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PROSODY IN SIGN LANGUAGES

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Abstract: *This chapter addresses the debate concerning the status of nonmanuals (head, face, body) as prosodic or not by exploring in detail how prosody is structured in speech and what might be parallels and differences in sign. Prosody is divided into two parts, rhythmic phrasing (timing, syllables, stress), and intonation. To maximize accessibility, in each part, an introduction to what is known for speech is presented, followed by what is known and/or claimed for sign languages. With the exception of the internal structure of syllables, sign languages are very similar to spoken languages in the rhythmic domain. In the intonational domain, the parallels are less strong, in part because analogies of nonmanual functions to spoken intonation tend to be based on older/simpler models of intonation. There needs to be much more detailed research on sign languages to catch up with the recent research on spoken intonation.*

Keywords: *prosody, rhythmic phrasing, intonation, discourse management, stress marking, sign languages*

1. INTRODUCTION AND SCOPE OF THIS CHAPTER

Fenlon and Brentari (2021) characterize the debate about prosody in sign languages as two opposing views, one with NMMs as 'intrinsically associated with specific syntactic constructions' and the other with prosodic structure interacting indirectly with syntax through the semantics. The fundamental tension between these two views is the existence of mismatches -- the prosodic structure does not always correspond to syntactic constituents ("non-isomorphy"). They conclude that since mismatches between prosody and syntax occur (Sandler, 2010; Brentari, Falk & Wolford, 2015), it is 'more fitting' to refer to the scope of NMMs as 'prosodic structure'. Their 'NMMs as prosodic structure' perspective includes the claim that intonation is carried by the upper face, which they suggest adds semantic/pragmatic meaning, whereas the hands produce the text and provide timing cues regarding prosodic constituent boundaries.

This chapter addresses this debate by exploring in detail how prosody is structured in speech (speech science) and what might be parallels and differences in sign (sign science). The systems to be discussed are divided in two: (1) Rhythmic phrasing, which includes timing, syllables, and stress, and (2) Intonation. Both sections provide an introduction to what is known for speech, followed by what is known and/or claimed for sign languages.

If we are going to be making prosodic analogies to speech for signed languages, it would be good to fully understand the domain of that analogy. Speech scientists have the luxury of well-established tools for analyzing and measuring speech characteristics, and a long enough history that they have converged on a common understanding, despite remaining debates about how prosody should be modeled. The well-studied domains of stress marking and rhythmic phrasing provide measurements and perceptual effects of various phenomena such as different types of stress, categorical perception (or not), impacts of artificial manipulations (replacing vowels with noise or coughs, lengthening or shortening voicing onset times, changing pitch values, and so on), and other detailed investigations. Because such tools are not currently available for parallel experiments on sign languages, only two of these domains will be directly relevant for this discussion: patterns of stress marking and patterns of intonation.

As a common starting point, consider what is typically included in 'prosody'. Pierrehumbert and Hirschberg (1990) distinguish phrasing, stress, tune, and pitch range. Phrasing includes how

words cluster into phrases as well as how larger utterances can be divided; phrasing may begin with syntactic phrases but by the time an utterance is produced, phrasing may undergo readjustments as a result of rate of production effects, thus is not fixed by the syntactic structure. Stress involves patterns of (relative) prominence within words, phrases, and clauses. Tune results from sequences of high and low tones used for the pitch (stress) accent, the intermediate phrasal accent, and the final end of intonational phrase boundary tone. The pitch range determines the possible top frequency for the high tone and low frequency for the low tone. In all, it is a componential system in which each piece has a form, location with respect to the word or phrase, and a discourse function (speaker alerting hearer how to process the current phrase or what to expect in the next phrase). Each piece then has the potential to qualify as a morpheme, although there is wide latitude as to what kind of morpheme it might be (free or bound).

The present discussion will address phrasing and stress marking together and then intonational tunes and possible pitch range analogies together.

1.1 Rhythmic Phrasing and Stress Marking

Identification of stress patterns requires recognition of rhythmic phrasing because stress is applied *within* words and phrases/sentences before it is applied *across* phrases and sentences. In this regard, there is a relatively high degree of correspondence between claims for sign languages and what is known for spoken languages. Part of the reason for this general correspondence is that characteristics of stress marking in speech (duration, loudness/amplitude, pitch/frequency) are paralleled by noticeable measurable changes for stress marking in sign languages (about which more below).

1.2 Intonation patterns

Identification of intonation patterns also requires recognition of phrasing, as it is the pattern of relative highs and lows of frequencies across phrases and sentences that lead to recognition of an intonational pattern. One immediate problem comparing speech and signs is what to take as the corresponding analogue of 'pitch', given the apparent absence of component frequencies in the visual signal. Analogies that have been drawn do not always reflect an understanding of intonation in spoken languages, and tend to reflect analogies to functions (such as distinguishing a statement from a question) or to models (e.g., to autosegmental layering).

2. RHYTHMIC PHRASING AND STRESS MARKING

Before stress can be addressed, it is necessary to understand how sentences/utterances are divided into rhythmic phrases, because stress is assigned within and across such phrases. These divisions are more or less obvious depending on the *rate* of utterance production (the faster, the less obvious). For initial discussion, we assume a rate that allows phrasing to be observed, then turn to the issue of rate effects on those observations. Indeed, for discussion purposes, we can even start with basic syntax as a window into the internal phrases of what is produced.

2.1 Rhythmic phrasing as reflected in pauses in speech and in sign

In speech there are at least two indications that the ends of phrases have been reached: tones (pitch, about which more below; Pierrehumbert & Hirschberg, 1990) and pausing (Grosjean and Deschamps, 1975). For English, pausing between constituents reflects constituent hierarchy (Grosjean and Collins, 1979): the longest pauses (> 445 ms) are between sentences, shorter between lesser syntactic boundaries (245-445 ms), and shortest within NP or VP constituents (<245ms).

To date, it appears that the only sign language that has been measured along these lines is ASL. Like speech, pause durations decrease with lesser syntactic boundaries, *but* notably the sign pause durations are generally shorter than those observed for speech (longest ~229 ms, shortest ~6 ms) (Grosjean and Lane, 1977).

2.1.2 Rate effects on pauses in speech and sign

When signers and speakers increase their production rates, for example, twice as fast, they use different strategies (Grosjean, 1979). Speakers adjust the amount of time they pause whereas signers adjust the amount of time they spend articulating (movement parameter). Speakers alter the number of pauses but not pause durations, which have as a minimum duration what is needed for a breath. If signers adjust pauses, they change both number and duration of pauses. Wilbur (2009) reports similar results: signers adjust sign duration, number of pauses, and pause duration with increasing rate.[1] The number of signs produced was not affected, confirming that with increased rate, signers make changes to prosodic variables rather than omitting signs from the scripts.[2]

2.2 The role of breathing and blinking in rhythmic phrasing

2.2.1 Breathing – in speech and in sign

Another difference between speaking and signing is that speakers breathe during pauses and generally not during the middle of a word, but signers may breathe any time they want (Grosjean and Lane, 1977). Note that speakers are almost prevented from breathing in the middle of a word as the air intake disrupts the articulation airflow out (although this disruption is seen in motor disorders such as speech with Parkinson's disease).[3]

2.2.2 Blinking – in speech and in sign

Baker and Padden (1978) report that speakers may blink anywhere they please. Stern and Dunham (1990) distinguish three blink types: startle reflex, involuntary periodic (e.g. for wetting the eye), and voluntary. Frequency of periodic blinks is impacted by perceptual and cognitive demands: about 18.4 blinks/minute while speaking, but only 3.6 when watching video screens. Task demands also show an impact - readers tend to place blinks at appropriate places in text, such as ends of sentences, paragraphs, or pages.

In contrast, blink locations in signing are linguistically determined (Wilbur, 1994a). Voluntary blinks (longer and slower) co-occur with lexical signs, and perform semantic and/or information functions of emphasis, assertion, or stress.[4] Periodic blinks will occur at the end of Intonational Phrases, and less regularly at the end of lower-level phrases (also reported by Nespor and Sandler, 1999, for Israeli Sign Language; Sze, 2008 for Hong Kong Sign Language).[5] These blinks could be considered as parallel to phrasal tones in speech.

There are occasions in which a quick head nod may substitute for a blink, or co-occur with a boundary blink (like blinks, there are several kinds of head nods; Wilbur, 2000; Puupponen et al, 2015).[6] Both blinks and head nods are affected when signing rate changes (Wilbur, 2009). Fewer blinks occur as signing rate increases (from 12.3 blinks in slow to 7.8 in fast); likewise the number of head nods decreases (6.7 in slow to 4.2 in fast) with increased signing rate, confirming that signers systematically modulate prosodic characteristics with changing signing rate. In faster production signers may drop or run together some

[1] Despite differences (Grosjean used fewer stimuli and signers, and had to rely on reel-to-reel video, whereas Wilbur was able to use digitized video, had three scripted stories as stimuli, and elicited four versions from each signer at each rate), the results were strikingly similar.

[2] In contrast to results from Wilbur & Petersen (1998) of massive sign omission when experienced signers speed up signing to try to speak and sign at the same time.

[3] Poizner et al. (2000) describe Parkinson signing characteristics: decreased facial nonmanuals, reduced path movement, timing cues disrupted, loss of rhythmic variation.

[4] Despite Baker & Padden's report that signers do not blink in the middle of a sign -- there is no perceptual or production reason that would block a signer from blinking in the middle of a sign.

[5] Tang et al. (2010) report that blinks in ASL, DSGS, Hong Kong Sign Language (HKSL), and Japanese Sign Language (JSL) occur at Intonational Phrase boundaries, but also blinks in HKSL frequently occur at lower-level prosodic boundaries. Pfau (2016) analyzes blinks as parallel to 'boundary tones' but it is not clear if that is intended to include lower-level prosodic boundaries.

[6] Puupponen et al identify four: (i) *nods* give affirmation and positive feedback; (ii) *nodding* provides positive feedback or echo phonology; (iii) *thrusts* occur in interrogatives and emphasis; and (iv) *pulls* occur for emphasis, contrast, and (semantic) exclusion. See also Liddell (1986) for analysis of ASL head thrusts.

markers (e.g., blinks, head nods, brow raises) as they produce signs more quickly by compressing sign and pause durations.

2.3 Modeling rhythmic phrasing in speech and in sign

The traditional approach to modeling the rhythmic phrasing in spoken prosodic structure starts with the Prosodic Hierarchy (Nespor and Vogel, 1986): syllable < prosodic word < prosodic phrase < intonational phrase. Traditionally, this perspective also includes a Strict Layering Hypothesis: each level in the hierarchy is composed *only* of phrases on the *next lowest* level.

Selkirk (2011) demonstrates that this Strict Layering Hypothesis cannot be maintained. The traditional approach using the Prosodic Hierarchy model fails generally to consider syntactic constituency, boundaries, or hierarchy in its composition by strict layering.[7] Instead, she proposes Match Theory: prosodic phrasing starts with a *match* between syntactic and prosodic constituents at each level. Each syntactic level (word, phrase, clause) must be matched with appropriate prosodic constituency in the phonological representation - this requirement predicts that phonological and syntactic domains *will* be closely matched at the *start* of a derivation. When additional phonological effects (rate effects, focus/contrast enhancements) occur, violations of Match constraints can result, leading to the non-isomorphism (mismatches) between syntax and prosody. Selkirk's approach *grounds the initial derivation of prosodic constituency in the syntactic constituency* (rather than from the lower layers of the Prosodic Hierarchy), and identifies relevant factors and circumstances under which prosodic constituency may be altered, resulting in non-isomorphism. Thus, mismatches are not simply random occurrences, and prosodic constituency is *not* a completely independent system operating solely on its own rules.[8]

The Prosodic Hierarchy has also been applied to sign languages (see Fenlon and Brentari, 2021 for review), but without Selkirk's update (except Wilbur, 2021). The absence of this revision is problematic because in the sign language literature, non-isomorphism has been taken as an indication that prosodic structure *is* an independent system. Thus, the relevance of Selkirk's revision to prosodic structure modeling for sign languages will become clear in the discussion of intonation below. First, we turn to syllables and stress within the prosodic phrasing.

2.4 Syllables in speech and in sign

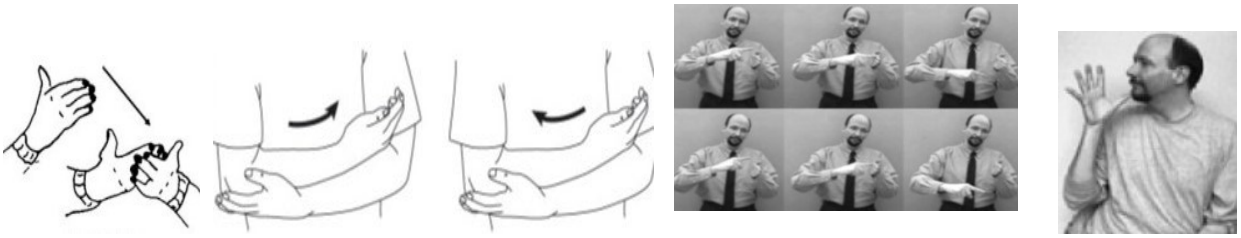
In speech, syllables are composed of at least one sonorant sound which forms the core/nucleus of the syllable. This is usually a vowel, although there are vocalic consonants that can serve this purpose. As a general rule, languages prefer syllables that have at least an onset (one or more consonants), and languages also allow consonants to serve as codas after the nucleus, albeit with more restrictions.

In signing, the absence of consonants and vowels in sign languages would seem to present a challenge for syllable formation. Early attempts to construct sign language analogies to consonants and vowels (with movement as the nucleus) were generally unrevealing but the Prosodic Model developed in Brentari (1998) solved a number of the challenges and has been widely (albeit not universally) adopted.[9] Wilbur (2011a) reviews the arguments and experimental evidence in support of sign syllables and discusses the difference between the internal structure of syllables in speech and those in sign languages. For the current dis-

[7] The way that Nespor and Vogel (1986) define 'phonological phrase' (lexical head and all elements on the non-recursive side up to the next head outside of the maximal projection) means that phonological phrases correspond with syntactic constituents such as noun and verb phrases. Intonational Phrase generally corresponds to the main sentence, with external constructions like topics and parentheticals forming their own Intonational Phrases.

[8] Wang and Narayan (2007) observe that as speech rate increases, and number of syllables decreases (what they called 'syllabic smearing'), the match between prosodic structure and syntactic structure is increasingly lost. Likewise, as signing rate is changed, the number of syntactic constituents remains unchanged (signs in the stimuli are not omitted) but the prosodic phrases, hence number of markers, are adjusted. As a result, the relationship between syntactic constituency and the resulting Intonational Phrases is less direct with varied signing rate.

[9] Cf. Van der Hulst and van der Kooij (2021)



ARRIVE BABY rotation of 180° CANCEL rotation of 90° MOTHER

Figure 1. *Four signs with different movement options. [Permission for CANCEL and MOTHER pictures granted by Dr. Bill Vicar]*

cussion, we only need the conclusion that sign syllables exist (they can be counted and tapped to). Syllables are linguistically relevant in a variety of ways, most importantly for stress assignment in signs, compounds, and phrases.[10]

Before providing examples, we should observe that most lexical signs across sign languages studied to date are monosyllabic, parallel to languages like Mandarin. Nonetheless, there are also disyllabic signs, but they are restricted such that the movement in the second syllable is rotated by 90° or 180° to the direction of movement of the first syllable. Another group consists of a single repetition of the first syllable, with a transition movement inserted between the first and second. There is a prosodic constraint that well-formed lexical signs can have no more than two syllables (transitions do not count). There are compounds that are the result of reductions of two separate signs which do not meet this constraint (see Lepic 2016), and as will be seen for stress assignment, they do not behave like lexical items. Those signs of compound origins which have been sufficiently reduced into the syllable requirements for single lexical items should no longer be referred to as compounds, because they behave like any other native lexical item and not like compounds (Wilbur, 2015).

Here we provide examples of lexical signs that are respectively one syllable (ARRIVE), two syllables (BABY, CANCEL), and smaller than a syllable (MOTHER, which requires at least a transitional movement to and/or away from the place of articulation to make a full syllable). Thus, it is important to distinguish between 'syllable' and 'morpheme'. A morpheme is defined as the smallest possible unit of meaning. Consider these differences: (a) ARRIVE is a single sign, a single syllable, and a single morpheme; (b) BABY is a single sign, two syllables, and a single morpheme (here, morpheme is larger than syllable – this morpheme has two syllables); (c) CANCEL is a single lexical item, a single morpheme, and two syllables (again, transitions do not count); and (d) MOTHER is a single lexical item (do we want to call it a 'sign'?), a single morpheme, but smaller than a syllable (it is missing movement). Whereas a syllable requires at least one movement, a morpheme may be as small as a feature specification (place of articulation, presence or absence of contact, direction of movement) or a single handshape, as in classifier constructions.

2.4.1 Prosodic words in sign

Prosodic word (PW) is the next category on the Prosodic Hierarchy (this part of the hierarchy is not affected by Selkirk's revision).

[10] Syllables are relevant to historical change (Frishberg, 1975), phonological phenomena such as contact/location metathesis (constrained to occur within syllables, not across syllable boundaries), to backwards signing (Wilbur and Petersen, 1997), to morphological nominalization (only light syllables, not heavy ones; Brentari, 1998: 242–243), and to fingerspelled loan signs.
Signed syllables can be counted and tapped to. Native deaf signers, hearing native signers, and hearing subjects with no sign familiarity perform differently on this task (Allen et al., 1991): comparable rhythmic tapping to repeated signs and to signs with primary stress, but the two fluent signing groups tap less to signs with secondary stress and unstressed signs than the sign naïve group. Transition movements between signs are ignored by signers when asked to tap to syllables (Wilbur and Allen, 1991; Wilbur and Nolen, 1986).

Figure 2. *One prosodic word, with GIVE + distributive aspect, repeated five times, accompanied by one lower face NMM, followed by the next prosodic word, containing WORK with its own lower face NMM*

Figure 3. *Sequence of three CAR-HITs, involving three syllables, three mouth changes, and three PWs*

The smallest prosodic word can be one syllable, but a prosodic word can have more syllables. Brentari and Crossley (2002) demonstrated that changes in lower face tension (LFT; mouth and cheeks) mark the end of a prosodic word in ASL. In Figure 2 one long PW is shown, composed of five movement repetitions in the sign GIVE-A-GIFT[distributive], extracted from the context 'every year at Christmas time, the boss gives each of the employees a gift.' A single lower face position (closed mouth with lip corners slightly down) covers all five syllables and then changes to a rounded mouth before the sign WORK(ERS), which is in a separate PW.

In contrast, Figure 3 shows a sequence of three PWs, extracted from the sequence "one car hits another car three times." The signer produces three mouth changes, once with each repetition.

With this as background, we can now turn to stress assignment.[11]

[11] We ignore 'phonological phrase' as the next Prosodic Hierarchy category. Fenlon and Brentari (2021) report only one phonological process, Non-dominant Hand Spreading (NHS) in Israeli Sign Language, that has the phonological phrase as its domain, and observe that ASL, Sign Language of the Netherlands (NGT) and Russian Sign Language (RSL) all allow spreading of the non-dominant hand beyond phonological phrase boundaries.
This is relevant because Sandler (2010) uses NHS behavior as one of the arguments that NMMs are prosodic. However, motion capture of elicited sentences and longer narratives in Malaia & Wilbur (2018) show that the spreading domain may, in fact, continue over multiple sentences, and suggests that the function of NHS is more likely to be semantic cohesion because the NDH marker often refers to an individual, object, or location in the discourse, and keeps this referent present in the discourse. Further, Crasborn (2011) observed longer spans and suggested that such usage might be evi-

2.5 Stress marking in speech and in sign

Typically in conversation, every sentence has one primary stress that is stronger than any other in that sentence and is located on the strongest syllable of the word (if multisyllabic) that bears that sentence's stress. Within each sentence, there may be smaller/weaker phrases that carry lesser stresses, and of course the words within each of these phrases may have their own stresses as well. The patterns of stress placements of weak and strong stresses are referred to as the metrical structure (Hayes, 1980). We attend first to the question of how we know a syllable is stressed, and then the patterns of stress placement across domains of various sizes (word, phrase, sentence).

In speech, the physical characteristics that are available for marking prominence and phrase position are duration (seconds), amplitude/loudness (dB), and frequency/pitch (Hz). In speech, both duration and fundamental frequency are involved in the marking of phrasally prominent syllables. There is strong evidence that such syllables are longer and often have increased fundamental frequency compared to syllables that are not phrasally prominent (Bolinger, 1985; Fry, 1955, 1958; Ladefoged, 1982). Syllables in phrase final position are also marked by increased duration (Phrase Final Lengthening) and with changes in fundamental frequency (further discussion below). In English, the stress pattern is part of the lexical entry of each word (that is, must be learned for each item). Some other spoken languages have more predictable stress patterns, for example Spanish prefers stress on the penultimate vowel (otherwise marked with an accent in writing).

One question is how sign languages mark linguistic prominence given that frequency is not an available marker. Here we need to start with a very brief physics refresher. When we talk about movement, we are talking about displacement (distance traveled by an object) over time (duration). When we talk about the speed (velocity) of movement, we are talking about the relationship of displacement (in units such as meters) to units of time (seconds). Our basic movement equation then is v=d/t. These are three dimensions that could be used to show stress on a sign. But modifying any one of these will automatically change at least one of the others, that is, they are not all free to vary independently. The options for modifications to show stress are also constrained by preferences of the visual system. At this point, it makes sense to ask how stress is recognized in signing before addressing how the stress assignment system works.

A critical question to address at this point is how we know that a sign is in fact stressed. In theory, stressed signs are modified and set off from other signs in a phrase by means of one or more cues. Experimental evidence comes from studies which ask signers to view videos of signing and to respond in one of several ways to indicate that a sign is stressed (Wilbur and Schick, 1987 asked judges to circle glosses; Allen, Wilbur and Schick, 1991 asked judges to tap with a metal wand). These judgments enable researchers to compare signs that are judged to be stressed with those that are not judged as stressed.

The earliest study of sign duration was reported by Liddell (1978), with increased duration in utterance final position; supporting results are reported in Wilbur and Nolen (1986). Thus, sign duration is already used as a marker for phrase *position*.[12] This raises an interesting set of questions. If change in duration is used to mark *both* phrase position and stress prominence, signers could be required to make a *four-way visual distinction* solely in duration in order to distinguish nonfinal-unstressed, nonfinal-stressed, final-unstressed, and final-stressed signs in certain contexts. We do not know if this is even possible. If it is, the question arises of whether the ability to make these distinctions is one that separates signers (with experience) from non-signers (no expe-

dence for the existence of a much larger 'discourse phrase' in which multiple sentential units are joined by 'prosodic cohesion'. Here we have two explanations for the same phenomenon – a prosodic discourse phrase and a semantic reference marker; they are not incompatible and could both be true. With competing hypotheses, carefully designed experiments are critical to find out more about how the system actually works.

[12] Also see Tyrone et al. (2010) for motion-capture data that the final syllable is longer in phrase-final lengthening.

rience). On the other hand, if duration is *not* used for stress (and again, frequency is unavailable), then it is necessary to identify what systematic cues signers do use to mark prominence.

Wilbur and Nolen (1986) report that stressed *syllables* are not longer in duration.[13] However, they note that stressed *signs* may have a significantly larger *number* of syllables than their unstressed counterparts. With different data and methodology, Wilbur and Schick (1987) confirmed these findings and further report that signs receiving prominence (1) display sharper transition boundaries between the stressed sign and the surrounding unstressed signs, (2) are produced physically higher in the signing space than their unstressed counterparts (which moves the sign closer to the central visual acuity area of the addressee), and (3) are produced with apparent increased muscle tension.[14] Prominent signs may also be marked by a *voluntary* eyeblink (Wilbur, 1994a) or by the body leaning forward (Wilbur and Patschke, 1998). Note that these methods of marking a sign as stressed do not obviously change any of the values for duration, displacement, or velocity. At the same time, it must be noted that the reliance on videotaped data does not permit accurate determination of the movement dimensions (except perhaps duration).

The advent of motion capture technology has made further investigation of sign production possible in a way that corresponds more to speech science. Wilbur (1999) reports a motion capture study of 13 ASL signers producing target signs in carrier phrases for four relevant contexts: target sign is (1) stressed final, (2) stressed medial, (3) unstressed final, and (4) unstressed medial. Given that ASL prefers prominence in final position, these carrier phrases were necessarily artificial although acceptable. The results provided instrumental (non-video) documentation of significant Phrase Final Lengthening effects on duration. In addition, whether target signs were stressed or unstressed did not affect duration; only peak velocity was significantly affected by stress. This provided the answer to an earlier question: signers do *not* have to make a four-way distinction in duration (i.e., a different average duration for each combination of stress and phrase position). Instead, phrase position is shown by duration, and stress is shown by velocity (v). Furthermore, displacement (d) (how far the hands travel) is not affected by either of these variables, meaning that it is available to vary as needed to permit the distinctions in duration (t) and velocity (v) with our basic equation v=d/t.

Wilbur and Malaia (2018) report a novel motion capture approach that does not require multiple repetitions of each stimulus or use artificial carrier phrases, analyzing data collected over several hours from one Deaf ASL signer. Relevant to the issue of stress marking, the signer produced the same 48 narratives from Wilbur and Schick (1987).[15] A novel perceptual measure used data from the judges in the Wilbur and Schick (1987) study: these judges had watched 14 other Deaf signers producing the same narratives and had circled the corresponding glosses if the sign appeared to be stressed. The total number of times each sign was judged to be stressed was converted to percent (out of 2 judges x 14 signers) to yield the variable Weight. Analysis of duration by position validated the novel procedure, showing that the data displayed Phrase Final Lengthening across the 144 sentences in 48 narratives. Final sign duration was 69% longer than initial signs and 52% longer than medial signs.

Paired t-tests were possible for several kinematic variables, including duration, peak velocity, minimum velocity, and acceleration. Only peak velocity was significantly different between stressed and unstressed counterparts. Thus the novel method yielded the same results as older studies, with the benefit of more natural signing.

Another benefit of the Wilbur and Malaia (2018) design was the ability to correlate the per-

[13] In contrast to claims in Friedman (1976).

[14] Higher in signing space may be parallel to increase in amplitude, literally 'louder'. Likewise, increase in muscle tension is the same mechanism that yields increase in voice frequency/pitch for speech.

[15] Procedures are parallel to Malaia and Wilbur (2012) and Malaia, Wilbur and Milković (2013).

ceptual judgments of the sign judges with the kinematic variables in the sign production motion capture recording using the calculated variable Weight. Weight statistically distinguished between stressed signs and unstressed counterparts.[16] Then regression analysis answered the question of which kinematic variables contribute to *perception* of stress: results showed that position effects were contributed by duration and Weight effects were provided by velocity. Thus, single productions of a sufficient number of stimuli by a single signer can obtain comparable power and results as traditional methods, with relatively more natural signing in longer narratives.[17]

2.6 Stress assignment – speech and sign

English *lexical stress* within words involves syllable weight, determining which syllables are permitted to carry stress and which one is the strongest in the word (Burzio, 1994; Halle and Vergnaud, 1987; Hayes, 1995). The syllable that receives strongest stress has an aligned High tone (the 'pitch accent') (Pierrehumbert and Hirschberg, 1990). Unlike English, ASL lexical stress assignment is more regularly predictable (more like French, which is usually last syllable, or Spanish, which is usually next to last syllable, or Bengali, which is initial syllable), and syllable weight is not known to be a factor.[18]

No sign language has been observed to have distinctive lexical stress, comparable to English '*permit* (noun) and *per'mit* (verb) (Jantunen and Takkinen, 2010). For ASL, there are at least two reasons for this absence: (1) the predominance of monosyllabic lexical items (Coulter, 1982); and (2) restrictions on multisyllabic sign formation. In any case, stress is predictable in all of them. First, multisyllabic signs can result from reduplication of monosyllabic items: the single lexical movement is repeated, with a transition movement between the two lexical movements, and then the resulting form becomes frozen as a new lexical item. In ASL, this process is productive and creates pairs of verbs (single syllable) and nouns (two syllables). In these cases, only the first syllable is prominent (Supalla & Newport, 1978). A different kind of multisyllabic lexical sign also has only two syllables, but in these cases, the morpheme itself requires two syllables. The second syllable movement is restricted with respect to the first, either rotated 180 degrees (back-and-forth, side-to-side (as illustrated with BABY in Figure 1), or up-and-down) (Supalla and Newport, 1978), or rotated 90 degrees from the first syllable (illustrated with CANCEL in Figure 1). These lexical disyllables have equal prominence on both syllables. Van der Kooij and Crasborn (2008) show that two-syllable signs also have predictable stress in NGT.

In sum, ASL lexical items have stress on the first, and often only, syllable. This pattern is what has been called the Basic Accentuation Principle for spoken languages (Kiparsky and Halle, 1977): stress the left-most accented vowel or, in the absence of accented vowels, the leftmost vowel. If this principle is re-worded in terms of syllables for sign languages, the Basic Accentuation Principle stresses the left-most (first) syllable. The exceptions to this generalization are those single morpheme lexical disyllables (like BABY and CANCEL), which are already exceptional (1) in being specified at the morphemic level for two syllables, and also (2) in requiring equal prominence on both syllables. At the level where *syllables* interface with *metrical structure*, namely in assignment of *lexical stress*, there is so far no evidence of a modality effect for sign languages as compared to spoken.

In contrast to monomorphemic lexical items, compound formation takes separate morphemes and creates new signs with two syllables, with the first weaker than the second (Frishberg, 1975; Kli-

[16] That is, judges' perceptions coincided with original stress narrative scripting, despite judges looking at 14 signers and this correlation with just one signer.

[17] Malaia, Wilbur, and Milković (2013) introduced another calculated measure, the Ratio of the Telic-Atelic Slopes, as an indication of how fast the movement comes to a stop (Maximum deceleration) in the two types of signs. In both ASL and HZJ, the slope for telics is greater than for atelics. A comparison of the Ratios reveals that HZJ telic slopes are nearly twice those of atelics whereas for ASL the difference is much smaller. This shows that in HZJ deceleration may be secondary to peak velocity, which indicates that a further study of HZJ stress marking is needed.

[18] Although ASL syllables may differ in weight (Brentari 1998).

ma and Bellugi, 1979; Vercellotti and Mortensen, 2012; Wilbur, 2015). That is, these new signs are treated more like reduced *phrases* with respect to stress. Stress assignment in ASL phrases follows a pattern observed even in English: a single prominence is assigned to the right-most constituent in the phrase (excluding hedges and other right-attached constituents outside of the main clause).[19] Halle and Vergnaud (1987) term this the Nuclear Stress Rule, and formalize it as 'right-head, terminal, unbounded' stress. Thus, the assignment of stress to ASL compounds and syntactic phrases follows a very general pattern: in compounds or phrases, a single stress is assigned to the *most prominent syllable of the right-most lexical item*.

With the exception of the internal structure of syllables, the discussion so far has highlighted similarities between spoken and signed languages. Some language-specific differences have also been noted, as for example the relevance of syllable weight in English and lack thereof in ASL for lexical stress assignment. Here another language-specific difference is highlighted: normally, English *sentence stress* is on the direct object (if one is present) (Haspelmath, 1997: 123), but English permits stress to move inside sentences to reflect changes of focus, which contrasts with the relative rigidity of ASL, which prefers its stress in final position (loosely defined), reshuffling its word order to ensure that focus is found in that position. Again, this is not a modality difference (Wilbur, 1997). The generalization regarding ASL's preferences is confirmed by attempting to elicit the ASL equivalents of English sentences with prominence moved to different positions (1) and (2).

(1) Ellen gave Harry a new shirt for his BIRTHDAY
(not for Christmas)

Ellen gave Harry a new SHIRT for his birthday
(not a jacket)

Ellen gave HARRY a new shirt for his birthday
(not Juan)

Ellen gave Harry a new shirt for his birthday
(not Selena)

(2) ELLEN GIVE HARRY NEW SHIRT WHY, POSS3 BIRTHDAY
br

ELLEN GIVE HARRY NEW SHIRT WHEN, BIRTHDAY
br

ELLEN GIVE HARRY WHAT, NEW SHIRT FOR BIRTHDAY
br

ELLEN GIVE HARRY WHAT FOR BIRTHDAY, NEW SHIRT
br

BIRTHDAY, ELLEN GIVE HARRY WHAT, NEW SHIRT
br br

ELLEN GIVE WHO NEW SHIRT FOR BIRTHDAY, HARRY
br

Vallduví (1992) calls the ability of English to move its stress around [+plastic]; in contrast, ASL is [-plastic]. Comparison of ASL with English and other languages (Russian, Spanish, Catalan) results in a four-way typological categorization in which one critical parameter is plasticity and the other is the basis for determining word order (sentence-internal grammatical relations or discourse information flow) (Lambrecht, 1994; Vallduví, 1992; Wilbur, 1997, 1999). Put another way, given particular discourse requirements, English can preserve word order and move both focus and prominence, while ASL preserves focus and prominence location and changes word order instead. This does not negate the generalization that ASL is underlyingly an SVO language, like English and Catalan (Aarons, Bahan, Kegl and Neidle, 1992; Wilbur, 1997). What it does is identify the *source* of the surface word order differences that typically occur among these languages. Given the right discourse conditions, all three languages could have SVO order and phrase final prominence. However, even minor changes in discourse information flow with respect to what is old/given and what is new/asserted will reflect the different parameter settings for each of these languages.

3. INTONATION IN SPOKEN AND SIGN LANGUAGE

This section introduces the structure of intonation in spoken languages and then assesses the

[19] Such hedges and other right-attached material are common in ASL (Wilbur, 1994b, 1997).

claim that (some) sign language NMMs basically perform prosodic functions, specifically intonational functions. To address this, there are two lines of discussion. One is whether NMMs actually behave like spoken language intonation, and the other is what else can be said about NMMs and prosody. It will be seen that the suggestion that NMMs, specifically eyebrow height, function parallel to intonation pitch pattern as it distinguishes statements from interrogatives cannot be maintained, as the structure of intonation is so much more complex than this analogy implies. It will be shown that there is evidence from Weast's (2008) work that there are non-manual articulator behaviors that could parallel intonational tune contours but, as she notes, this is not the analogy that has been suggested. Other approaches to the role of NMMs focus on their status as overt morphology, which requires attention to what licenses their presence in an utterance as well as whether they are allowed to spread over multiple signs and if so, what licenses their spreading domain (is it parallel to intonational contours). Additionally, there is an interaction between prosody and syntax in both spoken and sign languages that has been overlooked and needs recognition.

3.1 Understanding what is claimed for speech

Here, the use of frequencies (pitch) to compose the main components of spoken intonation is described for two specific purposes. The first is that the analogy to spoken language intonation has been made for sign language NMMs, and the basis (or lack thereof) of this analogy needs to be understood in order for it to be properly evaluated. The second is to provide an understanding of how the spoken language intonation system works so that parallels in sign languages, if they exist, can be more readily recognized.

Heim (2019) provides a recent history of the various approaches to analyzing intonation. The fundamental distinction is between (contour) 'tune' (a continuous contour that is not compositional) and 'tones' (separate units that compose an intonation pattern); the history is split between these perspectives. From the tone perspective, intonational tunes are composed of *sequences* of High (H) and Low (L) tones.[20] At least since Pierrehumbert (1980), the tune begins with a *pitch accent*, that is, the tone on a stressed syllable. Most frequently, a High tone is aligned with a stressed syllable (written H*); this choice may also signal that the stressed item represents new information to the hearer.[21] This is followed by a tone that can signal the end of an intermediate phrase (previously called *phrase accent*). The last intermediate phrase in the larger intonational phrase is also then marked by a third tone, the *boundary tone* (annotated with percent sign "%").[22]

Pierrehumbert and Hirschberg (1990) discuss the possible interpretations associated with the choice of tones at each position; many of those details are under reconsideration in more recent analyses (Heim, 2019; Heim and Wiltschko, 2020). However, it should be noted that Pierrehumbert and Hirschberg (1990: 284) explicitly reject some generalizations that have been made about possible tune meanings. For example, they say that 'speaker attitude' (including uncertainty, incredulity, politeness, irony) does *not* come from a particular tune, but instead arises as a result of the tune pattern *interacting with different contexts*, each of which leads to an interpretation for the tune (in other words, the tune itself is not morphemic). They also note that neither speaker emotions, speech acts, nor propositional attitudes are responsible for available tunes (at least in English), and conclude that in general it is better to

[20] The absolute value in Hz of the High and Low tones is not relevant. For example, a High tone that follows a Low tone (with no intervening phrasal reset) could have a frequency that is much lower than a High tone that follows another High tone ('downdrift' or 'downstep'). At phrasal resets, the absolute frequency values are set back to their default starting heights. The *pitch ranges* that contain the Highs and Lows may vary within and across speakers, depending on context, intention, style, and so on.

[21] Other options for pitch accent include simple L, and two-tone sequences, one of which aligns with the accented syllable: L*+H, H*+L, L+H*, and H+L*. These will be ignored in what follows.

[22] In an Intonational Phrase that consists of just one syllable (e.g., "Sue?"), the entire three tone sequence can be produced on that one syllable. In longer sentences, the three tones on the last intermediate phrase may be articulated on different syllables or different words.

separate intonational meaning from speaker beliefs.

Pierrehumbert and Hirschberg (1990) suggest that speakers use *pieces* of a tune (that is, morphemic tones) to indicate a relationship between the propositional content contained in the Intonational Phrase and the participants' mutual beliefs as they have been established up to that point in the current discourse ('common ground,' below). The idea here is that pieces of the tune signal discourse processing information to the listener (for example, whether to wait for the next phrase before interpreting the current one), no matter what syntactic structure the tune might occur in. Taking this one step further, since each of the pitch accents, phrase accents, and boundaries tones makes its own contribution to the interpretation of the domain that it is attached to, it would make sense to consider each as morphemic. If each accent is a morpheme, the resulting three-tone sequence (pitch accent, phrasal accent, boundary tone) is interpreted based on the composition of the tone morphemes in that sequence, rather than requiring a search for the best meaning for the entire three-tone tune.[23]

Heim (2019) focuses on the function of the sentence-final intonation (SFI), which is generally thought of as either falling or rising. He notes that there is a third, *modified* rising SFI which serves multiple functions between the falling and plain rising ones. With three SFI options, Heim demonstrates that the simple division between statement and question normally associated with falling and rising contours is insufficient (and inaccurate) for understanding intonational functions. To understand both the forms and functions of intonation and why the suggested analogy from sign language NMMs to intonation is also insufficient, it is worth spending some time to see how the system can be constructed with the building blocks Heim provides.

He observes that previous approaches have assumed two basic principles: (1) there are two relevant clause types (assertion and question; his Clause-Type Convention) and (2) there are two basic SFI settings (falling and rising; his Fall/Rise Convention). Typical presentations of intonation and function include just Assertion with Fall (down arrow ↓) (3a) and Question with Rise (up arrow ↑) (3b) [with standard supporting contexts in curly brackets { }].

(3) a. It is raining ↓ {after a glance out the window}

b. Is it raining ↑ {after the addressee reported that he checked the weather report}

That there are more than just these two options raises what he calls the Speech Act Problem. Consider the opposites of (3), the Assertion with Rise (4a) and the Question with Fall (4b) with the contexts that support them.

(4) a. It is raining ↑ {after the entrance of a wet coworker into a windowless office}

b. Is it raining ↓ {asking the same question again after no response}

What we see in (4a) is that assertion syntax (statement word order) can occur with rising SFI and in (4b) that question syntax (with auxiliary fronting) can occur with falling SFI. That is, it is an (inaccurate) oversimplification to say that "a question occurs with a rising intonation and an assertion occurs with a falling intonation"; the situation is more complicated and there needs to be a middle ground.[24] To provide this middle ground in an alternative approach, Heim suggests two factors that are both gradable in nature – Speaker Commitment to the propositional content and

[23] Consider an analogy here to lexical discourse connectives, like English 'and', 'but', and 'so', which convey conjunction, contrast, and causality, respectively (Larralde, Pouscoulous and Noveck, 2022). They set up expectations at the end of the first statement about what the next statement will convey, and therefore how to process it.

[24] These observations are not new. Heringer (1970) noted that the ambiguous sentence "all the boys didn't leave" has one reading (the NegQ reading, roughly "none of the boys left, all stayed") with a rising 'contrastive' SFI, and another reading (the NegV reading, roughly "not all the boys left, some left, some stayed") with a falling 'emphatic' SFI. But these distinctions have been omitted from the general, non-specialty discussions.

Table 1.

Forms	Terms used here	Alternative terms
DEC ↓	falling declarative	Canonical declarative
DEC ↓↗	fall-rise declarative	(rise) fall-rise contour, incredulity contour, surprise contour
DEC ↗	high-rising declarative	High-rise questions, uptalk, upspeak, high-rising terminals
DEC ↑	rising declarative	Declarative questions, queclaratives, biased questions
XP ↗	modified rise	List intonation, plateau contour, level intonation
XP ↑	(wh-) echo	Echo questions, in-situ interrogatives
WH-INT ↓	falling wh-interrogative	Variable questions, information questions, wh-questions, wh-interrogatives
INT ↗↓	disjunctive interrogative	Alternative questions, rhetorical questions
INT ↑	rising interrogative	Polar interrogatives, polarity questions

Speaker's Engagement of the Addressee in the conversation (common ground is shared by speaker and addressee), as defined in (5):

(5) Speaker Commitment: Degree to which the speaker publicly commits to the issue currently under negotiation for being entered into the common ground.

Addressee Engagement: Degree to which the speaker engages the addressee to resolve the issue currently under negotiation for being entered into the common ground.

Both Commitment and Engagement can be full, partial, or none, which affects the SFI that represents them. Another significant observation that contrasts with traditional intonational approaches is the contribution of the pitch *duration*, rather than just its frequency. Heim defends two correlations: (1) Speaker Commitment correlates with the duration of SFI, and (2) Addressee Engagement correlates with the pitch excursion (frequency change) of SFI. In essence, this enables the two factors to be layered without interfering with each other, with Engagement higher on the syntactic spine determining the pitch range, Commitment lower determining the pitch duration, and both of them above the main proposition (for layering in sign language, see Wilbur, 2000). Putting Commitment and Engagement settings together with the three SFI options (rising ↑, modified rising ↗, falling ↓), Heim constructs (and documents) the nine options in Table 1 (he provides other labels used in the literature in the right-most column):

It can be seen from this table that there are a number of combinations that are observed in natural languages that have been largely overlooked. What makes this more than a mere list of options, though, is that these forms also participate in a model of Common Ground Management between the speaker and addressee. Experimental evidence for this model has been provided in recent work (Heim and Wiltschko, 2020). Common ground management occurs in two stages – first the speaker makes an offering of a proposition for negotiation (initiation stage) and then the addressee indicates whether the proposition is accepted (reaction stage).

In addition, and critically for our discussion, these management pieces have been shown to be syntactically integrated in what Wiltschko calls the grammar of interactional language (Wiltschko, 2014, 2021). That is, there is syntactic control of this process [what can and cannot be included], demonstrating a primacy of syntax over discourse control that has not been appreciated in more recent theorizing since it was first introduced in the concept of 'hypersentence' in work by Ross (1970).

This more recent analysis of intonational structure raises the question then of what it would mean for sign language NMMs to be performing the functions of spoken language intonation.

3.2 Understanding what is known and has been claimed about sign languages

It has been suggested that (some of) the non-manuals represent the best analogy to spoken language intonation. For example, it has been suggested that the brow raise that distinguishes polar questions from statements is parallel to rising intonation that distinguishes spoken questions from statements (Dachkovsky and Sandler, 2009). However, Heim's work on SFI shows that there is much more to the system than this simple contour difference. Likewise, the analogy of NMMs to intonation suggests that NMMs, which can be layered (Wilbur, 2000), compose the tune (albeit simultaneously rather than sequentially). Again, from Heim, we see that, in addition to sequential tones, spoken intonation can be simultaneously composed, for example, with his observation that Speaker Commitment correlates with pitch duration, while Addressee Engagement uses pitch excursion, allowing both to be produced at the same time.

Fenlon and Brentari (2021) provide an overview of the basis for the analogy from earlier work (Dachkovsky and Sandler, 2009; Sandler and Lillo-Martin, 2006). They further suggest that prosodic structure interacts indirectly with syntax via semantics (e.g., Pierrehumbert and Hirschberg, 1990; Truckenbrodt, 2012). As we have seen, that is not how the syntax-prosody interface is modeled in Selkirk's (2011) Match Theory (where syntax and prosody correspond to each other before phonological modifications may obscure the correspondences) nor how Heim (2019; Heim and Wiltschko, 2020) decomposes the relationship between intonation (specifically, SFI) and the syntactic control of Speaker Commitment and Addressee Engagement (where syntax and prosody/SFI are all part of the same sentence spine system from the start).

The goal in the remainder of this paper is twofold: first, to show what intonational contours might possibly look like if they are carried on the face (discussion of Weast, below), and second, to consider alternate ways of modeling NMMs and their interaction with syntax and semantics based on what is known and not known.

3.2.1 Exploring the claim that NMMs are intonational contours: Patterns of eyebrow height by structure and emotion

In the context of modeling intonation as contours across intonational phrases, Weast (2008) reports quantitative analysis of eyebrow height over the production of ASL sentences, looking at three syntactic structures (statements, yes-no questions, wh-questions), in five different emotional states (neutral, happy, sad, surprise, angry). She made over 3500 measurements from six Deaf signers producing a total of 270 signed sentences. Weast used Screen Calipers (Iconico), an online digital measurement tool, to determine the pixel differences between the middle upper eyebrow (superior orbital [SO] in facial landmarks established by Clapham et al. (2006)) and the inferior skin fold below the orbital rim (IO, middle edge of the infraorbital dark circles under the eye) every 3 frames for the recorded sentences. Her signers showed a 12-pixel range (from minimum to maximum height) except for one who only showed 11-pixel range, thus she was able to use the raw pixel height data for analysis.

Her first observation is that the emotional states established the overall *range* within which the eyebrow height varied for syntactic purposes (Figure 4, wherein the Y-axis is the pixel measurement). In neutral affect, the brows over the entire sentence raise (maximums up 21% for yes/no questions) or lower (down 30% for wh-questions). In the 'emotional' questions, the percentages varied. It is an open question whether these are in any way the sign language equivalents of markers of Speaker Commitment, or related to the inventory in Table 1 above.

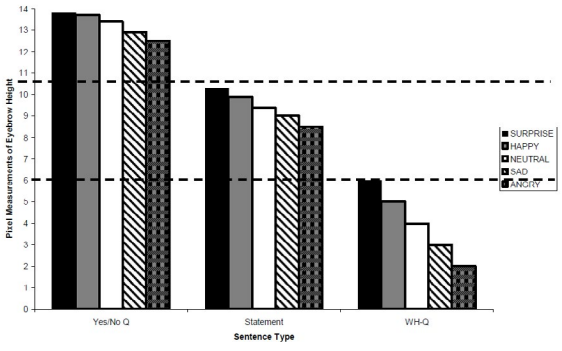


Figure 4. *Measured eyebrow height in pixels for three syntactic structures in five affects*

For wh-questions with brow lowering, Weast noted different spreading domains, which she attributes to different types of brow lowering.[25] First, wh-questions had lowered eyebrow height when compared to statements and yes/no questions. Second, lowering occurred on the wh-sign, regardless of sentence position, and lowering was observed in question-final position even if the wh-sign was missing. Moreover, this lowering also occurred even when the illocutionary force is not as a content question, indicating that the lowering is attached to the wh-sign rather than specifically to the interrogative function. Weast argues that this finding supports the view that the wh-question eyebrows are *syntactic* (Aarons, 1994; Bahan, 1996; Neidle et al., 2000). Third, if the wh-question is 'braced' by both an initial and final wh-sign, wh-questions show additional lowering over the entire braced constituent. Weast suggests that this intensity difference may be the reason for disputes about whether wh-lowering is obligatory with a sentence-initial wh-sign but optional when such initial sign is lacking. Fourth, Weast suggests that when emotions are taken into consideration, *then* eyebrow height correlates to interrogative intonation in spoken languages. Thus, on the basis of the wh-questions, eyebrow height is seen to behave both syntactically and prosodically (the actual height interacts with emotional states). Again, it is an open question whether these are sign language markers for Addressee Engagement, and/or related to the inventory in Table 1 above.

Likewise, with yes/no questions, the eyebrow height is consistently higher than wh-questions and statements, and if a topic is present, the eyebrows are even higher than they would be on a topic not associated with a yes/no question. Weast argues that this shows that raised eyebrows do not merely 'spread' (as claimed in Neidle et al., 2000).

One of the striking findings of Weast's measurements is the contour observed across sentences. She notes that there is overall declination of eyebrow height in statements. Yes/no questions show a lowering before the final rise; this lowering occurred in different places for different signers (over verb, over pronoun, sometimes at the beginning of the sentence), showing it is not tied to a particular sign or grammatical function. The overall contour for eyebrow height in ASL yes/no questions thus includes a lowered height followed by the final raising. Finally, she notes that eyebrow height also appears to perform a stress or focus function, and may involve height change over just a single sign within the overall raised or lowered syntactic pattern and/or within the prosodic declination over the sentence. It is an open question whether these declination patterns are sign language equivalents of sequences of tones as delineated by Pierrehumbert and Hirschberg (1990).

In short, from Weast's work we can see that there are numerous possibilities for further investigation of the role of the NMMs in the form of eyebrow height: Speaker Commitment, Addressee Engagement, SFI inventory, among others. Until these options are more thoroughly explored, it cannot be said definitively that NMMs do or do not perform intonational or other prosodic functions.

3.2.2 Head, chin, and brow as morphological components

Based on his analysis of the role of the head in Japanese Sign Language (JSL), Ichida (2010: 16) argues that the idea that NMMs are the signed analogue of intonation is incorrect because the role of NMMs "is far larger than that of intonation in spoken languages". Ichida noted that there are five different types of head movements (down, up, shake, thrust, change position), each of which can combine with four different chin positions (up, down, forward, back), yielding twenty movement and position combinations. There are also two different timing options (simultaneous/after/repeat; hold/release), and with the three available brow height positions (up, down, neutral; Wilbur and Patschke, 1999), 120 distinct combinations of head/chin/brow are possible. Some of these combinations are obligatorily used to determine sentence types (conditionals, purposive clauses,

[25] Weast indicates that it is brow *lowering* that should be investigated rather than brow *furrowing*, which is less systematically related to syntax. She also argues that ASL nonmanuals should not be compared to pitch (intonation) in English but rather to layering through pitch in tone languages.

embeddings, relative clauses), while others provide different semantic and pragmatic nuances - for example, negation and negated questions (e.g., indicating what the signer expects as an answer). While the meanings associated with all the individual pieces in each combination may not yet have been identified, Ichida argues that these NMM combinations of head, chin, and brow are performing the functions of *overt morphology* in spoken languages (whether as independent words or bound as prefix/suffix/affix), in addition to some functions of intonation. Because they have been mostly overlooked in research on JSL, Ichida cites his need to argue with those claiming that JSL has *no* grammar and lacks complex sentences, as well as with those who have erroneously concluded that it has the *same* grammar as Japanese because the basic word order is the same (subject-object-verb). He notes that researchers completely missed the contribution to the grammar of the head and other non-manual markers, and thus underestimated the complexity of the language by giving a false sense of what information is conveyed.

3.2.3 NMMs as morphemes

In our discussion of Weast's research, we have seen some non-manual behaviors that provide evidence that there may be something like intonational patterns across signed sentences, although the pieces and rules governing them are not yet clearly identified in the same way that pitch accents, phrasal accents, and boundary tones, or SFIs have been. It is clear that much further work needs to be done.

When we talk about NMMs as possible morphemes, it is clear that the common conception of 'morpheme' needs expansion. Most sign language researchers have probably not had extensive experience with a wide typology of languages, and even basic introductions to morphology often overlook the variety of shapes and functions that morphemes can take across languages.

It is often necessary to point out that morphemes can be the size of words, single segment units (for example, the plural '-s' suffix in English), or even smaller single distinctive features (McCarthy, 1983 provides numerous examples from a variety of languages, including single *tone* morphemes). For signs, we illustrated morphemes of different sizes in Figure 1. In addition to different size possibilities, morphemes also can perform different functions. Typically, familiar types of morphemes are lexical items (roots) and derivational or inflectional affixes (prefixes, suffixes). Less familiar are bound morphemes that can attach to syntactic constituents (clitics), nasalization used for negation (in Akan; Schachter and Fromkin, 1968), and process morphemes (morphological rules that manipulate morpheme pieces, such as reduplication and metathesis).

A clear reflection of this general problem is the claim that 'point(ing) must be extralinguistic (gestural) because there are an infinite number of points, so they could never be listed' (e.g. Liddell, 2003, 2011). The idea that the morphological inventory of a language must be listable is incorrect (Wilbur, 1973). Languages with reduplication, doubling, metathesis, or other forms of morpheme shape manipulation do not have listable morphemic inventories. For example, the future in Tagalog is formed by reduplication. The first CV of a consonant initial stem is copied and prefixed to the stem. For vowel initial stems, only the first V is copied. To capture this process, we can say that the first syllable is copied and prefixed onto the stem. But if we try to make a list of the future prefixes in segments, we would need to add /su-/ for /sulat/ 'to write', /li-/ for /libak/, /i-/ for /ibig/ and so on for each verb in the language. Moreover, normal phonological processes in Tagalog result in the future prefix /mi-/ for /bigay/ after another prefix /man-/ (and so on for other verbs that undergo regressive nasal assimilation before reduplication occurs). Attempting to make such a list misses the generalization that each verb's prefix is based on its first syllable and would imply that children would have to learn each prefix separately as well as that the future prefix for /bigay/ is somehow exceptional rather than regular in the language. The morphology of a language must be learnable, but there does not appear to be

any requirement that it be maximally simple or elegant.[26]

In this section, we consider the hypothesis that NMMs are morphemes of various types (Wilbur, 2016).

(6) Non-manual Morpheme Hypothesis (NMH): (Some/most/all?) NMM are morphemes.

In fact, the NMH is roughly where the field started with its analyses of NMMs as part of the grammar and separated from affective expressions. There were 'conglomerate' treatments (e.g., Liddell, 1978), for example, 'question' marking, 'topic' marking, 'relative clause' marking, and so on. But there were also detailed attempts at understanding what markers might be able to function as morphemes on their own.

Consider two analyses from Baker-Shenk (1983). One focused on the NMMs that are added to the sign WRONG to create the idiomatic 'unexpectedly'. These include brow raise, eyes widen, and mouth opening. Testing of each piece separately led to the conclusion that the three together are necessary to contribute the meaning 'surprise'. The second one focused on the NMMs headshake and tongue protrusion that co-occur with the sign NOT-YET. Baker-Shenk determined that separately the headshake contributes negation, while the tongue position contributes 'lack of control, attention, or completion'. From this analysis, we understand that the NMM morpheme meaning 'surprise' generally includes all three components, whereas negation in general (with or without a manual sign) is accompanied by headshake, and tongue protrusion contributes 'lack of control' and can occur without the negative headshake. Note what this analysis does NOT mean: there is no requirement that the negative headshake must be present, or that there are no *other* morphemes (NMM or manual) with the meanings of 'surprise', negation, 'lack of control', or that if there are other such morphemes that these NMM morphemes must occur with them. Each of these implications is a testable hypothesis, and may be true in some sign languages but not others (for example, in the domain of negation, Zeshan's (2006) finding that some languages are 'manual dominant' and others are 'non-manual dominant').

Another early investigation of NMM morphemes was Aaron's (1994) analysis of the different NMM markings that occur with three different topic types (only two will be discussed here). For example, 'tm1' is the NMM marking that occurs with moved topics (syntactic fronting of the object to initial position), and includes brow raise, widened eyes, and the head slighted tilted back and to the side, which moves down and forward on the topicalized sign(s). A non-moved topic could have 'tm2', which also has brow raise but involved a large movement of the head back and to the side before moving down and forward. It is instructive here to consider what we do not yet know about these common NMMs and directions for future research. To date, no-one has investigated whether the 'head moving down and forward' (part of both 'tm1' and 'tm2') makes its own independent contribution to these topic markers. The NMH leads us to expect that it might, and possibly parallel to the lean forward identified in Wilbur and Patschke (1998). 'tm1' clearly marks that a constituent has been syntactically moved – a relevant question is whether it is part of the syntactic movement rule or possibly a syntactic clitic. In contrast, 'tm2' is associated with other kinds of topics – this suggests that its origin might be non-syntactic and a relevant question would be how it gets placed into a sentence and what meaning it contributes to the topic phrase (e.g., the kind of topic). An alternative might be that it signals something to the addressee about the processing of the remainder of the sentence as observed for intermediate phrasal accents. It is instructive at this point to look back at Table 1 and to consider that, by analogy, there is much information about NMM behavior that has not yet been addressed.

[26] While making this analogy to spoken language typology, it should be pointed out that reduplication in sign languages appears to be parallel to that found in spoken languages, and can be decomposed into multiple morphemes that occur sequentially as well as simultaneously, allowing various reduplicated forms to be built compositionally (Wilbur, 2005, 2009, 2015).

3.2.4 Lower face research

Another early observation regarding NMMs was the separation of upper from lower face (Liddell, 1978, 1980; see layering discussion in Wilbur, 2000). Liddell initially identified three lower face NMMs, which serve primarily adjectival/adverbial modifier functions. Brentari and Crossley (2002) observed that changes in the lower face tension correlated with the ends of prosodic words. Only recently have the semantic functions of the lower face been the renewed focus of attention, with the realization that the articulators there perform more than just modifier functions (Bross, 2018, 2020; Bross and Hole, 2017; Nikolai and Wilbur, 2019; Karabüklü and Wilbur, 2019; Wilbur and Nikolai, 2019; Pentecost, Wilbur and Crabtree, 2019, inter alia).

3.2.5 Two kinds of NMMs: Position and Transition NMM

Two lower face NMM behaviors were illustrated in Figures 2 and 3. In one case, the lower face configuration was held/continuous across the entire prosodic word (a "position NMM" or P-NMM), whereas in the other, the lower face configuration was changed/discontinuous during the prosodic word (a "transition NMM" or T-NMM). Schalber (2006) identified the correlation of mouth T-NMMs with telic verb signs and mouth P-NMMs with atelic verb signs for Austrian Sign Language (ÖGS). Looking at Figure 3, we see that in ASL the T-NMM is copied by reduplication along with the manual movements – that is, the NMM is associated to the verb *before* reduplication applies, and when there are three manual productions, there are three NMM productions. A safe bet is that if there were a fourth manual production, there would also be a fourth NMM production (see also Pfau, 2016 for similar reduplication data from NGT). From an analytic point of view, we say that in the construction of the utterance, this NMM-to-verb association happens early (or lower) in the sentence.[27] In contrast, the P-NMM in Figure 2 is associated with the verb *after* GIVE is combined with the distributive to yield the five movements/syllables; then the NMM spreads across the single prosodic word that is created, so it is added later (or higher) in the sentence.[28] This difference illustrates the idea that NMMs are not all the same with respect to when or why they are added to a constituent. A purely *prosodic* approach to analyzing the NMMs in Figures 2 and 3 might predict that Figure 2 could have repeated NMMs for each manual production of GIVE, or it might predict that Figure 3 could have one single NMM across all three manual productions of HIT. Neither of these predictions is correct. A purely *syntactic* approach would have to admit that the NMM in Figure 3 is represented lower in the tree (below the verb phrase VP) than the NMM in Figure 2, which needs to have the NMM represented higher above the VP in the Aspect Phrase (AspP). The point here is that what a syntactic approach would have to admit is that there is morphology associated with the different phrases, thus it would no longer be 'purely syntactic'. These difficulties contribute support for the treatment of NMMs as morphemes.

3.2.6 Further uses of NMM morphemes: Modal meanings

Now that the notion of location in the syntactic tree has been introduced, we can consider an expansion of this idea from Bross and Hole (2017) and Bross (2018, 2020). Bross and Hole (2017) identified strong correlations of NMMs with phrasal constituents in cartographic syntax (Cinque 1999, inter alia; Bocci et al 2021) and in doing so made it clear that NMMs are not functionally unique to sign languages (even though they are phonologically unique). In the discussion above of Heim's work on spoken language intonation, we mentioned that Addressee Engagement and Speaker Commitment were syntactically controlled but did not go into further details. For the same reason that we had to expand the

[27] It is associated with the verb's telic *Aktionsart*.

[28] It is associated with the verb's aspectual viewpoint, in this case, Imperfective; for recent treatment see Ramchand (2018:118); for analysis in sign language reduplication, see Wilbur, 2005, 2009).

notion of morpheme beyond what is most commonly familiar, we also need to adjust how syntax is conceived. While it is true that syntax focuses on the structure of a sentence, it is not true that this is done in isolation of the interaction of the conversation partners, or of the context and conversational history, or of the cognitive concepts that users have when they produce/understand such sentences.

Here is an expanded view of syntactic structure needed to understand cartographic claims. The central component of a tree is referred to as the spine. At the bottom is the verb phrase VP; Ramchand (2008) explains at length how we get from the cognitive event or state that we are describing to the VP of a sentence, what she refers to as 'first phase syntax'. Above this, Ramchand (2018) explains how the event/state description in the VP is given spatiotemporal properties (like Aspect and Tense) to create 'situations'. This latter part involves modals and tense (Tense Phrase TP). These situations are then anchored *in the context* to create 'propositions', which is what a sentence that is a statement asserts (syntactically Complement Phrase CP).

Beyond this, Wiltschko (2021) argues that above CP on the spine are the pieces that are necessary to control the *interaction* of the conversational participants, which she refers to as the Interactional Spine Hypothesis. For simplicity, she refers to the sentence as 'p' for proposition. Above p is the Ground for the Speaker; above that is the Ground for the Addressee; and above that is the Response Phrase (RespP; for example, when the Addressee becomes the Speaker and says in response 'well' or 'I agree' or whatever particles can fill this function). That is, her claim is that speech acts, traditionally treated as separate from syntax, are actually syntacticized – they are part of the syntax spine and are controlled in the same way as other types of syntactic control (e.g., allowable pronominal references, deletions, etc). This perspective includes the role of the addressee, adjacency pairs (turn-taking issues), going beyond the sentence as the unit of analysis, including meaning beyond truth conditions, and updating the common ground. From the discussion of Heim's work above, his Speaker Commitment would be part of the Ground for the Speaker, and the Addressee Engagement (what the speaker wants from the addressee) would be part of the RespP. The two Grounds (Speaker and Addressee) also include what is taken to be common ground.

The spine, then, includes a lot more than traditionally associated with sentence structure, but the model traces back to the Performative Hypothesis of Ross (1970). The field of cartographic syntax, led by Cinque, has been investigating the pieces that occur cross-linguistically along the spine. Bross and Hole (2017) brought this analytical approach together with sign language research with their Mapping Hypothesis. They noted a correlation between the height of a linguistic function on the central spine and the *body parts* used for that function in German Sign Language (DGS). More specifically, those pieces highest in the spine hierarchy are more likely to have wider/ higher scope and more likely to be produced with a body part that can be ordered relative to other expressions on a vertical axis (Bross & Hole 2017: 14). Higher up functions are likely to be made with NMMs of facial expression, head or shoulders. Lower functions are more likely to be made on the hands.

Cinque's hierarchy has 'speech acts' at the top of the spine. This is consistent with Wiltschko's Interactional Spine Hypothesis and the claim of syntacticization of speech acts. Likewise, speaker's evaluation (a type of commitment) is high on the spine, as is the epistemic use of modals (Ramchand 2018 also puts epistemic use in the top portion of her tree). Bross and Hole (2017) report that these categories are mapped to the upper face (eyebrows, eyes) in DGS; Karabüklü et el (2018) report similar results for TİD.

Lower on Cinque's hierarchy are functions like scalarity (e.g., a lot), which are made on the lower face in DGS (Bross & Hole, 2017; Bross, 2018, 2020) and ASL ('puffed cheeks', Baker-Shenk, 1983; Wilbur and Nikolai, 2019). The earlier work on lower face as adjectives and adverbs can now be situated in the bigger picture. There is also clearly a lot of cross-linguistic work that is still needed.

To finish off discussion of the Mapping Hypothesis, we take a brief step away from the NMMs. Those functions further down on the hierarchy are made on the hands, and in DGS this translates into at least three portions: ordering of the (modal) functions left-to-right (higher on the spine comes *before* lower on the spine), with subsequent switch to ordering right-to-left (higher on the spine comes *after* lower on the spine), and finally to modification of the sign movement itself for functions inside the VP (an example from ASL would be fast deceleration to a stop of telic verb movement; Malaia and Wilbur, 2012). Karabüklü et al (2018) report that TİD does not allow modals to precede the verb, so they are always to the right (after) the verb. This means that TİD must use other mechanisms to distinguish the functions that are shown in DGS by different scopal orderings.

It is hard to see how a prosodic approach to NMMs would be able to explain these NMM-syntactic spine correlations. Bross and Hole's approach also predicts which combinations of NMMs are more likely to occur and what they will mean, rather than merely treating combinations of head/brow/eye positions as surprising occurrences of pragmatic composition.

Here, we provide one more example of the Mapping Hypothesis and its implications for NMM research. As mentioned, epistemic modality is a high category. It refers to the subject's use of knowledge to infer a given state of affairs. If you see a light on and you think 'Paul must be home', you are using 'must' in an epistemic way: given the current situation (which includes a light on in the place where Paul lives), you conclude that something must be true. Note that of course it could turn out to be false, that Paul left the light on accidentally, or that someone else is in Paul's home. 'Must' in English can also be used deontically, that is, in the sense of obligation: rules and regulations govern what we must do: 'if you borrow money, you must pay it back'. In the Cinque hierarchy, epistemic modality is higher than deontic modality. Investigating this for ASL, we found that the Mapping Hypothesis is supported: the NMM marker for epistemic is higher on the face (eye squint) than the NMM for deontic (taut mouth) (Pentecost, Wilbur and Crabtree, 2019). These NMMs occur with the manual sign that is glossed as MUST. The NMM provides the disambiguating information, whether the interpretation is epistemic or deontic. Without the Mapping Hypothesis, it is not clear that the lower face would have been examined for a NMM that performs a modality identification function.

3.2.7 Upper face research

The upper face and head have received much more attention. We discussed above Ichida's work on the 120 possible combinations of head, brow, and chin in JSL, in which he identified some combinations as sentence structure makers, and others as contributing semantic or pragmatic information. Puupponen et al.'s (2015) motion capture work on head movements in Finnish Sign Language led to the observation that head thrusts are associated with interrogative marking; their identification of head 'pulls' as indicators of semantic exclusion raises the question of whether that function is similar to what Wilbur and Patschke (1998) reported for 'lean back'.

3.2.8 Commitment and Engagement Markers

As noted above, Heim (2019) reports four possible combinations of intonation SFI (rising, falling) and sentence type (statement, question). A similar set of combinations has been reported by Tankersley (2021) for ASL, although not for statements and questions, but for the two types of questions – yes/no (polar) questions and wh-questions (content). As reported in Weast (2008) and standardly referred to in the literature (and teaching curricula), typically yes/no questions in ASL occur with raised brows and wh-questions with lowered brows. Tankersley reports results from analysis of 5 hours of annotated ASL conversations from publicly available videos: out of 90 questions in the data, fully 31% of the questions were 'mismatched', his term for occurring with the opposite brow position (10% were yes/no questions with lowered brows, and 21% were wh-questions with raised brows). For the yes/no questions with lowered brows, Tankersley indicates that the signers

seemed to express uncertainty about the proposition, and that the addressees responded with detailed answers despite having been asked a yes/no question. From Heim's perspective, this mismatch would be seen as signaling both reduced Speaker Commitment and increased expected Addressee Engagement. Tankersley suggests that, regardless of question type, lowered brows can signal open-endedness, uncertainty toward the proposition, desire for more detailed response, as well as the traditionally identified function of requesting specific information (as in wh-questions).[29] As for wh-questions with raised brows, Tankersley divides them into two groups, those in which a topicalizing function might be involved, and those which appear to be performing discourse management functions. He suggests that independent of the question type, raised brows may signal topicalization or focus, turn-ending or passing control, concessive questions, and confirmation seeking (as typically seen with yes/no questions).

Likewise, Ichida (2010) reports that there are two possible eyebrow positions in Japanese SL WH-questions – up and down. He notes that one cannot use eyebrows up with a question such as "what was your name again?" when it is a repetitive question (has already been asked before). He states that the eyebrow position is dependent on where the focus of the initiative lies – with either the signer or the recipient.

Ichida's research on imperatives, which use the two eyebrow positions crossed with the four chin positions, provides an example of how detailed investigation can reveal semantic distinctions that might otherwise be missed. His analysis of chin position alone had already revealed that chin down and chin back conveyed a strong message when compared to chin up or chin front. Eyebrow-down also appears to be stronger than eyebrow-up, so that when these are crossed, stronger and more negative imperative messages are conveyed. What we see here then is that when potential distinctions are carefully investigated, they may indeed be found.

Chin position	Eyebrow-up	Eyebrow-down
Up	Direction	Coercion
Down	Advice	Persuasion
Front	Suggestion	Recommendation
Back	Irresponsible suggestion	Imposition

3.2.9 Negative headshake

Pfau and Quer (2002, 2007, 2010) distinguish cross-linguistic differences in the function of negative headshake 'neg hs', observing that in ASL it is syntactic whereas in Catalan Sign Language (*Llengua de Signes Catalana*, LSC), and German Sign Language (*Deutsche Gebärdensprache*, DGS) it is more clearly morphological. In LSC, 'neg hs' may attach to just the negative sign or the verb sign alone if there is no negative sign, which is evidence that the 'neg hs' is independent to some degree from the negative manual sign. In DGS, 'neg hs' may not attach to only the negative sign (that is, it must spread) but can attach to the verb sign alone if there is no negative sign. These examples reflect the morphological affix status of negative headshake in LSC and DGS, as well as showing that the two languages have different constraints on the NMM behavior despite their similarity as affixes. In contrast, in ASL 'neg hs' can occur either on a negative manual sign alone or else must spread over the whole c-command domain. Further language specific morphological rules determine what the affix must attach to if no manual negative sign is present. These data provide very clear evidence that the same NMM can have different status in different sign languages, as would be expected if they are in fact morphemes.

3.2.10 Spreading domains

We have seen in Weast (2008) that brow lowering (not brow furrowing) is used to mark wh-questions, and that brow raise is used to mark yes/no questions. Of these two brow heights, the spreading domain of brow lowering is the simpler to explain. From the Non-manual Morpheme Hy-

[29] Despite citing Weast, Tankersley refers to the brows as 'furrowed' rather than 'lowered'. Because he provides pictures where the brows can be seen, the labeling has been changed to 'lowered' here for consistency.

pothesis (NMH) perspective, we can treat brow lowering in ASL as a morpheme that functions to mark wh-interrogative signs (see Pfau and Quer, 2002 for wh-lowering in other SLs). This NM-morpheme then spreads from the wh-word over the signs that are in the c-command domain of the wh-word (unless the wh-word remains in situ, in which case it is not required to spread); note that it does not matter whether this spread is rightward or leftward.[30]

As Wilbur (2021) observes, the larger NMM debate has generally failed to consider that at least in ASL, there is a clear difference between raised 'br' and lowered brows 'bl' or negative headshake 'neg hs'. Brow raise does not spread over its (c-command) domain (Wilbur and Patschke, 1999), unlike negative headshake and brow lowering (Pfau, 2002, 2005; Pfau and Quer, 2002, 2007, 2010; Neidle et al., 2000). Initially thought to be prosodic (Wilbur, 1991), syntactic (Wilbur and Patschke, 1999; Neidle et al., 2000), or a discourse marker for 'looking forward' parallel to rising pitch phrasal accent (Dachkovsky and Sandler, 2009; Sandler and Lillo-Martin, 2006), the puzzle was finally solved when it was recognized that the function of brow raise, at least in ASL, is related to a specific kind of semantic operator -- dyadic operators which relate two semantic constituents to each other (Krifka et al., 1995:24). These semantic constituents could be events, situations, or conditions, for example, an event that is dependent on a condition being met, as in (7).

(7) If X, (then) Y. e.g., If it rains tomorrow, the picnic is cancelled.

The two semantic constituents being related are X and Y; the dyadic operator in (7) is the conditional. The 'restriction' of the conditional is X, the condition that must be met in order for Y to occur.

(8) Operator [Restriction] [Nuclear Scope]

(9) IF [X=it rains] [Y= the picnic is cancelled]

Structures which are analyzed as having these three parts include conditionals, topics, yes/no questions, restrictive relative clauses, among others. It turns out that in ASL, brow raise covers the *restriction* part of these constructions but does not spread over the remainder of the sentence (unless the whole sentence is the restriction, as in yes/no questions). Compare the spread of brow raise ('br') and brow lowering ('bl'), both of which start with the first sign in the example (for more examples and details, see Wilbur and Patschke, 1999; Wilbur, 2011b, 2021):

(10) examples with brow raise

(a)

br
RAIN TOMORROW, PICNIC CANCEL
"If it rains tomorrow, the picnic is/will be cancelled."[31]

(b) Context: And what about Fred? What did he eat?

br
BEANS THAT, FRED EAT
"It's *beans* that Fred ate."

(c) From Aarons (1994)

br br
$JOHN_i$, VEGETABLE, HE_i PREFER ARTICHOKE
"As for John, as for vegetables, he prefers artichokes."

(d) From Liddell (1977, 1978)

br
DOG CHASE CAT BARK
"The dog that chased the cat barked."

br
$_1ASK_3$ $GIVE_1$ DOG URSULA KICK $THAT_c$
"I asked him to give me the dog that Ursula kicked."

[30] See Pfau (2016) for suggestion of spreading domains as prosodically determined. Many of his suggestions likely hold up, but the problem presented by brow raising as well as Tankersley's observations of mismatched brows remains problematic.

[31] Without 'br', the two clauses are read as conjoined: It's supposed to rain tomorrow and the picnic has been cancelled.

br
DOG BITE$_i$ CHASE CAT BEFORE THAT$_c$
"The dog that bit me chased the cat before."

(e) From Wilbur and Patschke (1999)

br
SHE GIVE HARRY WHAT, NEW SHIRT
"What she gave Harry was a new shirt."

br
BUT STAY HOME ALL-DAY EVERYDAY CAN'T
"But (I discovered that) I *can't* stay home all day, every day."

Context: explanation why ASL videotape has no "voice" (soundtrack for hearing people):

br br
SUPPOSE ADD VOICE, YOU LISTEN, LEARN NUMBERS CAN'T
"Suppose a soundtrack were added, you'd listen (to it) and *not* learn the (ASL) numbers."

br
BILL THINK MARY BECOME DOCTOR SHOULD
"Bill thinks Mary *should* become a doctor."

Near-minimal pair (rest of NMMs not noted) illustrates difference in 'br' function:

br
MARY, JIM LOVE TEASE *t*
"(Jim doesn't like to tease Jane.) It's *Mary* who Jim likes to tease."

br
MARY, JIM LOVE TEASE Ø
"As for Mary, Jim loves to tease her."

(f) From Lillo-Martin (1986)

br br
$_a$BILL, $_b$MARY KNOW $_a$INDEX, NOT^NECESSARY
"As for Bill, that Mary knows him is not necessary."

(11) Examples with brow lowering

(a) From Lillo-Martin and Fischer (1992) [bf > bl]

br bl
BOOK, YOU WANT WH-MANY
"How many books do you want?"

(b) From Petronio (1993)

whq/bl
WHO BUY C-A-R WHO
"Who bought the car?"

whq/bl
WHAT JOHN BUY WHAT
"What did John buy?"

whq/bl
WHO ANN EXPECT PASS TEST WHO
"Who does Ann expect to pass the test?"

The semantic operator analysis provides an explanation for the more limited spreading domain of the brow raise in ASL as compared to the more general spreading domain of brow lowering and negative headshake (among others). The suggestion that these NMMs are instead intonational/prosodic (Sandler and Lillo-Martin, 2006; Sandler, 2012; Dachkovsky and Sandler, 2009), while consistent with the idea that NMMs are componential and layered, does not address the difference in the spreading domains, and does not identify the source of the difference in these markers (again, more details in Wilbur, 2011, 2021).

3.2.11 Prosodic breaks and NMM resets are syntactically predictable

Extending spoken language syntax-prosody interaction work from Wagner (2005), Churng (2011) demonstrates that two pieces of syntactic information can predict the prosodic phrasing and the resetting of NMMs in certain wh-structures. The first of these is whether there is extraction of a phrase across a functional (as opposed to lexical) projection; when an extraction meeting this re-

quirement occurs, a prosodic break (pause) is inserted after the phrase that is moved. Theoretically a prosodic break follows every prosodic phrase (at an ideal signing rate); these inserted breaks then accumulate and reflect the number of levels of syntactic hierarchy that have been crossed. The second piece of relevant syntactic information is that any A-bar movement (non-argument, here 'wh-movement') results in a resetting of the NMMs at the end of the phrase that has been moved followed by different NMM settings in the next phrase, whereas A-movement (typically, movement of arguments to other argument positions) does not reset the NMMs but continues the NMM settings. Because so much of the argument for the analogy of sign language NMMs to intonation is based on mismatch between syntax and prosodic phrasing, it is worth walking through the details of how Churng's analysis works.

Churng uses a variety of ASL wh-question types, including a triplet that has the same sequence of four signs but with different NMMs reflecting which part is in focus; this yields three different interpretations. We start with the English equivalents to clarify the syntactic and semantic differences.

The three wh-questions are:

(12) What did you eat why?
"stacked question" Qswh

(13) What and why did you eat?
"at all reading" Qwh&wh-at-all

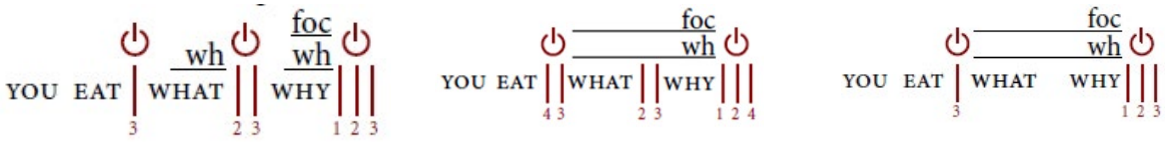
(14) What did you eat and why?
"it reading" Qwh&wh-it

Note first that in English, these three questions are syntactically different – they all contain two wh-words 'what' and 'why', but in the first one, 'what' has been fronted and 'why' is left in its original place (in situ), whereas in the second and third there is a conjunction with 'and'. In the second question, 'what' and 'why' are conjoined and both are fronted, and in the third, 'why' is left in a second separate clause.

These syntactic differences give rise to semantic differences. The first 'stacked question' has the interpretation of 'what foods did you eat for what reasons?', with a possible answer as a list: 'I ate oatmeal and I ate it because it makes me feel healthy; caviar, because it makes me feel wealthy; …'. The second question has the interpretation 'what did you eat, and why did you eat at all?', where a possible reply might be 'just a snack – I didn't realize it was so close to dinner time.' Finally, for the third 'it reading', Churng provides as a possible context 'I heard you started your low-cholesterol diet with breakfast this morning. What did you eat, and why did you eat it?'; a possible answer might be 'I ate oatmeal, and I ate it because it's heart-healthy'. This would have as its starting structure something like [you eat what, and you eat it why].

For ASL, the questions are schematized in Figure 5 (Churng 2011):

The numbers in Figure (5a-c) represent required gaps, which are represented by a vertical bar. Churng (2011) derives Figure (5a) with three syntactic operations, each of which leaves a break (including the final one): (1) WHY moves to Fo-



a. Regular 'what' followed by focused 'why'

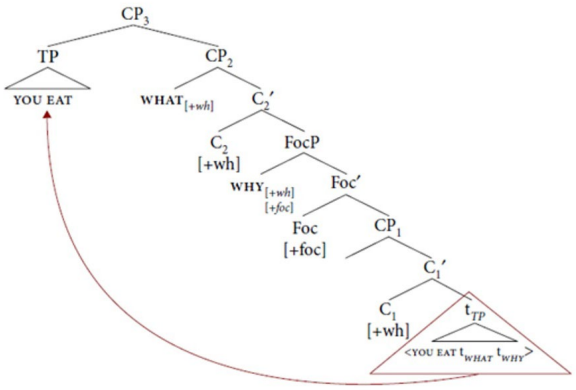
b. 'At all'-reading

c. 'It'-reading

Figure 5. *Three different productions of multiple WH-questions. Straight vertical line = 'gap', on/off power button symbol = 'reset' of NMM (Churng, 2011: 39-40)*

cusP (vertical bar labeled '1' in Figure (5a) above; FocP above CP_1 and below CP_2 in tree 15 below); (2) WHAT moves to SpecCP_2 (normal wh-movement) (vertical bar labeled '2' in Figure 5a above; CP_2 sister to TP phrase in tree 15 below; note that it has crossed functional projections CP_1 and FocP), and (3) YOU EAT moves to Topic position adjoining CP (vertical bar labeled '3' in Figure 5a above; adjoined as sister to CP_2 in tree 15 below).

(15)



Each of these three movements is an A-bar movement, which then predicts that there should be a NMM reset after each phrase, which accords with Churng's data, as shown in Figure (5) above (the power button symbol). This approach to analyzing the prosodic structure from the syntactic movements makes additional predictions as well: the prosodic break at the end of the utterance will be the longest, the one between 'what' and 'why' will be next longest, and the one after the topic will be shortest. Further we would expect that if signing rate is speeded up, the breaks will shorten accordingly, maintaining their relative durational ranking, and that if a prosodic reset is going to be lost in faster signing, it would be most likely that the one after the topic would be lost first, and the one between 'what' and 'why' lost next. What this means is that this approach makes additional testable predictions to determine its accuracy.

The remaining two wh-questions in the triplet are underlying biclausal, that is, there are two clauses conjoined with 'and' at the start of the derivation. In the 'at all'-reading (13; Figure 5b), two separate TPs are extracted to the left periphery, with a prosodic gap between WHAT and WHY but without NMMs reset, as both are wh-marked and focus marked. In the 'it'-reading (14; Figure 5c), one large TP is moved, so there is no break between WHAT and WHY, and also no reset between them because again, they are both wh-marked and focus-marked. Churng's analysis exactly matches the NMMs resets and gaps to the differences between the three syntactic derivations and meanings (the reader is referred to Churng's work for details).

Churng's work is important because it illustrates how semantics, syntax, and prosody are all intertwined: If you change the syntax, the prosody changes, and then you get a different semantic interpretation. To accomplish this, she did not need to make any special assumptions about ASL, syntax, or prosody. We take this as additional evidence for a model like Selkirk's with three components: syntax, prosody/phonology, and a syntax-phonology interface.

4. CONCLUSION

In this chapter, we divided prosody into rhythmic phrasing and intonational marking. We reviewed how phrasing is indicated in speech and sign, and considered the idea that the two modalities are generally parallel in meeting the needs of the signal producer and the recipient perceiver, such as phrase final lengthening. Differences include how functions are marked (breathing locations for speech, blinking locations for sign). Likewise, despite modality differences in syllable-internal structure, correlations of stress marking to syllables are generally the same (Basic Accentuation Principle), when language-specific differences like the stress 'plasticity' of a language are considered.

With respect to intonation, much more research is needed before we can fully understand how this part of the prosodic system works. We noted that the typical view of spoken intonation tends to be overly simplistic compared to the evidence; an effort has been made to explain an updated understanding of the relationship between syntax and prosody (Selkirk), and components of intonation (Heim, Wiltschko, earlier work by Pierrehumbert and Hirschberg). We see that the analogy of NMMs to intonation faces significant difficulties because it

(1) fails to explain spreading behavior difference between ASL brow raise and brow lowering; (2) does not explain which NMMs are present and why, which becomes clearer when their morphemic status is reviewed; (3) overlooks brow height behavior documented by Weast that appears to be parallel to intonational contours across the domain of a sentence; and (4) relies on analogy to a model of spoken intonation that has been shown to be insufficient. Recent investigation by Tankersley of NMMs and question types shows that even the basic pattern of brow position and question type is more complex than generally recognized.

From the morphemic perspective, NMMs reflect syntactic and semantic functions (and there are some NMMs, like specific kind of eyeblinks, which do perform prosodic jobs). Ichida rejects intonational analysis of NMMs and argues that they perform functions of overt morphology. Wilbur identifies differences in spreading behavior of two groups of NMMs, and argues that both types are morphological but differ in semantic function. Bross provides additional morphemic functions for NMMs in DGS related to functional categories in Cinque's hierarchy. Further, the work of Bross & Hole, and Karabüklü et al., documents that lower face NMMs are not just adverbials and mouthing as previously claimed, but also functional operator domains with scopes that must be marked. Thus, even lower face NMMs contribute to the broader syntactic and semantic structure of the signed utterance.

Given Selkirk's Match Theory of alignment of syntax and prosody, prosody reflects syntax but is not completely isomorphic. The idea is that they begin in coordination, but production factors (speaking/signing rate) may change the prosody and obscure the underlying syntax. Churng's analysis of ASL, where she demonstrates that the location of prosodic pauses between phrases (before rate effects) and the location of prosodic resetting of NMMs between phrases are both syntactically predictable, shows the matching of syntax and prosody.

Taken together, these arguments support the claim that NMMs are morphemes that perform semantic, syntactic, and likely pragmatic functions. Once the NMMs are present in the sentence, everything (hands and NMMs) is then subject to the prosodic rules, which are sensitive to phonological hierarchies/constraints as well as lower-level production effects, style of production, and contextual intentions. But most NMMs themselves are *not* there to indicate intonation patterns in the way that the analogy has suggested.

The argument has been made that a separation must exist between *why* a NMM is present in the sentence (the message it conveys) and *how* the movement or other articulation behaves with respect to the other articulators over the time course. The entire production is temporally coordinated to enable the signer to produce it with ease and the viewer to visually receive and interpret it with ease. Thus, finding that the beginnings and ends (boundaries) are coordinated with various phrasal sizes (phonological, clausal, sentential) says much about the motor and visual system but not much about the linguistic system itself. Correlation of NMMs with prosodic alignment does not entail causation – that is, the prosody does not *put* the NMMs there, rather it makes the NMMs *conform* to the prosodic phrasing.

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