1. Introduction: what the eyebrows reveal

Interpretations of eyebrow movement contribute to one of the strongest debates in current signed language literature. Do eyebrows represent syntax or intonation? How does eyebrow movement interact with emotion? ASL eyebrow analysis to date is limited to recording only impressions of eyebrow height or muscle movement. Could greater detail on eyebrow movement provide insight into the interpretation of eyebrows? Through the first quantitative analysis of eyebrows in signed languages, this chapter demonstrates both syntax and intonation, clarifies the co-effects of the emotional and linguistic expressions through eyebrow height, and introduces eleven properties of eyebrow movement in ASL. Eyebrow behavior in ASL questions is compared to the behavior of pitch in some tone languages, where emotional prosody, grammatical intonation, and syntax can all overlap through one change in pitch. Similarly, in the data, one change in eyebrow height simultaneously conveys emotional prosody, grammatical intonation, and syntax in ASL questions.

2. Nonmanuals of the face

Eyebrows are one of several nonmanual channels which convey information beyond the manual signs. Nonmanuals of the face can be separated into the lower face and the upper face. The lower face includes channels such as the lips, tongue, and cheek muscles. The lower face nonmanuals attach to individual signs to convey morphological and lexical information (Liddell 1980, 2003). For example, in ASL they can generate a minimal pair, such as in the sign NOT-YET. NOT-YET is produced with the tongue protruding during the sign, while the same hand sign without the tongue protrusion creates the sign LATE. Tongue movement can also signal adverbial information in ASL,
such as the ‘th’ shape that is added over signs to indicate a state of being ‘careless’. For example, signing DRIVE and the vehicle classifier with the ‘th’ tongue shape means ‘driving carelessly’, while the same sign without this nonmanual loses the careless meaning.

The upper face nonmanuals include channels such as the eyes and eyebrows. Directed eye gaze in ASL can signal referents such as subject or object. Eyebrow movement is considered to extend across phrases in several types of constituents in ASL, such as topicalized elements, yes/no questions, wh-questions, conditionals, and relative clauses (Liddell 1980, Baker-Shenk 1983, Neidle et al. 2000).

3. **Current methodologies and research on ASL eyebrows**

Eyebrows are considered to play a role through similar patterns in several signed languages. For example, eyebrows are raised in yes/no (polar) questions of Israeli Sign Language (Nespor & Sandler 1999) and several signed languages in a cross-linguistic study (Zeshan 2004). This is not universal, however, as Croatian Sign Language lowers the eyebrows for yes/no questions (Kuhn and Wilbur 2006). The question, then, is how to capture the information eyebrows convey in order to examine these language-specific differences.

Thus far, ASL eyebrow analysis has used impressionistic or qualitative methodologies. One common method uses the Facial Action Coding System, FACS (Ekman et al. 1978), and records impressions of muscle movements. This method was first applied to ASL by Baker (1976). Such research influenced subsequent ASL curricula (e.g. Signing Naturally Lentz et al. 1988), with general findings that eyebrows raise in yes/no (polar) questions and lower in wh- (content) questions (Baker 1976; Liddell 1980; Baker-Shenk 1983).

Another common method uses SignStream™ transcriptions (Neidle et al. 1997) or similar recording methods. With SignStream™, impressions of eyebrow heights are recorded on a 4 point scale: raised, raised -, lowered - , and lowered (Neidle et al. 1997).

Eyebrows in ASL are considered to spread across groups of signs, and are not considered associated with any particular manual sign (e.g. Emmorey 2002, Aarons 1994). Brow furrowing (brows coming together) is often used to describe eyebrow behavior in wh-questions, and is not separated from lowering in ASL FACS analysis (Ekman et al. 1978), a distinction shown to be important later in this chapter. These current methodologies provide a
glimpse of eyebrow movements, but these impressions create variable results which also fuel the debate.

When Baker (1976) first observed the strong correlation between eyebrow movements and yes/no questions, she labeled the eyebrows as raised. At the same time, she recorded that 30% of sentences did not appear to show these raised eyebrows. In part to explain these potential exceptions to the general pattern, many researchers turned to investigate whether raised eyebrows are obligatory or not, and whether they reflect syntax or intonation.

3.1 Do eyebrow movements represent syntax or intonation?

Researchers currently debate interpretations of the upper face nonmanuals, and eyebrows are a central part of the discussion: do eyebrows best compare to pitch in the intonation of English, or do eyebrows represent aspects of syntax? The upper face nonmanuals are considered comparable to English prosody and intonation by several researchers of different signed languages, such as Israeli Sign Language (Nespor & Sandler 1999), American Sign Language (Reilly et al. 1990; Brentari 1998), and British Sign Language (Atkinson et al. 2004). For example, Sandler and Lillo-Martin (2006) conclude that raised and lowered eyebrows in ASL questions represent intonational tunes, and that a pragmatic force creates the question nonmanual marker, not the syntax.

An alternative account for the upper face nonmanuals (including eyebrows) is that they reflect the syntax and can serve as facial morphemes, particles, or clitics (Stokoe 1978, Baker & Padden 1978, Liddell 1980, Baker-Shenk 1983, Neidle et al. 2000). For example, Aarons (1994) states that yes/no questions show the obligatory eyebrow raise over the c-command domain of the Complementizer, and spreads obligatorily over the entire IP (clause) because it is not associated with any lexical material in the Complementizer.

Perhaps the most extensive examination of eyebrows in ASL can be found in Wilbur’s work (Wilbur 1994b, 1995, 2000, and 2003). Wilbur and Patschke (1999) searched for a unified account and concluded that only a syntactic analysis explains all occurrences of raised and lowered eyebrows in ASL. Furthermore, while most of the debate considers all upper face nonmanuals as either intonation or syntax, Wilbur’s work extends this debate to allow for a layering, where multiple channels function independently. While still analyzing eyebrows as syntax, for example, Wilbur considers many other simultaneous upper face nonmanuals to represent functions such as intonation or prosody (e.g. eyeblinks, Wilbur 1994). This notion of layering suggests
that different morphological, syntactic, prosodic, and semantic functions can co-occur when distributed to distinct channels (Wilbur 2000, 2003).

3.2 Distinction between grammar and emotion in nonmanuals

These channels also include emotional nonmanuals that co-occur with linguistic nonmanuals. Emotional expressions are generally considered to be universal involuntary expressions and eyebrows play a significant role in conveying emotion (Ekman & Friesen 1978). In addition, eyebrows can convey linguistic information in both spoken languages (Ekman 1979) and signed languages (Baker 1976). Are there distinctions, then, in how the brain organizes these emotional and linguistic expressions in language?

Brain imaging shows distinct functions between grammatical and emotional facial expressions. In spoken language, both emotional and linguistic information is predominantly controlled by separate hemispheres in the brain: linguistic centers located mostly in the left hemisphere, and paralinguistic centers for emotional communication in the right hemisphere (Segalowitz & Bryden 1983).

Similar distinctions are seen between linguistic and emotional nonmanuals in signed languages (Corina et al. 1999). Researchers imaging the brain hemispheres during signing (Bellugi et al. 1989) found emotional facial expressions show additional right hemisphere activation, the same hemisphere as emotional spoken language, while linguistic ASL facial nonmanuals show additional engagement of the left hemisphere, activating the language centers of the brain. Both linguistic and affective facial expressions are distinct, then, evident by timing and distribution in signed languages (Baker & Padden 1978; Liddell 1980; Coulter 1978, 1979; Baker-Shenk 1983; Bahan 1996; Veinberg & Wilbur 1990; Wilbur 2000, 2003).

Signed language research on eyebrows in questions has focused on neutral sentences, but one study (de Vos 2006) recently used FACS to examine emotional questions in a different sign language, Sign Language of the Netherlands, Nederlandse Gebarentaal (NGT). De vos (2006) concluded, based on muscle impressions, that eyebrows show somewhat conflicting results: sometimes the grammar overwhelms emotion, removing emotional expressions, while other times the emotion overwhelms the grammar, removing the linguistic eyebrow movement.

What about ASL? Would quantitative measurements show more regular patterns? The emotional expression of anger includes lowered eyebrows (Ekman & Friesen 1978). If a signer is angry and producing raised eyebrows
during a yes/no question in American Sign Language, how will the raised eyebrows be influenced? When emotions use similar facial muscles as linguistic expressions, as in this example, can the two distinct functions be observed through a phonetic analysis? These first data of emotional ASL questions allow such an observation, and reveal complex layering, where both emotional and linguistic eyebrow movements co-occur.

3.3 A layered perspective

Rather than two divergent paths in the debate, new quantified data suggests that researchers on both sides of the debate can be on separate paths going the same direction. Not all differences will be resolved, but a new framework can broaden the discussion. In this investigation, the eyebrows are seen to simultaneously represent both syntax and intonation. To explore how this is possible, the following is a brief comparison to tone languages.

In tone languages, such as Thai, lexical tones create minimal pairs. For example, a fall from the highest-to-mid trajectory for the word Kha means ‘to kill’, while a rise from mid-to-high Kha means ‘to trade’. Emotion is then simultaneously conveyed within each required pitch trajectory’s tone latitude (Ross et al. 1992). Too low or too high and the lexical tone is altered, but within a range, the emotion is allowed to vary the tone while not removing the lexical material. Tone languages, then, can have a lexical tone over a word and simultaneously expression emotional intonation through the same use of pitch. Tone languages can also allow pitch to create question distinctions. For example, in Igbo, a question beginning with a pronoun will place a low tone on the pronoun, and without this low tone, the question becomes a statement (Green 1949). Additionally, some tone languages can incorporate grammatical intonation such as focus and other prosodic cues that are then simultaneously overlapped onto the lexical tone (Lindau 1986).

I argue that ASL nonmanuals show some similarities to pitch in tone languages, especially in regards to eyebrow height. Nonmanuals that are attached to lexical items, such as the lower face adverbials, can be analogized to syntactic tone attached to syllables in tone languages. For ASL, this chapter demonstrates that eyebrow height attaches to lexical items in questions, allows both syntactic and intonation types of spread across constituents, and further allows emotional states to influence this eyebrow height without removing the linguistic distinctions (Weast 2008a, 2008b).
4. Methodology

Participant demographics of the six consultants: each is at least second generation Deaf, with one consultant fourth generation Deaf. They all learned ASL as a first language from their parents. Consultants (C1 - C6) were ages 21-51, and there were two males and four females. While all six currently reside in either north or central Texas, three had previously graduated from Gallaudet University, located in Washington D.C.

4.1 Data and collection

For this study, each sentence set includes one sentence unit (or group of signs) and each sentence unit is then signed in three sentence types: a yes/no question, a wh-question, and a statement. Next, each of these sentence types for this one sentence unit is also signed in five emotional states. Sentence sets and sentence set types were created by a native Deaf consultant, and also verified by consultant signers. A modified elicited approach was used to collect the questions and statements, in order to not restrict the natural nonmanuals and sign movements. This permitted consultants to sit back comfortably in their chairs and to relax while signing, and to sign in normal space, rather than asking them to limit their range of motion for the camera. The consultants were then videotaped from approximately waist level so as to include the entire sign space. A Panasonic 3CCD PV-GS320 digital video camera was placed on a tripod at eye level exactly 1.5 meters in front of the seated consultant as measured from the camera to the consultant’s nose.

To help become comfortable with signing in front of the camera, prior to collecting the scripted data, consultants first signed two short stories. They were also videotaped answering questions to confirm eligibility for the study, and both the interview and narratives were examined in data analysis to confirm that the range of eyebrow heights in the scripted data was similar to the range of eyebrow heights in the unscripted conversational data.

One sentence set example used the signs NOW and RAIN, differentiated only by nonmanuals between the statement “It is raining now.” and the yes/no question “Is it raining now?” For the wh-question, a wh-word was added, to sign the English equivalent of “Where is it raining?” Each sentence set was then given a scenario to situate the emotional settings, and help frame similar
interpretations of sentence sets. For example, for this sentence set, ideas included planning a fun picnic but now it rains (sad), leaving the car window open with important papers in the car but now it rains (angry), and so on.

Consultants each signed six target sentence sets using neutral and the emotions happy, sad, angry, surprise. There were a total of fifteen sentences for each sentence set, with five sentences signed as a yes/no question for each of these five emotions, five signed as a wh-question for each emotion, and five signed as a statement for each emotion. The six sentence sets contain a total of 90 sentences per consultant, further signed with three renditions each, so that the middle rendition could be selected whenever possible, consistent with traditional phonetic analysis. With six consultants, this resulted in a total of 540 sentences (middle renditions) for the data. Only the first three sentence sets were selected for analysis, which resulted in 270 sentences for the final data of this investigation.

During data collection, the sentence types were elicited by holding up cards. For example, if a sentence was to be signed as a happy yes/no statement, the card was seen as in Figure 1, similar to the method used in Baker & Padden 1978.

![Sample card seen by consultants listing emotion and sentence-type.](image)

The cards similar to Figure 1 were also mixed into random orders. As signing continued for about an hour, this allowed consultants to view cards and not be influenced by expressions from an interlocutor. After signing, consultants viewed their own sentences to verify the target emotions were achieved, and also recorded impressions of signing from other consultants.
4.2 Measuring instrument and procedure for analysis

Figure 2 shows the measurement tool and facial landmarks for recording values. This includes detail on the application of this digital tool that is new to the field of ASL research.

Outside the field of signed languages, hand calipers have been used frequently for facial measurements, and Clapham et al. 2006 investigated their accuracy in comparison to newer digital technology. The results of their study showed the measurements from SO to IO (seen in Figure 2) were accurate in tests of variance with p-values <.05 for both hand calipers and measurements of still frames in Adobe Photoshop. Correlation scores, however, showed digital measurements were overall more accurate. One possible explanation is that individuals may move or alter expressions when a physical tool is placed over their faces. Any such movement would most certainly be repeated and even magnified in a signed language study of subtle facial movements. For ASL, then, the combination of a caliper tool and digital images proved to be an ideal and novel combination. This was found in a digital version of calipers, seen in figure 2.

This online version of the caliper instrument called Screen Calipers™ (Iconico) was located and applied for the first time to signed language research. This tool is traditionally applied to engineering, medicine, and other scientific projects. The standard version is free, but the upgrade was purchased for an affordable $30 (USD) for the ability to move 360 degrees as needed during analysis. The tool was situated on the face using points A, B, and C in Figure 2, situated into the SO, LC, and IO locations respectively.
With this tool, all 270 sentences at 30 frames per second were stopped at least every 3 frames (and more often if there appeared to be a change), and eyebrow heights were recorded by hand. In total, over 3500 measurements required more than 170 hours to code, including over 39 hours of training the tool to each face prior to coding. The Screen Calipers™ tool was used to generate pixel measurements. Pixels are units of small dots relative to screen size, measured in increments of 1 pixel (px) at a time. Researchers can replicate similar measures by using the same screen size in this study, and the same distance from the camera to the signer during data collection. For analysis, the computer screen was obscured so that only the upper face was visible during coding of the facial measurements, recorded based on time stamp.

5. Statistical results

Table 1 shows the range of eyebrow heights in the data for each signer (C1-C6) in terms of pixel measurements. Each signer showed the same individual range in both the natural and elicited data.

<table>
<thead>
<tr>
<th>Consultant</th>
<th>Min. brow Height in Pixels</th>
<th>Max. brow Height in Pixels</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>C2</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>C3</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>C4</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>C5</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>C6</td>
<td>2</td>
<td>14</td>
</tr>
</tbody>
</table>

In Table 1, all consultants show a 12 pixel range for eyebrow height, except Consultant 4 (C4), who shows an 11 pixel range for eyebrow height in all data.

For comparison across signers, it was initially hypothesized that consultants would show great variability in pixel ranges because of physiological differences across individuals. For example, perhaps one signer might range from 5-16 pixels when signing while another might range from 1-10 pixels. The eyebrow heights, then, were to be set to zero, to compare change in heights across consultants.
Instead, as seen in Table 1, all six consultants ranged within 1-3 pixels of each other from both maximum and minimum height levels. With such a similar range of production in this study, there was no need to limit the results by setting values to zero. Rather, the raw values of eyebrow height were used in all statistical tests and contour charts of measures.

**Property 1 emotional organization:** The ranges of eyebrow height are organized by emotional state.

Figure 3 shows overall emotional eyebrow heights, and question distinctions that are often made within these emotional levels. A mixed model analysis was performed using SAS software for the onset, maximum, and minimum eyebrow heights for each sentence. All three showed similar patterns, and these patterns are seen in the results for maximum values of each sentence in Figure 3.

![Figure 3](image)

*Figure 3.* Eyebrow height for ASL questions and statements with added emotion: maximum values for all 270 sentence samples. Yes/no questions (Y/N), wh-questions (WH), and statements (DECL): mixed model means across (left to right) surprise, happy, neutral, sad, and angry.

The boxes represent the 25th to 75th percentile of means, with the 50th percentile at the line. The whiskers show the distribution of values in the means for all sentences. Looking at the overall distribution in Figure 3, it becomes apparent why curricula continue to teach only the basic “eyebrows raised” or “eyebrows lowered” for questions: neutral yes/no questions and
neutral wh-questions are spread farthest from their respective statements, appearing as a degree of extreme raising or lowering. The picture becomes less obvious, however, when noting the spread in emotional question distinctions. The mean maximum eyebrow heights in ASL sentences make significant distinctions between yes/no and wh-questions with $p < .05$, but make no distinctions between questions and statements within emotions.

In Figure 3, eyebrows raise for neutral questions on average 21% from statements, and lower 30% from statements, generally the largest extremes. Notice, however, that when emotion is added to the conversation, there is a much tighter distribution. For example, while on average angry yes/no questions reach higher heights of raised eyebrows than angry statements, there is only a subtle raising, and angry wh-questions are only slightly lowered from angry statements. Also, compared to neutral state, many sad and angry yes/no questions may not even employ eyebrow heights as high as the ‘lowered’ wh-question in neutral.

In Figure 4, the mixed model data show type-by-emotion interaction which further demonstrates that emotions do influence the linguistic question distinctions.

Figure 4 shows the difference in mean eyebrow maximum values for eyebrow height. The minimum and onset values are also categorically similar to each other for the three sentence types across the same data set of emotions. All five emotions are statistically significant ($p < .05$) from each other, except for surprise and happy (no difference, $p = .9632$). There is generally no difference between sad and angry for eyebrow height, but the
data do show a categorical distinction which ranks these negative emotions together as statistically lower than the other emotions. The type by emotion results show a \( p < .05 \) difference exists between sad and angry and all other emotions in the data, in all sentence types, with only two exceptions, seen in Figure 4 in the small box. The two values that do not show this categorical distinction represent a surprise wh-question and a neutral wh-question. For both of these values, there was a significant difference for all of the comparisons except two, which were when comparing the surprise and neutral wh-questions against neutral statements or against each other. Therefore these two are excluded from the grouping. Perhaps a larger study could resolve these exceptions and show they too will fit into the categorical ranking.

The overall declination of eyebrow heights and distinctions between positive and negative emotional states reveal the first property, that the ranges of eyebrow height are organized by emotional states.

With such variability from emotional states, then, are there any consistent patterns produced by eyebrow height to distinguish between question types and statements in American Sign Language? Consistent distinctions do exist, but are found when looking not at the range of eyebrow height, but at both the timing and spread of raised and lowered eyebrows.

6. **Contour results**

The results focus on both raised and lowered eyebrows, but not furrowed eyebrows, because of the variable nature of furrowed brows revealed in the data. For example, brow furrowing was frequently omitted from wh-questions, depending on the emotion and sentence type combination.

Contour charts plot the raised and lowered eyebrows over the entire sentence and reveal a bigger picture of eyebrow behavior in signers.

**Property 2 height change at boundaries:** Eyebrow height changes either at lexical boundaries or with sign movements.

Figure 5 shows statements of one sentence set for one consultant signing in the five emotional states. Each mark across the x-axis represents three frames, and the y-axis shows the pixel heights for each measurement.
Figure 5 reveals the second property of eyebrow movement. When the eyebrow levels change, as seen in the Figure 5 line values, the raising or lowering occurs either at lexical sign boundaries, or in timing with sign movements.

**Property 3 Declination In Statements:** Eyebrow height shows a declination effect in simple statements.

Figure 5 also shows the third property of eyebrow movement: a declination effect in statements, visible with an overall lowering by sentence-final position. This can be analogized to the declination of pitch in the intonation of spoken languages. The data also show a frequent sentence-medial rise, visible in angry and happy in Figure 5. However, Figure 6, shows a striking difference for wh-questions.

**Property 4 wh-word lowering:** Eyebrows show a subtle lexical lowering (at least 1 pixel) over wh-words.

Bracing wh-questions, with wh-words in both initial and final position, occurred in some sentences in the data. Figure 6 reveals two examples of signed bracing wh-questions, in the emotions happy and angry.

Figure 6 shows the fourth property of eyebrow movement: a subtle lexical lowering over WH words. Wh-words such as the sign WHERE in Figure 6 show a consistent lexical lowering of at least (and often exactly) one pixel across all 90 wh-questions in the data across emotions. This occurs regardless
of positioning in the sentences. This obligatory lexical signature for lowering can then be compared to syntax.

**Property 5 wh-constituent end lowering:** Eyebrows lower at least 1 pixel (subtle lowering) over an element at the end of a wh-constituent. Not only is there a lexical attachment of lowering over every wh-word, but there is also at least a one pixel lowering over an element at the end of the wh-constituent. In Figure 6 this occurs over WHERE in sentence-final position. This is the fifth property of eyebrow movement. In final position, this lowering occurs over a wh-word when available, but when one does not exist, the lexical lowering occurs over a substitute or non-overt wh-element. Thus, final position maintains this lexical lowering in the presence or absence of any wh-word. In contrast, when a sentence-initial wh-word is omitted, there is no lexical lowering assigned to any element in initial position. This lexical lowering, therefore, is triggered by the presence of a wh-word in initial position.

**Property 6 narrow spread in bracing wh-questions:** Eyebrows show an obligatory narrow spread of lowering in bracing wh-questions.

Figure 6 shows two examples of wh-word bracing where the sentence begins and ends with a wh-word. When a word such as the verb RAIN in Figure 6 is braced by wh-words, the eyebrows are raised only one pixel in the data. This
sixth property of eyebrow movement is what I call narrow spread, because
the content between the wh-words receives an additional lowering that limits
the eyebrow raise to only about one pixel above the wh-word height. This
occurs in all of the sentences with bracing wh-words, and is syntactic because
limiting the raising is associated with a specific type of grammatical word, a
wh-word, regardless of emotional context.

Property 7 wh-constituent variable lowering: There is a variable broad
spread of eyebrow lowering over the entire wh-constituent.

Another eyebrow property, the seventh property, includes a variable broad
spread of lowering over wh-questions in the data. This is what was seen in
Figure 3 with the statistical means where wh-questions are generally lower
than corresponding statements and yes/no questions. This broad spread can
be omitted, possibly by speaker intent or emotional state. While in Figure 6
C1 showed an angry wh-question ranging from 3-4 pixels, in Figure 5, C1
showed an angry statement ranging from 1-3 pixels, lower than the wh-ques-
tion. While many of the 90 wh-questions maintained an overall lower height
range than statements, this pattern was not consistent, therefore the overall
broad spread of lowering best corresponds to intonation, that can vary based
on pragmatic or other effects. The wh-questions are normally lowered, but
the degree to which they lower varies. They are also signed in a brow range
lower than the statement range, but this can also vary.

English Translation: “Where is it raining?”

Figure 7. C6 eyebrow height in wh-questions sentence-final for Set 1
Figure 7 shows examples of wh-questions without bracing wh-words, with only wh-words in sentence-final position. In the absence of an initial wh-word, the additional narrow spread is not triggered, so the sentence shows a declination similar to statements until the wh-word occurs. Without the sentence-initial wh-word, the sentence often begins at a higher pixel range of eyebrow height when compared within similar emotional states. Once the wh-word occurs such as in the lowest contour of angry in Figure 7, whatever follows the wh-word will retain the narrow spread of lowering, such as in this tag question of the particle of indefiniteness (part:indef, Conlin et al. 2003) that only raises one pixel after the wh-word. While the narrow spread does not occur in Figure 7, the overall broad spread of lowering still exists with simultaneously a lexical wh-lowering.

Property 8 y/n variable broad raising: There is a variable broad spread of overall raised eyebrows across the entire yes/no constituent.

Figure 8 shows height in yes/no questions. Yes/no questions reveal the eighth eyebrow property. Figure 8 shows a broad spread, but of overall raised levels across the constituent. These values are not always higher than the corresponding statements or neutral conversation, however, so this broad spread of eyebrow ranges behaves similar to intonation. For example, in Figure 8, the neutral yes/no question is signed with raised eyebrows at higher levels than all other emotional states, including surprise and happy.

English Translation: “Is it raining?”

Figure 8. Eyebrow height in yes/no questions, C1 Set 1
Property 9 y/n obligatory narrow raising: There is an obligatory narrow spread of raised eyebrows in yes/no constituents, with a rise of at least one pixel at some point and to the end.

Additionally, a further property of eyebrows, the ninth property, includes narrow spread of eyebrow raising in the yes/no questions as seen in Figure 8. Yes/no questions in the data either show a rise to a sentence-final level, as in surprise and neutral in Figure 8 above, or a lexical lowering in the sentence prior to a final rise of at least one pixel, which remains until sentence-final position as in happy, angry, and sad in Figure 8. This consistent narrow spread of eyebrow raising corresponds to syntax.

Also, while statements frequently show a sentence-medial rise, yes/no questions often show a lexical lowering over a particular sign, usually a verb such as RAIN in Figure 8, but not always. Whether this is merely an effect of the sentence-final rise, or an independent phenomenon, is the subject of future research.

7. Other lexical attachment in all sentence types

Property 10 variable focus lowering: Lowered eyebrows show variable lexical attachments across sentence types, potentially as an expression of stress or focus (e.g. NOW).

The data show additional lexical attachment that occurs in both statements and questions, and which can be either syntactic or intonational in nature. For example, across all six consultants, the sign NOW showed a lexical attachment of eyebrow lowering that coincides with the vertical lowering of the two hands in the second part of the sign. This did not occur in every instance of the sign, but when present, gives the appearance of an effect of stress or emphasis, perhaps added as a focus or intonational component of the language. This type of variable lexical attachment across sentence types is the tenth property, potentially as an expression of stress or focus.

Property 11 obligatory lexical lowering: Lowered eyebrows show obligatory lexical attachments across sentence types, such as a subtle lowering of at least one pixel over the N in the lexicalized sign #WHEN.
An eleventh property shows an obligatory lexical attachment across sentence types. In the data, for example, there was a lexical attachment for eyebrow lowering which occurred over the N in the lexicalized sign #WHEN. This appears to be obligatory in the data, as the subtle lowering of at least 1 pixel occurred in every instance of the sign, across all consultants. This correlates to a syntactic attachment of eyebrow lowering. This could either be a lexical syntactic lowering that is not fully realized until the final letter N, or some type of morphological lowering attached to the final element of the sign.

8. **Conclusion: properties of eyebrow movement**

This chapter introduced eleven properties of eyebrow movement. These properties show behavior that corresponds to intonation, syntax, and emotional prosody. The following is a summary of the properties, grouped by sentence type:

*General Properties*

1. **EMOTIONAL ORGANIZATION**: The ranges of eyebrow height are organized by emotional state.
2. **HEIGHT CHANGE AT BOUNDARIES**: Eyebrow height changes either at lexical boundaries or with sign movements.

*Statements*

3. **DECLINATION IN STATEMENTS**: Eyebrow height shows a declination effect in simple statements.

*Wh-Questions*

4. **WH-WORD LOWERING**: Eyebrows show a subtle lexical lowering (at least 1 pixel) over wh-words.
5. **WH-CONSTITUENT END LOWERING**: Eyebrows lower at least 1 pixel (subtle lowering) over an element at the end of a wh-constituent.
6. **NARROW SPREAD IN BRACING WH-QUESTIONS**: Eyebrows show an obligatory narrow spread of lowering in bracing wh-questions.
7. **WH CONSTITUENT VARIABLE LOWERING**: There is a variable broad spread of eyebrow lowering over the entire wh-constituent.
Yes/No Questions
8. Y/N VARIABLE BROAD RAISING: There is a variable broad spread of overall raised eyebrows across the entire yes/no constituent.
9. Y/N OBLIGATORY NARROW RAISING: There is an obligatory narrow spread of raised eyebrows in yes/no constituents, with a rise of at least one pixel at some point and to the end.

Other Lexical Properties
10. VARIABLE FOCUS LOWERING: Lowered eyebrows show variable lexical attachments across sentence types, potentially as an expression of stress or focus (e.g. NOW).
11. OBLIGATORY LEXICAL LOWERING: Lowered eyebrows show obligatory lexical attachments across sentence types, such as a subtle lowering of at least one pixel over the N in the lexicalized sign #WHEN.

The data distinguish between questions and statements across emotions, showing that emotion does not remove linguistic eyebrow height. The data show, for example, that eyebrows in wh-questions can simultaneously alter the height for stress or focus on a particular sign, may show or omit overall lowered levels in a wh-constituent (aspects of intonation), will produce subtle lowering over every wh-word and show a further lowering between bracing wh-words (both obligatory aspects of syntax), all while maintaining an overall range of height that is organized around emotional states.

Therefore, the layered functions of ASL eyebrows are not best compared to pitch in English, but instead function similar to pitch in tone languages. The data show that one nonmanual, the eyebrow channel, can simultaneously function as syntax, grammatical intonation, and emotional prosody in one change of eyebrow height. This corresponds to how pitch functions in some tone languages, where grammatical intonation, emotional prosody, and tone all co-occur through one change in pitch. This expands the theoretical debate on nonmanuals from the assumption of a mutually exclusive analysis of either syntax or intonation, to a more defined question of when syntax and intonation can or cannot co-occur in signed languages, and the interaction of emotional and grammatical effects. The introduction of affordable quantitative measurements also broadens the options for future research.
References

Aarons, D.

2004 Understanding ‘not’: Neuropsychological dissociations between hand and head markers of negation in BSL. *Neuropsychologia* 42(2): 214–229

Bahan, B.

Baker, C.

Baker, C. & C. Padden

Baker-Shenk, C. L.

Bellugi, U., Poizner, H. & E.S. Klima.

Brentari, D.

Clapham, L., Bottoms, S., Mehta, R. & A. Davis.

Conlin, F., P. Hagstrom, and C. Neidle.

Coulter, G.

Coulter, G. R.

De Vos, C.

Ekman, P., Wallace V., & W.V. Friesen.

Emmorey, K.

Green, M.


Kuhn, N. & R. Wilbur.

Liddell, S.K.
Liddell, S.K.

Lindau, M.


Nespor, M. and W. Sandler.

Ross, E. D., J. Edmondson, et al.

Sandler, W. & D.C. Lillo-Martin.

Segalowitz S.J. and M.P. Bryden.

Stokoe, W. C.

Weast, T.  

Weast, T.  

Wilbur, R.B. and C. Patschke.  

Wilbur, R.  

Wilbur, R. B.  

Wilbur, R.B.  

Wilbur, R. B.  

Zeshan, U.  