllable as a given, and that movement is its nucleus (the carrier of its perceptual salience; Jantunen and Takkinen 2010).

3.1 Syllable measurements

Investigators have measured sign duration, including signs that are clearly single syllables (Bellugi and Fischer 1972; Friedman 1976; Liddell 1978, 1984). For those signs which are monosyllabic, the measured duration means range from 233 to 835 msecs as a function of context. Liddell (1978) reported the effects of sentence position and syntactic function on duration of the monosyllabic signs DOG and CAT. His measurements show phrase-final lengthening, as the durations were longest in sentence-final position. Duration in sentence-initial position was next longest, and medial position in relative clauses had the shortest duration. His measurements also show a syntactic effect: objects were shorter than subjects or heads of relative clauses.

My investigation of syllable duration began in 1984, when videotape was “reel to reel,” which meant that the tapes could be moved by hand, forward and backward, and measurement was in “fields” – 60 per second. To measure syllables, movements, and holds, we had to provide our own mechanical guidelines and demonstrate that they could be reliably used (Wilbur and Nolen 1986; Wilbur and
Sign Syllables

We started with the cues identified by Green (1984) for beginnings and ends of signs, which worked well for signs that were perceptually monosyllabic. These cues included points of contact and changes in facial expressions and eye gaze. However, Green’s procedures were not sufficient for determining syllable boundaries when the sign and the syllable are not coterminous, i.e. when we have more than one syllable in a sign. To capture the behavior of multisyllabic signs such as bidirectional signs (Figure 56.2 above), reduplicated forms, and compounds, additional cues were needed. With the aid of native signers, we determined that a change in the direction of movement marked a boundary between two adjacent syllables. For elliptical movements, we accepted Newkirk’s (1979, 1980, 1981) argument that they were segmentable into two parts, and then we used the change in direction of movement as the boundary between the two parts. By contrast, circular movements, which show no internal structure, were treated as one syllable per circle. For holds, we established a procedure in which the end of a hold would be marked by one or more of the following cues: start of the next movement, loss of tension in the signing hand(s), change of eye gaze, initiation of signing by the other signer, or change of eye gaze by the other signer (Wilbur and Nolen 1986). Syllables were measured by two people at a time; if they could not agree, a third person was consulted. Over three thousand syllables were measured in four situations – natural conversation, elicited paragraphs, lists of signs, and phrases and compounds.

In conversations, 889 syllables from three signers had a mean of 248 msecs, comparable to the estimated 250 msecs for spoken English (Adams 1979; Hoequist 1983). This similarity may be a reflection of an underlying timing mechanism for motion that may surface not only in speech and signing, but also in non-linguistic motor behaviors. For example, in baseball, a bat swing takes about 200 msecs (Schmidt and Lee 2005).

For the lists, mean syllable duration was 299 msecs for the first production, and 417 msecs for the second. Thus, signers can have different durations at different times. For paragraphs, 14 signers produced paragraphs with either a stressed or unstressed target sign. The stressed target mean was 317 msecs, and the unstressed target mean 299 msecs. There were more syllables in the stressed condition, i.e. repeated syllables and/or resyllabification (similar to English please pronounced as puh-leeze).

In the last condition, compounds may have two syllables or can be reduced to one (Coulter 1982; Liddell 1984). Eighteen sets of compounds and their two component signs were provided by Ursula Bellugi. In each set, the two signs appeared in a phrase in isolation (e.g. FACE CLEAN) and in context (HE HAS FACE CLEAN ‘He has a clean face’). The same morphemes also appeared in a compound (FACE-CLEAN ‘handsome’) in isolation and in context (HE FACE-CLEAN ‘He is handsome’). The compounds had significantly more syllables per sign than simple lexical items (Wilbur and Nolen 1986). Also, the signs in isolation (whether simple lexical items or compounds) had significantly more syllables than in context, reflecting prosodic effects. Thus signers manipulate both syllable duration and number of syllables in their sign productions.

The evidence so far lends support to one of the two criteria that started our discussion, i.e. “Can syllables be reliably measured in sign languages?” We turn now to the other criterion, i.e. “Are syllables linguistically useful?”
4 Phonological applications identified for “syllable”

In this section, I briefly review the arguments that have been offered to show that syllables contribute to the statement of phonological processes and to our understanding of why some processes behave the way they do. The notion of syllables has proven to be useful in the statement of a variety of historical changes (Battison 1978; Frishberg 1978), synchronic morphological processes (Chinchor 1981), and phonological processes (Coulter 1982; Wilbur 1990b, 1993). Blevins (1993), Padden (1993) and the work of Brentari (1990a, 1990b, 1993, 1996, 1998) provide further arguments in favor of the role of syllable structure in ASL phonology. I review only a few, and refer the reader to the original authors for further evidence and discussions.

4.1 Fingerspelling and fingerspelled loan signs

Battison’s (1978) discussion of the creation of new signs from fingerspelled words provides data to support the notion of syllables. Theoretically, each fingerspelled letter consists of a handshape and, when produced in slow sequences, a transition movement (handshape change) to reach each handshape. Thus, there could potentially be as many syllables as there are letters in the word being fingerspelled, because there could be one movement to make each handshape and each could therefore be a syllable. In actuality, fluent fingerspelling is performed with a phrasal rhythm that smoothes the transition handshape changes and reduces the prominence of certain handshapes while increasing the prominence of others (Akamatsu 1982, 1985; Wilcox 1992). In the process of becoming a lexicalized fingerspelled loan sign, some letters in a word are dropped, and remaining handshapes are associated to syllabic nodes, reducing the number of syllables produced. Fingerspelling the word “sick” (Figure 56.5) involves handshape changes from each letter to the following letter. Since fingerspelling is based on English spelling, each English word will have a different set of handshapes and a corresponding different set of transitional handshape changes. In contrast, in the fingerspelled loan sign #SICK (where # denotes a fingerspelled loan sign (Figure 56.6), the middle letters have been dropped, and the handshape change from S to K has created the movement nucleus of the syllable, to which a slight directional path movement has been added (the arrow does not do justice to this – the middle finger can appear to flick forward from the fist while the index finger straightens up). At the syllable-internal level, the features for

![Figure 56.5](image-url) Handshapes S, I, C, K, with three transition movements between them
the handshapes S and K are associated with the same syllabic node, i.e. the only syllabic node. The handshape change from S to K is not permitted in core lexical items as reflected in Brentari’s model, thus this form is clearly identified as of foreign origin from English. Brentari (1994) used the fingerspelled loan signs from published ASL lectures (Valli and Lucas 1992) to determine the processes involved in lexicalization. She found that long fingerspelled words with as many as eight or more letters reduced to fewer handshapes and just two movements. The result is that the newly lexicalized forms fit the phonotactics of ASL, having a maximum of two syllables.

4.2 Evidence for a sonority hierarchy

Several researchers have suggested a relationship between visibility and syllable sonority (Corina 1990; Perlmutter 1992; Sandler 1993; Brentari 1998). The sonority hierarchy treats movements made with joints closer/proximal to the body/trunk, such as elbows and shoulders, as more sonorous, because of their visibility in motion when compared to those lower down and more distal, such as hands and fingers, which are considered less visible and hence less sonorous (1) (see CHAPTER 49: SORORITY for an overview of issues surrounding the sonority hierarchy in spoken language):

(1)  
Sonority hierarchy with respect to the relevant joints (from Brentari 1998)

<table>
<thead>
<tr>
<th>Most sonorous</th>
<th>Least sonorous</th>
</tr>
</thead>
<tbody>
<tr>
<td>shoulder &gt; elbow &gt; wrist &gt; base finger &gt; non-base finger</td>
<td></td>
</tr>
<tr>
<td>joint</td>
<td>joint</td>
</tr>
<tr>
<td>joints</td>
<td>joints</td>
</tr>
</tbody>
</table>

Movements made with the wrist joint have a higher sonority value, i.e. are more visible due to larger movements, than movements made with the use of finger joints. With respect to the development of fingerspelled loan signs above, the addition of the slight path movement in the loan sign #SICK may be viewed as adding a higher sonority value to the less sonorous handshape change from S to K, thereby producing a more sonorous syllable and hence more acceptable lexical item. Thus what we observe is that the proposed prosodic hierarchy provides a rationale for why finger positions are dropped and wrist or elbow movements (depending on how the small path is made) are retained in fingerspelled loan words (CHAPTER 95: LOANWORD PHONOLOGY).
4.3 **Contact metathesis**

Another situation where the notion of syllable is phonologically relevant is found with two-location contacting signs, which in certain circumstances can undergo a change that causes the two locations to switch their order (i.e. metathesis; Kegl and Wilbur 1976; Johnson 1986; Sandler 1986; Wilbur 1987; chapter 59: metathesis). For example, the location points in signs such as DEAF, PARENTS, and FLOWER may switch from A-to-B to B-to-A (Figure 56.7), depending on preceding phonological context:

The process of metathesis is limited to signs that are both single morphemes and single syllables. Some were originally compounds and may be articulated in a way which reflects their origins. For example, the sign PARENTS might be deliberately made to emphasize its origin from FATHER + MOTHER: movement to contact at the forehead (FATHER) and then movement to contact at the chin (MOTHER). This form would be two syllables, and not subject to metathesis. In the monosyllabic version of PARENTS, the forehead contact is preceded by a transition movement, and the lexical syllable consists of the change in location from the forehead contact to the chin contact. This latter form can undergo metathesis, i.e. the hand can touch the chin first and the forehead second.

The statement of metathesis in terms of syllables greatly simplifies the formalization of the rule. We can see that the statement in terms of syllables is the correct one, as opposed to morphemes or signs. PARENTS can undergo metathesis in one form of production but not in another, so the rule about which signs can undergo metathesis could not refer to “contacts in the same sign” or “contacts in the same morpheme,” but only to “contacts in the same syllable.”

4.4 **Handshape change (change in aperture)**

Brentari and Poizner (1994) show that handshape change timing is different within syllables than it is between syllables (chapter 9: handshape in sign language phonology). Within syllables, if there is path movement and handshape change, the handshape change coordinates with the beginning and end of the path. However, when two signs in sequence have different handshapes, there must be a transitional handshape between the end of the first sign and the beginning of the second (as discussed for fingerspelling, above). In such conditions, the
change in handshape is not coordinated with the path movement in the same way as within signs, that is, the timing of the change does not distribute evenly over the transitional path movement.

4.5 Consistency in movement

Likewise, Tyrone et al. (2007) compare monosyllabic sign movements toward the body to the same location (e.g. forehead) in two conditions: (i) the movement is part of the sign (THINK), and (ii) the movement is transitional prior to the sign (SMART). They report that within-syllable within-sign movements show typical bell-shaped velocity curves for targeted movement, whereas transitional movement between signs is less regular. These findings, along with the handshape change findings above, converge on the necessity of separating phonological syllable movement from phonetic epenthetic/transitional movement.

4.6 Minimal word

Simply put, the syllable is the smallest possible well-formed sign/word. Furthermore, two syllables is the maximum for well-formed core lexical signs (Perlmutter 1992; Sandler 1993; Brentari 1998; Jantunen 2007). Alternative formulations without mention of syllables would necessarily be more complex.

4.7 Prosodic constraints

Miller (1997) argued, on the basis of Quebec Sign Language (LSQ), that Phonological Phrases require a disyllabic foot. Similarly, van der Kooij and Crasborn (2008) suggest that in Sign Language of the Netherlands (NGT) the phonological constraint on the addition of sentence-final pointing must be stated in syllabic terms: sentence-final pointing is permitted only if the outcome is a disyllabic foot. Wilbur (1999a) observes that ASL pronouns in sentence-final position tend to be extrametrical with respect to stress assignment at the phrase level, supporting prosodic constraints proposed in Halle and Vergnaud (1987) for spoken languages.

5 Syllables and prosody

The last two arguments in favor of syllables also provide evidence for the prosodic hierarchy in sign languages. That is, metrical structure (lexical, phrasal, and clausal stress assignment), rhythmic structure, and intonational phrasing are dependent to some degree on the syllable level. (2) shows the prosodic hierarchy we adopt for further discussions (see CHAPTER 33: SYLLABLE-INTERNAL STRUCTURE; CHAPTER 40: THE FOOT; CHAPTER 51: THE PHONOLOGICAL WORD; CHAPTER 57: QUANTITY-SENSITIVITY; CHAPTER 84: CLITICS for more discussion of the prosodic hierarchy). Prosodic words will be discussed in this chapter; for discussion of Intonational Phrases see Wilbur (1994), Sandler and Lillo-Martin (2006), and Weast (2008).

(2) Prosodic hierarchy

syllable < prosodic word < prosodic phrase < intonational phrase
Ronnie Wilbur

5.1 Prosodic words

As indicated, the minimal prosodic word is at least one syllable, and the prosodic constraint on well-formed lexical items is a maximum of two syllables. Brentari and Crossley (2002) demonstrated that changes in lower face tension (mouth and cheeks) mark the end of a prosodic word (PW), which is above the syllable in the prosodic hierarchy. Figure 56.8 shows a single lower face position, i.e. closed mouth with lip corners slightly down, referred to as posture non-manuals (P-NM), which stretches over one long PW, followed by the sign WORK, which has a round mouth and is in a different prosodic word. The context was “every year at Christmas time, the boss gives each of the employees a gift.” Note that the single PW contains five syllables (five repetitions of the lexical item GIVE-A-GIFT).

(3) represents the marking of the relevant prosodic words through sign language glossing conventions. The tier above the glosses represents non-manual marking, and the line indicates the spread of the non-manual marker:

(3) Prosodic grouping for Figure 56.8

\[
\begin{align*}
\text{P-NM} & \quad \text{P-NM} \\
\{ \text{GIVE-A-GIFT [Repeat } \times 5] \} & \quad \{ \text{WORK(ERS)} \}
\end{align*}
\]

In contrast, Figure 56.9 shows “one car hits another car three times.” The signer produces three mouth changes (Transition-NMs), once for each repetition. These changes result in three PWs, as represented in (4):

(4) Prosodic grouping for Figure 56.9

\[
\begin{align*}
\text{T-NM} & \quad \text{T-NM} & \quad \text{T-NM} \\
\{ \text{HIT-CAR} \} & \quad \{ \text{HIT-CAR} \} & \quad \{ \text{HIT-CAR} \}
\end{align*}
\]
5.2 Stress assignment

Stress assignment is a prosodic process, and may occur on lexical items, compounds, and phrases. Early research on ASL stress focused on marking stress on lexical items (Covington 1973; Friedman 1976; Wilbur and Schick 1987; Coulter 1990). Stressed signs can be set off from unstressed signs by several cues: (i) faster/shorter transition movement than between unstressed signs, breaking the rhythmic pattern; (ii) higher in the signing space compared to their unstressed counterparts; (iii) increased repetitions compared to their unstressed counterparts, changing the duration; (iv) increased speed (higher peak instantaneous velocity) compared to their unstressed counterparts; (v) increased muscle tension compared to their unstressed counterparts; and (vi) stressed signs have a following pause (Wilbur and Schick 1987; Wilbur 1990a, 1990b, 1999b, 2009; Allen et al. 1991).

5.2.1 Lexical items

So far, no sign language has been shown to have distinctive lexical stress, comparable to English *permit* and *permít* (Jantunen and Takkinen 2010). The predominance of monosyllabic lexical items is partly responsible for this absence. Another reason is that polysyllabic signs are restricted to three possibilities:

*Lexicalization of repetition:* A sign may have more than one syllable if it is formed as a result of lexicalization of a repeated form (e.g. ASL FINGERSPELL; Brentari 1998: 169). The result is a two-movement sign with a Return transition in the middle: A-Return-A. In these forms, only the first syllable is prominent/stressed (Supalla and Newport 1978; Coulter 1990).

*Lexical disyllables:* A sign may have two syllables if it is a lexical disyllable, i.e. if the morpheme itself requires two syllables. There are two types of disyllables, both of which are subject to constraints on the nature of the movements in each syllable (Wilbur 1990b). In the first type, the movement of the second syllable must be rotated in direction 180° from that of the first, returning the hands to their original location (BABY; Figure 56.2). In the second type, the movement of the second syllable is rotated 90° from the first (creating a crossing movement) (CANCEL; Figure 56.4). Supalla and Newport (1978) discuss the first type, and note that prominence is equal on both syllables. It is also the case that prominence is equal on both syllables in the second type. Thus all lexical disyllables have equal stress on both syllables. Similarly, van der Kooij and Crasborn (2008) show that NGT has both trochaic and iambic stress patterns for disyllabic signs, the
type being predictable on the basis of the phonotactics of the rest of the sign. Thus, as for ASL, stress is not distinctive in NGT.

Lexical items have stress on the first, and perhaps only, syllable. Lexical disyllables are exceptional in being specified at the morphemic level for two syllables and in requiring equal prominence on both syllables.

Compounds and phrases: A sign may have two syllables if it is a compound, with the first weaker than the second. Unlike lexical items, the assignment of stress to ASL compounds and syntactic phrases follows a very general pattern. In a compound or phrase, a single stress is assigned to the most prominent syllable of the rightmost lexical item.

6 The internal structure of syllables

6.1 The debate

Historically, models of the internal structure of syllables (Chapter 33: Syllable-Internal Structure) have taken one of two views. The first view is that sign syllables, like spoken syllables, are composed of sequences of segments (Chapter 54: The Skeleton). These segments are of two types (like consonant and vowel in spoken language), namely Movement (M) (the hands are in motion) and a contrasting type with the hands not in motion. Distinctive features are distributed among these phonological segments parallel to spoken language C and V.

Liddell (1984) argued for two types of segments, movements (M) and holds (H). The remaining information – handshape, contact, orientation, location, and facial expression – is represented as features occurring simultaneously with each segment, thus there is a sequence of feature matrices within each sign. Signed syllables could then be of several types, e.g. M, MH, HM, HMH. Sandler (1986, 1989, 2008) proposed a different model, in which the segment opposition is between movement (M) and location (L), with handshape configuration on a separate autosegmental tier. The presence or absence of holds would be characterized by a binary feature in the location feature matrix; rather than having holds underlyingly, there will be some phonetic holds (list rhythm), some phonological holds (at utterance boundary), some morphological holds (ASL aspectual inflections may include final hold as part of their pattern), and some pragmatic holds (end of conversational turn, waiting for back-channel nod). For these models (e.g. Liddell and Johnson 1989; Sandler 1989, 2008; Sandler and Lillo-Martin 2006), the segments are at the top of the phonological trees containing the distinctive features, i.e. the mother nodes in a feature geometry model. That is, the syllable is composed of segments, which are characterized by relevant phonological features.

In the other view, supported in Brentari (1998) for ASL and van der Kooij (2002) for NGT, movements are dynamic prosodic units with similar autosegmental status as tones in contrastive tonal languages (e.g. Mandarin, Cantonese; Chapter 45: The Representation of Tone; Chapter 107: Chinese Tone Sandhi). An important step leading to this alternative view was van der Hulst’s (1993) Head–Dependency Model, in which features that did not change during the sign were considered to be heads, with changing features treated as dependents (for detailed discussion see Chapter 24: The Phonology of Movement in Sign Language). Head features
could be location, orientation, the active (selected) fingers, or their configuration. Movement itself was dependent on change of location (path movement) or hand configuration or orientation (local movement) (see similar arguments in Wilbur 1987). Brentari (1998) provides arguments against the notion of dependent/emerging movement, and instead identifies those features that do not change within the syllable as Inherent Features (IF) and those that do change as Prosodic Features (PF). From this perspective, ASL syllables contain distinctive features which may be accessed by phonological rules only in terms of their tiers and syllabic positions (e.g. syllable-initial, syllable-final), without further subdivision or organization. The segments are abstract timing slots at the bottom of the tree, onto which the phonological features are mapped, i.e. the terminal nodes in a feature geometry approach. Thus the question arises of how these two models should be distinguished.

6.2 Evidence related to syllable structure

Jantunen and Takkinen (2010) observe that there is no “direct phonetic evidence” to support the sequential segmental models. In fact, evidence against the segmental arrangement of internal syllable structure comes from a variety of experimental sources: tapping, slips of the hand, and backwards signing.

6.2.1 Tapping

Spoken syllables have a rhythmic focus at the onset of the nuclear vowel (Allen 1972). That is, native English speakers who tap in time to speech cluster their taps at the stressed vowel onset. In a comparable study of ASL, native Deaf signers, native hearing signers and sign-naive hearing subjects were asked to “tap the rhythm” of five different three-sentence signed stories. Each story was presented 30 times. One story was repeated as the sixth condition (30 repetitions) for reliability; these conditions represent “tap the rhythm” (Allen et al. 1991). Finally, another one of the stories was repeated (30 repetitions) with new instructions to “tap the syllables.” Analysis of the tap responses in this condition showed that for all groups, taps are evenly distributed within syllables and do not differ from chance distribution. That is, no syllable-internal rhythmic focus is apparent (Wilbur and Allen 1991). This result is very crucial, and can only be predicted if the sign syllable is composed of constantly changing movement (smoothly changing muscular activity), meaning that there is no single point in time which attracts perceptual attention in the way that the onset of a spoken stressed vowel does, with large changes in muscular and acoustic energy (Allen 1972). The absence of such peaks is consistent with the proposal in the Prosodic Model that there is no further segmentation inside the sign syllable.

6.2.2 Slips of the hand

Additional arguments against segmental models come from sign errors (Meier 1993; Wilbur 1993). English slips of the tongue tend to involve all the features of the segments involved (Fromkin 1971, 1973). If sign phonological features are distributed across segments, as suggested in segmental models, all features associated to each segment should be able to behave as a group. Therefore, parallel to speech, we might expect that the initial segments of two signs could switch with everything else remaining the same. In the corpus of 131 slips of the hand (Klima and Bellugi 1979), the predicted segmental switch did not occur. Instead,
observed slips involved handshape, location, orientation, or handedness (one vs. two hands) features, with handshape involvement being the most common.

In one slip involving BLACK and WHITE, the handshape sequence in WHITE (open fingers and thumb changing to closed fingers and thumb touching at tips) is anticipated in BLACK, with its regular handshape completely replaced by the handshape change from WHITE, whereas its location (at the forehead) and movement direction (brushing across) remained unaffected (Klima and Bellugi 1979: 139). What did not happen was a complete replacement of the initial handshape, location, and orientation of BLACK with those of WHITE, which would have created a form that started at the chest, not at the forehead. In none of their examples did the features act together as a group, as would be predicted from segmental models.

6.2.3 Backwards signing

Backwards signing demonstrates that signers have access both to syllable sequences and to individual features within syllables which can be exchanged in temporal sequence, but not to units corresponding to segments as defined by the segmental models. This contrasts with the evidence from spoken language games and backwards speaking (Sherzer 1970; Cowan and Leavitt 1981, 1990; Cowan et al. 1982; Treiman 1983; Cowan et al. 1985; Cowan et al. 1987; Cowan 1989). Cowan et al. (1985: 680) report that fluent backwards talkers segment speech into “phonemic or syllabic” units, and then reverse their order. Their subjects fall into two groups, using either orthography or phonology as the basis for reversal. For example, for ‘terrace’, orthographic reversers would say /ekare/, including the final “silent e” and adjusting the pronunciation of the letter “c” followed by back vowels to /k/. Phonological reversers would say /s\ret/, simply reversing phonological segment order.

Data from backwards signing (Wilbur and Petersen 1997) provide evidence that signers treat monosyllabic signs in ways that are not compatible with segmental models. For example, Liddell’s (1984) representation for THINK in (5) consists of two segments MH, i.e. M-[approach](AP) followed by H with contact. The exchange of these segments should yield HM, i.e. H with contact followed by M-[approach]. Signers actually produce “contact” followed by “move away,” a result which would be predicted if the starting and ending locations of the movement are exchanged. That is, if movement is represented as a sequence of features, say [-contact] [+contact] (5b) (or [neutral] [forehead] rather than [approach]), then exchanging those features within-syllable to [+contact] [-contact] will result in the correct prediction of movement away from the forehead. Note that in Liddell’s model in (5a), there is a sequence of [-contact] [+contact], but these features cannot switch independently of the segments AP and H to which they are assigned. This is what we mean by having the segments at the top of the model.

(5)  

a. *Liddell’s model of THINK*

<table>
<thead>
<tr>
<th>Segment</th>
<th>AP</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Handshape</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Orientation</td>
<td>TI</td>
<td>TI</td>
</tr>
<tr>
<td>Location</td>
<td>FH</td>
<td>FH</td>
</tr>
<tr>
<td>Contact</td>
<td>−</td>
<td>+</td>
</tr>
<tr>
<td>Non-manual markings</td>
<td>−</td>
<td>−</td>
</tr>
</tbody>
</table>
b. Feature representation of change seen in backwards signing of THINK

\[
\sigma
\]

\[
[-\text{contact}] \quad [+\text{contact}] \quad \rightarrow \quad [+\text{contact}] \quad [-\text{contact}]
\]

Incorrect predictions from segmental models are more obvious with the sign FLY, represented as a single M segment. The predicted backwards version should be the same as the original, because there is nothing available to exchange. Backwards signing shows that the direction of movement of FLY is reversed (Figure 56.10), comparable to the movement reversal in THINK. This remains an inexplicable fact in segmental models which treat movement as a single M segment with its own feature matrix. The only recourse is to change the representation to H₂MH₁ and then reverse the two Hs, but evidence for the presence of those H segments would need to be provided. In any case, the lack of analogy with spoken segment sequences can be seen: the backwards form of cat /kæt/ is /tæk/, with the vowel unchanged. But, clearly, in the backwards form of FLY the movement has changed.

Any segmental model containing M segments will have the same problem, because it is the phonological features associated with the movement that must be available to signers to be exchanged. In backwards signing, movements are consistently reversed by exchanging end specification with start specification, as though initial and final features are exchanged on their own tiers: end location with beginning location; end handshape with beginning handshape; end orientation with beginning orientation. Wilbur and Petersen (1997) argue that movement is not inside the syllable, but rather that movement is the syllable, a conception of “syllable” that takes movement as a dynamic gesture with only starting and ending specifications for the movement trajectory and no further linguistically meaningful internal specifications (see current arguments from gestural phonology approaches, e.g. Mauk and Tyrone 2008; Tyrone and Mauk 2008). For speech, Bagemihl (1989) and Pierrehumbert and Nair (1995) argue that sub-syllabic constituents, such as onset and rime or coda, do not participate in language game behavior, with Pierrehumbert and Nair extending this observation to phonological theory in general, claiming that these sub-syllabic constituents do not exist and that a flat syllable model, such as that proposed by Clements and Keyser (1983), is adequate to account for the facts. Bagemihl (1989: 485f.) notes that language

![Figure 56.10](image-url) The sign FLY, made (a) with normal movement and (b) in backwards signing
games in cultures lacking phonemic alphabet writing systems do not use segments, only syllables. Furthermore, children do not use segmental language games until they are exposed to those writing systems. He suggests that alphabetic writing systems may be necessary for the development of metalinguistic awareness of segments as opposed to syllables.

Brentari (1998) capitalizes on these and other observations by separating the specifications that do not change during a syllable (Inherent Features) from those that do (Prosodic Features). Each syllable has two timing slots, one after the other, representing sequentiality, and the Prosodic Features are associated accordingly. The Inherent Features spread across both slots. Thus, her timing slots (sequentiality) are at the bottom of the tree, whereas for Sandler and Liddell, the sequentiality is at the top of their models. Jantunen and Takkinen (2010) review the sign language studies, and note that there is no evidence for internally structured sequential segmental syllables of the kind found in spoken languages (such as an onset–nucleus–coda distinction). Hence there is no justification for positing an intermediate level between segment (referring here to the timing slots in Brentari’s model) and syllable, or more than two segments/slots per syllable. Finally, another benefit of the Prosodic Model for sign languages is that it provides seamless access to the prosodic hierarchy above the syllable.

7 What does simultaneity in syllable structure buy us?

It is time to turn our attention to the benefits of the notion of simultaneity in sign syllables, that is, what it accounts for that the other approaches do not. There are two important concepts that come from this model of syllable representation, namely the notion of *syllable weight* and the analogue to spoken language *sonority*. In addition, aspectual reduplication can be seen to operate prosodically on verb *roots*, whether one or two syllables.

7.1 Syllable weight

Consider the difference in speech between syllables of different structures CV, CVC, CVCC, CCVC, CVC. It is easy to identify an increase in syllable weight as more consonants are added to these syllables, even without knowing what those consonants are or the type of vowel in the nucleus or whether there is a distinction between short and long vowels or open syllable vowel lengthening (Chapter 57: *quantity-sensitivity*).

If sign syllables do not have the same internal structure as spoken language syllables, then is there a syllable weight distinction in sign languages, and, if so, how does it manifest itself? Brentari (1998) argues that there is a weight distinction in ASL, based on the number of simultaneous movements specified for the syllable. Syllables with one movement are light and those with two are heavy; more technically, a weight unit is constructed for every prosodic foot. With this analysis, she can explain the pattern of verbs that can and cannot take reduplication to form nouns, i.e. respectively light and heavy verbs. For example, the sign FLY in Figure 56.10a above is able to form a repeated nominalization for AIRPLANE because it is a light (one-movement) syllable. In contrast, syllables
with complex movements (for example, a path movement combined with a
handshape change) cannot undergo reduplicated nominalization, even if the
verb qualifies semantically. Similarly, activity verbs that form activity nouns
with the addition of the feature [trilled movement] must have light syllable
structure to start with (Brentari 1998: 242–243). Brentari also shows the correla-
tion between verb heaviness and preference for sentence-final position, that
is, the word order is sensitive to the weight of the verb, which is determined by
the number of movements in the syllable (and if reduplicated, the number of
syllables).

In Brentari’s analysis, the maximum number of weight units per syllable is
two. Using data from Finnish Sign Language (FinSL), Jantunen (2005; see also
Jantunen and Takkinen 2010) argues that an extended system is necessary for
FinSL because more than two weight units per syllable are possible if one takes
the non-manual movements into account – in fact, three or four may be possible.
For Jantunen, a movement is complex (not simple) if more than one articulator
is involved. He is then able to make a weight distinction between two mono-
syllabic signs, MUSTA ‘black’ which has only path movement, hence one weight
unit, and UJO ‘shy’, which has local movement accompanied by a head move-
ment, and hence has two weight units. Thus, even though both are monosyllabic,
the difference in weight results from the non-manual head specification. Another
benefit of this line of reasoning is that in FinSL there are lexical items which
are made entirely with non-manual articulation (there are a few in ASL also)
– these would be assigned a single weight unit, and that is the desired result.
One additional generalization can be stated: both FinSL and ASL prefer syllables
with simple movements over complex movements (Brentari 1998; Jantunen and
Takkinen 2010). This generalization would be lost from a segmental perspective
on syllable structure.

7.2 Sonority

Sonority is not built on syllable weight, as a mora-based generalization might
suggest (Perlmutter 1992). Brentari suggests that sonority be approached as
multidimensional salience. She suggests that sonority is correlated articulatorily
with closeness of the articulator to the body’s midline, and that articulation
closer to the midline has greater visual salience than articulation further away.
Thus, strengthening of visual salience (Enhancement Theory; Stevens and Keyser
1989) by choice of articulator higher up on the hierarchy (and likewise, reduction
by choice lower down) is captured directly by the Prosodic Model in a way that
segmental models cannot (Brentari 1998: 135). She suggests the following hierarchy,
repeated here from (1) above:

(6) Brentari hierarchy

\[
\text{shoulder} > \text{elbow} > \text{wrist} > \text{base finger} > \text{non-base finger}
\]

\[
\text{joint} \quad \text{joint} \quad \text{joint} \quad \text{joints} \quad \text{joints}
\]

This distinction can be observed in cases where a movement can be articulated
by different articulators, that is, if a wrist movement and an elbow movement
can convey the same phonology. In such cases, if the movement is made by an articulator that is up the hierarchy, say an elbow joint replacing a wrist movement, then “proximalization” is said to occur, whereas if the articulator used is down the hierarchy, from elbow to wrist, then “distalization” is said to happen (see Mirus et al. 2001 for an empirical test of the factors involved). Crasborn (2001) likewise provided evidence in NGT for some of the factors relating to proximalization/distalization. An important methodological aspect of Crasborn’s study is that it looked at fluent L1 signers, whereas Mirus et al. looked at L2 acquisition, for which the presence of sonority effects might be obscured by developmental performance factors.

Looking at data from British Sign Language and the echoing of manual movements by the signer’s mouth, Woll (2001) suggests that non-manual articulations can also provide insight into the sonority hierarchy. Based on detailed investigation of these aspects of Finnish Sign Language, Jantunen (2005, 2006, 2007) suggests that non-manual movement should be included in the hierarchy, as in (7), from Jantunen (2005: 56):

(7) upper body and head > hands (including Brentari’s hierarchy) > mouth

7.3 Another perspective on reduplication: Templatic vs. prosodic

Klima and Bellugi (1979) treat reduplication as part of a templatic approach to aspectual modification (CHAPTER 100: REDUPLICATION). They refer to formational terms such as Planar locus (horizontal, vertical), Cyclicity (repetition), Direction (e.g. upward, downward), Geometric array (line, arc, circle, other arrangement), Quality (small, large), and Manner (continuous, hold, restrained). Thus, each morphological function (e.g. iterative, durative) involves a template composed of some of these formational features. But the choices of feature combinations in each template are not explained. Similarly, Sandler (CHAPTER 24: THE PHONOLOGY OF MOVEMENT IN SIGN LANGUAGE) argues for a templatic approach to reduplication, using additional M (movement) or L (location) segments to account for differences in movement type or final holding (what Klima and Bellugi refer to as “end marking”).

Further discussion of reduplication with Klima and Bellugi led us to an interesting separation of function for spatial and temporal formational properties, with the spatial properties providing information about the arguments of the verb and the temporal/rhythmic properties providing information about aspect on the verb (Wilbur et al. 1983). We speculated that reduplication could be analyzed the same way as in spoken languages. It took over 20 years to work it out, but a standard Base–Copy reduplication approach can be applied to sign languages using the Prosodic Model (Wilbur 2005, 2009). In Brentari’s model (8), the node dominating syllables and associated features is the root (CHAPTER 24: THE PHONOLOGY OF MOVEMENT IN SIGN LANGUAGE).

It is important to distinguish repetition from reduplication. Here, repetition is viewed as prosodically driven, to fill the needs of a prosodic foot. Lexicalized repetition creates nouns from verbs, with only two formations of the lexically meaningful movement required. Reduplication is aspectually driven.
Brentari’s Prosodic Model of syllable structure

Whether one syllable or two in a root, the Base for reduplication is the root, and the entire Base is copied. A simple example with Base and Copies is illustrated in Figure 56.11; planar difference indicates argument differences.

There are, however, two modality differences between standard Base–Copy and what occurs in sign languages. First, multiple copies are common (Figure 56.11); indeed, a single copy implies “dual,” so aspectual reduplication typically has two or more copies of the Base. A second difference is that for many aspectual reduplications the hand must return to its initial position in the Base before it can articulate the Copy, thus the sequence is Base–Return–Copy. Aspectual reduplication is a combinatorial system of Base event (verb root), followed by Return to initial position, which reflects the time between the end of the Base event and the onset of the repeated event in aspects involving iteration (Wilbur 2005, 2009). Different aspects determine the size of the Return (smaller than, equal to or greater than the Base) (Table 56.1). Whether the shape includes a stopping point or is smooth (circular, elliptical) is dependent entirely on whether the verb is telic (contains a stop) or atelic (cannot stop) (Wilbur 2008).

Figure 56.11  Base–Copy reduplication schemata for apportionative external and internal. By permission of Ursula Bellugi, The Salk Institute for Biological Studies
For telic events (Figure 56.12), when Return and Base are equal in size, there is the appearance of equal prominence on both (habitual); when the Return is smaller, there is a tendency for the Base to reduce as well (incessant). When the Return is larger than the Base, an arc is added (the morpheme EXTRA; Wilbur 2008). Thus, featurally, incessant aspect has [repeat] [return] [less than], habitual [repeat] [return] [equal] and iterative [repeat] [return] [greater than].

For atelic events (Figure 56.13), only two of the three options are possible, and the Base must be curved. Both of these requirements result from the absence of stops in the formation of atelic roots. Durative has [repeat] [return] [equal] and continuative has [repeat] [return] [greater than]. The atelic equivalent of the incessant, [repeat] [return] [less than], is not possible, because shortened movements would be perceptually equivalent either to stops, creating confusion with telics, or to trilled movement, which has a different interpretation (stative, not repeated). The difference between the modifications shown in Figures 56.12 and 56.13 is the Base root, which reflects the event structure in the semantics of the verb.

**Table 56.1** Combinations of Return options and Base event type yield aspectual inflections

<table>
<thead>
<tr>
<th>time between events</th>
<th>telic event root</th>
<th>atelic event root</th>
</tr>
</thead>
<tbody>
<tr>
<td>[return = root]</td>
<td>habitual</td>
<td>durative</td>
</tr>
<tr>
<td>[return &lt; root]</td>
<td>incessant</td>
<td>n/a</td>
</tr>
<tr>
<td>[return &gt; root]</td>
<td>iterative</td>
<td>continuative</td>
</tr>
</tbody>
</table>

**Figure 56.12** LOOK-AT and three inflections. By permission of Ursula Bellugi, The Salk Institute for Biological Studies

**Figure 56.13** LOOK-stative and durative and continuative aspects. By permission of Ursula Bellugi, The Salk Institute for Biological Studies
These observations are not captured by a templatic approach to reduplication. Sandler’s (1989, 2008) evidence for templatic analysis (for signs like BLOW-TOP, FAINT, and SNOOP) are all compatible with the generalization that aspectual reduplication copies the verb root. She argues that for the sign BLOW-TOP, which is a two-syllable compound created from HEAD and EXPLODE-OFF, EXPLODE-OFF is copied but not HEAD. Her explanation is that the rightmost M is copied in reduplication, whereas in lexicalized monosyllabic (single M) signs like FAINT (originally from MIND+DROP), the whole form is repeated. But in the alternative analysis presented here it is expected that EXPLODE-OFF will be copied. Similarly, Sandle cites SNOOP (from NOSE+STICK-IN) as an exception, with the syllable associated with STICK-IN reduplicating, even though the entire form is monosyllabic (single M). An explanation for this is that the initial movement to the nose for NOSE is purely epenthetic (as for MOTHER (Figure 56.3), and one of the two versions of PARENTS in §4.3). That is, SNOOP starts its STICK-IN movement at the nose but does not return there for subsequent repetitions. If so, it might be appropriate to consider the initial location at the nose to be something akin to a prefixal location adjoined/cliticized onto the beginning location of STICK-IN, resulting from the compound-to-lexical-item reduction process, leaving STICK-IN to be copied by reduplication with its original location, as shows up in subsequent repetitions.

This discussion highlights the kind of phonological level analysis that can be conducted with respect to syllables and their contents. Thus, factors other than phonology, such as verbal telicity and type of aspectual morphology, affect the final form of reduplicated signs (Wilbur 2005, 2009).

8 Conclusion

In this chapter, we started with two basic criteria for discussion of syllables in sign languages: linguistic meaningfulness and reliable measurement. To address the requirements of these criteria, we introduced the reader to relevant historical discussions of the status of syllables in sign languages. The key is that movement is the defining feature of a phonological syllable in sign languages. Then, we provided evidence that syllables in sign languages can be reliably measured. As for the criteria of linguistic meaningfulness, we reviewed several phenomena for which one has to make reference to the syllable for a reasonable account. Among those discussed were the phonologization of fingerspelled loan words, contact metathesis, handshape changes within and between signs, and some prosodic constraints.

We then turned to the debate concerning the formal representation of sign syllables. We reviewed the sequential and simultaneous models of syllable representation. Data presented – tapping, slips of the hand, and backwards signing – strongly favor the Prosodic Model proposed by Brentari (1998), resulting in a syllable model that is internally different from those that exist in speech. We then considered the implications of this conclusion, especially since it goes against expectations of similarity between signed and spoken languages. Issues of sonority, syllable weight, and Base–Copy reduplication indicate that the syllable performs similarly in sign language and spoken language phonologies despite the internal differences in organization.
To get to the point where we can use syllables for explaining other phenomena, we have needed a consistent and well-developed syllable model that makes empirically testable claims. This model has been tested in a variety of ways reviewed in this chapter, and there is more that has been omitted for reasons of space (variability of non-manual marking; judgments of well-formed syllables; Brentari and Wilbur 2008). The critical feature of the model is that it is a prosodic model, and the lowest level of the prosodic hierarchy is the syllable, for sign languages as well as spoken languages.

ACKNOWLEDGMENTS


REFERENCES


