QUESTIONS IN AMERICAN SIGN LANGUAGE: A QUANTITATIVE ANALYSIS OF RAISED AND LOWERED EYEBROWS

by

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ABSTRACT

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Although much of linguistic information in American Sign Language (ASL) is conveyed through nonmanual signals, the majority of more than 40 years of research focuses on manual signs. As a result, we are just beginning to understand the role of the face, head, and upper body in signed languages, including eyebrow movement. While researchers generally agree that eyebrows play a role in questions of examined sign languages, they disagree whether upper face nonmanuals are syntactic or prosodic and intonational. Wilbur 2000, 2003 widens the debate to suggest a layered combination in the upper face,

where eyebrows represent syntax, and other upper face nonmanuals can simultaneously represent intonation and prosody. The debate over the upper face continues greatly due to a lack of quantitative data, with reliance on only qualitative movement impressions. As a result, ASL curricula do not adequately teach the role of nonmanuals, and ASL questions are often misinterpreted with serious consequences.

This research presents the first quantitative analysis of eyebrows and reveals how, despite emotional state, ASL maintains linguistic distinctions between questions and statements through eyebrow height. In this study, six native Deaf participants signed yes/no questions, wh-questions, and statements, each in *neutral*, *happy*, *sad*, *surprise*, and *angry* states. Over 3500 measurements of consultant eyebrows were recorded from a total of 270 signed sentences. A mixed model was performed using SAS and the eyebrow levels were also charted on a timed series to see patterns. In *neutral*, brows for the entire sentence raise or lower, with maximums elevating 21% for yes/no questions and lowering 30% for wh-questions, but emotional questions show variable percent changes. Consistent distinctions across emotional states exist between sentence types, however, that depend on timing and spread of raised and lowered eyebrows.

The data expand on the layering of upper face nonmanuals to support a theory for even more complexity on the face, where both sides of the debate have merit, as eyebrows simultaneously represent syntax, grammatical

intonation, and other prosodic intonation that correlates to spoken languages. The work suggests that it is not brow furrowing that should be the focus of investigation into consistent patterns, but brow lowering. The data show a first glimpse at eyebrow height attached to signs in ASL, and new information on how raised and lowered eyebrows spread across constituents in ASL questions, with recommendations for curricula improvements. The results also show that ASL nonmanuals should not be compared to pitch in English but instead better correlate to the layering through pitch in tone languages.

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NOTATION CONVENTIONS

BALL	Word in capital letters shows an English gloss representation for ASL signs (closest translation).
GO-OUT	A hyphen separates words when the multi-word gloss represents only one sign in ASL.
IX-2p	This symbol (index) refers to the second person pronoun, and –3p is for the third person pronoun.
CL:1 “walk”	A classifier construction with the one hand shape. The word in quotes provides the best English translation of what the classifier represents.
_____t ALICIA	A line over a gloss represents the spread of occurrence of a nonmanual feature, and the letters on the line represent the nonmanual feature of discussion. In this example, ‘t’ (topic) refers to the set of non-manuals that create a topic, such as raised eyebrows.
Wh-Q	This represents the nonmanual set for wh-questions (content questions).
y/n	This represents the nonmanual set for yes/no (polar) questions.
d	The letter ‘d’ represents the

nd	dominant hand, and ‘nd’ represents the non-dominant hand. When not otherwise noted, signs are produced by the dominant hand (except for the two-handed signs).
#WHEN	This represents a fingerspelled sign, where the English spelling has become lexicalized as an ASL sign, usually with changes to movement and some hand shapes.
*	Indicates an ungrammatical construction.

CHAPTER 1

INTRODUCTION

1.1 Introduction

For over four decades of research, ASL literature has demonstrated the involvement of the eyebrows, eyes, nose, mouth, and other nonmanual (non-sign) linguistic channels. The nature of this language on the face, however, is greatly under-researched compared to the general body of literature. This study investigates raised and lowered eyebrows in American Sign Language (ASL) by examining questions in neutral and four distinct emotional states.

Among research on the upper face, interpretations of eyebrow movement contribute to one of the strongest debates in current signed language literature. In this research I argue that the differences are not as great as they appear, but that the limits of past technology have prevented a more unified perspective on nonmanuals in signed languages. Without the tools for quantitative measurements, prior research has limited eyebrow analysis to recording only impressions of eyebrow height or muscle movement, both qualitative methods. I contend that many of the differences over similar data can be resolved with a closer look through more precise measurements, and with affordable and accessible technological advancements, it is now

possible to record objective measures of eyebrow movements. This research presents such a method.

The prior impressionistic studies provide valuable insight into nonmanuals, but appear to take researchers onto two different paths, with conclusions of either syntax or intonation. Rather than divergent paths, however, I contend that the studies instead represent two different lanes on the same larger road. The data suggest there is validity to both theoretical extremes discussed in the literature, but that they are not mutually exclusive, instead co-occurring across questions. This research refines the theoretical focus by showing the existence of complex layering within a single nonmanual channel, the eyebrows.

Nonmanuals in ASL, particularly raised and lowered eyebrows, are integral to grammatical questions, and misunderstandings of ASL questions result in life-threatening consequences. Current ASL education teaches little to no information on the face. ASL curricula have not been given further breath or depth on the critical subject of nonmanuals beyond details extracted from the first years of ASL research. A broader theoretical understanding will lead to more specific knowledge of the role of eyebrows in ASL questions, and can increase the effectiveness of future curricula.

The remainder of this chapter discusses the motivation and background for the research, the significance of the study, the research questions, and the scope and limitations of the work. Section 1.2, “Background for the Research:

Nonmanuals in ASL", provides a brief history of nonmanual research and an overview of nonmanual functions across levels of discourse, situating eyebrows within the domain of upper face nonmanuals. Section 1.3, "Purpose of the Research" outlines the goals of this work.

Section 1.4, "Motivation for the Study" provides information on the pedagogical portion of the work, including an overview of ASL in Deaf education and the need for improved ASL curricula regarding the linguistic uses of the face. Section 1.5, "Contributions and Significance of the Study" summarizes the theoretical implications for this research, with a brief reference to curricula improvements. 1.6 "Research Questions and Hypotheses" describes the research questions under consideration and then the hypotheses that are tested in the work.

Section 1.7 "Definition of Terms" makes a distinction between eyebrow furrowing and eyebrow lowering, and section 1.8 "Scope and Limitations" reviews that this research makes objective measurements of eyebrow height only, although other nonmanual impressions are occasionally mentioned. Finally, section 1.9, "Overview of Chapters", lists the key focus of every chapter.

1.2 Background for the Research: Nonmanuals in ASL

Research into the linguistics of American Sign Language began almost 50 years ago when Stokoe (1960) and then Stokoe, Casterline, and Croneberg

(1965) first analyzed sign structure and argued that ASL was a natural language.

1.2.1 History of Nonmanual Research

The majority of ASL linguistic research over these past four decades focuses on the manual (hand) signs. There is another major part of ASL, however, that is greatly under-researched: the linguistic uses of the face, head, and upper body, known as nonmanual signals. The face and body are generally considered to make universal expressions of emotion (Ekman & Friesen 1975, 1978), but in addition, known signed languages use some of these same facial configurations as part of the language itself.

The importance of these nonmanuals was first recorded in Stokoe et al. 1965. Without examining the nature of the facial expressions themselves, the yes/no questions were observed to contain a required facial expression. In Stokoe et al. 1965, hearing signers who omitted these facial signals in yes/no questions did not receive a response from Deaf signers because their utterances were not recognized as yes/no questions. Details on the nature of these nonmanuals were first examined after Baker (1976a, 1978) noticed linguistic facial expressions in American Sign Language while viewing a split screen videotape. Even though the signer's hands were obstructed from view, she understood much of the conversation from the face alone (Baker and Padden 1978, Baker-Shenk 1983). Intrigued, she and a few others began investigating the significance of these facial markers in ASL.

Coulter (1979) was also among the first to separate out different nonmanual pieces and consider their individual functions, and Liddell (1978, 1980) examined yes/no questions, relative clauses, topics, negation, and other constituents for their characteristic facial and body movements and scope of occurrence. Today nonmanuals remain comparatively under-represented in the literature, but several researchers continue to provide insight into the nature and linguistic significance of nonmanuals in ASL. Liddell (1986, 2003), Reilly, McIntire, and Bellugi (1990a), Wilbur (1994a, 1994b, 1995a, 1995b, 2000, 2003), Aarons (1994), Bahan (1996), Wilbur and Patschke (1999), Nespor and Sandler (1999), Neidle et al. (2000), Grossman (2001) and Grossman and Kegl (2006) among others continue to investigate components of these nonmanual signals.

1.2.2 Linguistic Nonmanuals in ASL: Upper and Lower Face Domains

Nonmanuals of the face can be separated into the lower face and the upper face. The lower face is considered in ASL research to have a smaller domain, limited to mostly single signs, while the upper face is considered to have a larger domain (e.g Coerts 1992) spreading across constituents.

1.2.2.1 Lower Face ASL Nonmanuals

Lower face nonmanuals, such as the lips, tongue, and cheek muscles, can provide lexical or morphological information when attached to lexical items (Liddell 1980, 2003). At the lexical level, a sign without a required nonmanual is

not well-formed, and in some cases creates an altogether different sign, such as that observed in figure 1.1.

(a) (b)

Figure 1.1 (a) NOT-YET with tongue protrusion, and (b) LATE without the tongue movement. Image drawings are from consultants in this research.

For instances such as figure 1.1, the nonmanual distinguishes minimal pairs, such as the example of (a) NOT-YET and (b) LATE. In NOT-YET, the tongue protrudes during the entire sign, while the same sign and movement without the tongue protrusion produces the sign for LATE.

At the morphological level, Liddell (1978, 1980) identified ways the face provides adverbial and adjectival information in ASL. One example is when ASL nonmanuals signal adverbial information through the marker for CARELESS, seen in figure 1.2.

____th
DRIVE 'Driving carelessly'

Figure 1.2 Adverbial nonmanual in "driving carelessly"

In figure 1.2, the nonmanual marker called 'th', where the tongue makes a "th" shape, overlaps onto another sign and is the only way the adverbial content is transmitted. Without this nonmanual marker, the sign loses its "careless" meaning (Liddell 1978, 1980).

Other adverbial nonmanuals can communicate the distance of time from the focus moment. For example, the sign RECENT can express a proximal 'just recently' or a more distal 'not too long ago' sense, all dependent on the amount of facial marker contrast displayed by the signer (Siple 1978).

(a) (b)

_____cs _____cs
Figure 1.3 (a) RECENT “not too long ago” and (b) RECENT “just recently”

In Figure 1.3 the sign RECENT is overlaid with the mouth movement transcribed as ‘cs’ that includes closed teeth and open mouth, seen here with different degrees of intensity or tension. Figure 1.3a shows the least degree of intensity and a greater distance of time, and Figure 1.3b shows a greater intensity but that less time has passed, indicated through more mouth tension, a closer lean to the shoulder, and squinted eyes.

1.2.2.2 Upper Face ASL Nonmanuals

The upper face such as the eyes and eyebrows also contribute to linguistic information for ASL. One example is a directed eye gaze to signal referents such as subject or object (Liddell 1980). Nonmanuals can also extend

across phrases. Nonmanual markers occur over topicalized elements, yes/no questions, WH questions, conditionals, negative phrases, and relative clauses (Coulter 1979; Liddell 1980; Baker-Shenk 1983; Coerts 1992 for NSL, Aarons et al. 1995; Neidle et al.2000). Also, an upper body twist to the left or right signals a role shift in narration (Liddell 1980). In addition, voluntary eye blinks are seen in ASL for purposes such as signaling ends of phrases (e.g. Wilbur 1994b).

1.2.2.2.1 ASL Eyebrows in Perspective

Figure 1.4 shows how eyebrows fit into the greater linguistic framework of ASL. ASL is comprised of both hand signs and nonmanuals, as seen in figure 1.4.

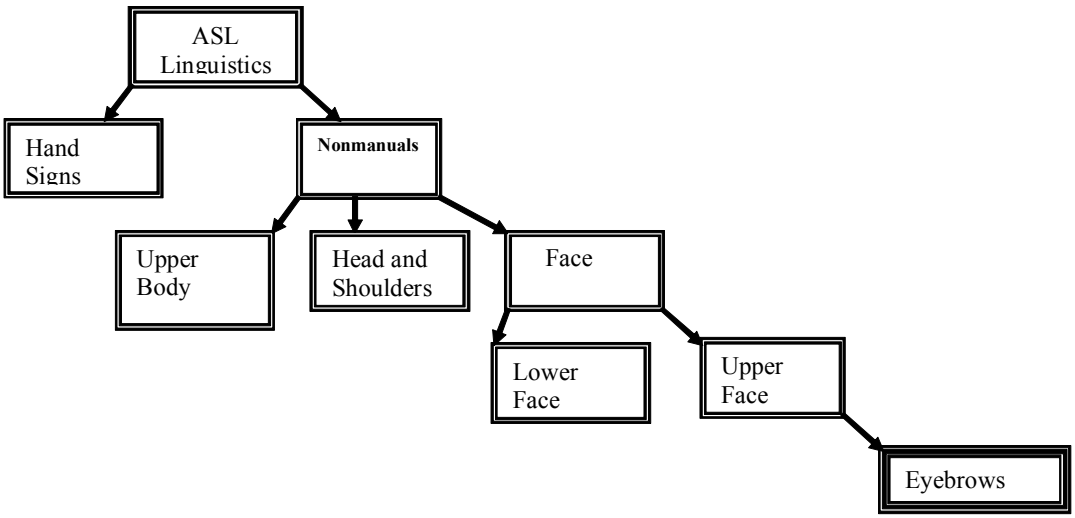


Figure 1.4 Hierarchy of nonmanuals in ASL: Eyebrow organization

Nonmanuals in ASL can be further divided between the upper body, shoulders and head, and face. The face is then separated into two parts, the lower face, and the upper face, and the eyebrows are a subset of the upper

face nonmanual group. My work focuses on a subset of eyebrows in ASL: their role in questions.

This section provided only a brief overview of our knowledge of ASL nonmanuals. While important nonmanual research continues in ASL, there is much we still do not know about both individual and combined nonmanuals. The body of literature available on nonmanuals and nonmanual behavior is growing, but their role in signed languages is a subject of much debate. Researchers generally agree with Liddell (1978, 1980) about the adverbial and adjectival elements discussed in this section, and about other linguistic signals of the lower face. It is the domain of the upper face that generates most of the controversy and heated debate in current ASL literature. The upper face and specifically the eyebrows is the focus of this research.

1.3 Purpose of the Research

This work has three key purposes. First, to investigate whether- and how- eyebrow height creates distinctions between yes/no (polar) and wh- (content) questions. Second, to assess the effect of adding emotion to the linguistic eyebrow height, which is also used to distinguish question types. Third, to investigate the range and use of eyebrow height by means of quantitative measurements in yes/no questions, wh-questions, and statements.

1.4 Motivation for the Study

American Sign Language curricula often avoid a discussion of nonmanuals, or include only superficial and widely accepted generalities. For textbooks that do include some nonmanuals, such as the most widely used text Signing Naturally (Lentz et al. 1988), students are taught only that eyebrows are "raised" for topics and yes/no questions and "lowered" for wh-questions, and that without the eyebrow movement in a yes/no question, for example, the statement does not become a question (e.g. Signing Naturally, Lentz et al.1988). This limited information, however, does not provide enough clues to the role of the face in ASL questions, leaving both ASL students and interpreters to struggle with recognizing the different ASL sentence types.

As a professional interpreter, I observed many situations in which colleagues struggled with repeated question-and-answer exchanges to resolve the frequent and critical misunderstandings that occur, for example, in medical and business settings. As an instructor in an interpreting program, I struggled to improve student recognition of ASL questions. I wondered, since much of everyday conversation can be emotional, how emotion impacts recognition of question types, and how the linguistic use of the face could be quantified and taught to ASL learners for more accurate identification of statements and questions. I sought out to investigate reasons for these frequent misunderstandings.

There is evidence that adult second language learners have difficulty acquiring these and other linguistic facial expressions, especially when the signer expresses emotion at the same time (McIntire and Reilly, 1988). In contrast, no research suggests that Deaf signers who acquire ASL as a native language have much if any difficulty distinguishing question subtypes from each other or from statements, despite relying on the nonmanual eyebrow movement. I began this investigation, then, to explore what linguistic patterns could be detected through eyebrow analysis, and potentially misunderstood by ASL learners.

1.4.1 ASL in Deaf Education

In the United States, 90% of deaf children are born to hearing parents, usually in a non-signing environment. These children are often kept from ASL by their parents, and when they enter school, the classroom frequently uses only an English signing system, if there is any signing in the school at all (Padden and Humphries 2005).

This frequent suppression of ASL brings severe consequences for these students trying to receive an education, often struggling without a native language from which to begin. Schools are failing these children, since deaf and hard of hearing students graduating high school, despite normal to high intelligence levels, demonstrate only a fourth grade reading level on average (Gallaudet Research Institute 1996). To improve Deaf education, ASL must be incorporated into classrooms for deaf children beginning at an early age.

Research has increased awareness of ASL and its importance to deaf children, and small programs that encourage a bilingual-bicultural method are growing around the United States (Wilcox 1989a, 1989b). Such programs are successful and produce better results by encouraging Deaf students to learn English as a Second Language and other subjects through their own native language, ASL (Wilcox 1989a, 1989b).

Unfortunately, the growing demand in ASL courses for children and adults is often met by hearing signers who are still beginning to learn the language. Deaf individuals are often not employed as instructors, even though most agree ASL is best taught by native signers, just as spoken languages are best taught by native speakers. Fluency requirements are increasing for ASL instructors, but certification for Deaf Education generally requires only one to two semesters of “signing”. Deaf ASL learners, often kept from signs in early childhood, deserve more competent instruction in their own language. All educators and students would benefit from more fluent and preferably native instructors, a more informed curricula that outlines greater detail of nonmanuals than what exists in available texts, and specific instructions on how to more effectively train interpreting students to recognize these linguistic signals on the face.

1.4.2 A Need for Better Instruction on ASL Questions in Interpreting Programs

There are documented videotapes of incorrect sign language interpretation (Fiorio 2000). Unqualified interpreters can miss subtle changes

on the face, and one mistake can lead to tragedy. “A deaf person could end up in jail or a patient could be misdiagnosed, just because an interpreter makes one error. It happens all the time.” (Coppelli 2000: 1).

The findings in this dissertation will show how changes in eyebrow height across emotions can contribute to this misunderstanding. The discussion will highlight the need for curricular expansion and contribute specific recommendations for improving the instruction of ASL questions and nonmanuals as a whole. Specifically, the discussion will suggest new training points that should be incorporated into every ASL classroom. Interpreting students often take courses to learn the basic signs and then attempt to gain fluency through exposure to natural signed conversations. While this socialization is crucial for a true competence in the language, it can be aided by further depth of instruction in the classroom. If research could provide greater detail to add to curricula, interpreters could more actively improve their skills.

The next section provides the foundation to examine eyebrows, through an overview of facial grammar in American Sign Language.

1.5 Contribution and Significance of the Study

Detailed eyebrow analysis is time-intensive and often expensive, but has allowed researchers to posit theories of what purpose eyebrows serve in ASL questions. Most researchers are currently polarized over whether eyebrows (and other upper face nonmanuals) are a realization of syntax or instead a

representation of a prosody and intonation comparable to spoken English. This debate is examined in detail in Chapter 2. A third proposal in the literature, however, suggests a layering occurs (Wilbur 2000, 2003) where raised and furrowed eyebrows represent syntax (Wilbur and Patschke 1999) while simultaneously other upper face nonmanuals can be facial intonation or prosody.

This work contributes to the debate by arguing in favor of Wilbur's analysis as it relates to eyebrow height, and then presenting an extension of the layering notion by arguing that eyebrows can not only can serve a different purpose than other co-occurring nonmanuals, but that eyebrows also can serve such multiple purposes simultaneously. The data and analysis support this theory as they demonstrate that eyebrow height in ASL questions can at once represent the syntax, grammatical intonation, and affective prosody of ASL.

The conclusions are intended to broaden our understanding of subtle linguistic eyebrow movements, to present new findings that support an expanded theoretical perspective on eyebrows and signed language nonmanuals in general, to demonstrate objective measures through a novel approach, and to suggest pedagogical tools for curricula improvement, with hopes to lessen life-threatening consequences of interpreter misunderstandings of ASL questions.

1.6 Research Questions and Hypotheses

This study investigates three research questions. First, does eyebrow height play a role in misunderstandings of ASL questions? Second, to what degree does eyebrow height distinguish between question types in ASL? Third, how does the addition of emotion alter any linguistic eyebrow behavior in ASL questions?

The hypotheses for the study are as follows:

Hypothesis 0 - (null hypothesis)	There is no change in eyebrow height across neutral questions or statements, nor across questions or statements in happy, sad, angry, and surprise states.
Hypothesis 1-	There are statistically significant distinctions from maximum and minimum eyebrow heights between question types, and also between questions and statements.
Hypothesis 2-	Despite the addition of emotion, these significant distinctions, if any, remain for all sentence types.
Hypothesis 3-	The question type determines the eyebrow height range, and emotions rank sentences only within this set range: emotions are expressed within the highest range for yes/no questions, the middle range for statements, and lowest range for wh-questions.

1.7 Definition of Terms

Eyebrow *height* is the term I use to describe what is examined in this work. This term refers to the measurements of raised and lowered eyebrows

on a face, as described in detail in Chapter 3. It does not include the coming together of the eyebrows, commonly called brow *furrowing*. Brow furrowing was not chosen for analysis because, as the data will show, it does not occur over every wh-question, unlike brow lowering. I do mention the general pattern of brow furrowing over certain emotions, but it is important to recognize that there is a difference between brow furrowing and brow lowering, often confused with each other in the literature. As far as I am aware no study contrasts the occurrence of brow furrowing with brow lowering in ASL wh-questions until now, and the focus of this work is on brow lowering.

1.8 Scope and Limitations

This research is limited to measures of raised and lowered eyebrows in ASL. This is the first study to examine emotion added to questions in ASL, and while it shows more detail than prior research by using a 12-13 point range for eyebrow height across signers, many other nonmanuals co-occur during the production of ASL questions. The methodology and measuring instrument in this work is very time-intensive, so only one nonmanual channel was examined for this investigation. If time were not an obstacle, however, the tool could be used by any researcher interested in hand coding for objective data, and is affordable at $30. It would be beneficial in future studies to obtain quantitative measurements for the interaction of all nonmanuals for every video frame of signed data.

After completing the data analysis, I discovered subtle changes over lexical signs, such as the fingerspelled loan sign #WHEN[1]. I have included some examples of this in the findings and discussion, but the scope of this study does not allow for an extensive examination of these phenomena.

Every three frames (0.1 sec., as video capture is at 30 frames/sec.) were measured unless a height change was observed qualitatively between these three frames, and then every frame was measured until the height change ceased. Contour charts all display the data points at each three frame interval (0.1 second) for consistent intervals across consultants and sentences. This is sufficient to capture detailed eyebrow height changes in questions, but the significance of these extra lexical height changes between three frames is discussed in Chapter 5, with examples of their occurrence.

Finally, there were six signing consultants for this study, a relatively small number for some studies, but for ASL research it a comparatively large consultant population. Demographics limited this study to signers in Texas, although three of the six consultants graduated from Gallaudet in Washington, D.C. ASL has regional signs that vary across the United States in the same way as the English language shows regional varieties, and while it is possible nonmanuals could vary by region, there is no evidence to suggest such variety would impact eyebrow height as examined in this research.

[1] Fingerspelled signs in ASL generally originate from an English word that is spelled in the manual alphabet but becomes lexicalized as a sign with some changes, often in movement and handshapes.

1.9 Organization of Chapters

The purpose of this study is to investigate eyebrow height in ASL questions in four emotional states and neutral. Chapter 2 “Eyebrows in ASL” reviews the literature on raised and lowered eyebrows and the theoretical debate on their interpretation, primarily in relation to yes/no and wh-questions. On the debate, both the syntactic and intonation interpretations of the upper face and specifically eyebrows are reviewed, and then a summary is included of a third perspective from Wilbur (2000, 2003) where eyebrows are realizations of syntax while the other upper face nonmanuals represent functions such as the prosody and intonation of English. Co-occurrences of different nonmanual markers in prior research are examined, including results from different methodological approaches to eyebrows and questions. This chapter concludes with what remains to be investigated in the literature on eyebrows and the need for objective measurements in data, and finally, this work introduces an expanded theory that one nonmanual alone can simultaneously serve multiple functions, as seen in the data for eyebrows.

In Chapter 3, “Methodology”, the procedures and analysis are described, with details on the selection of the digital instrument and facial landmarks for measurements of eyebrow height.

In Chapter 4, “Results”, the statistical data and contour charts are presented in two parts. First, the maximum and minimum eyebrow height for each sentence is examined through a mixed model. The findings show that

ASL does indeed use eyebrow height to distinguish between question types in a statistically significant manner, where on average neutral yes/no questions raise eyebrows 21% higher than statements, and lower eyebrow height 30% for wh-questions. Emotions are shown to vary these percentages significantly. The overall eyebrow levels generated by each emotional state are examined, and the results show how eyebrow height organizes these emotional ranges, where sad and angry are categorically distinct from neutral, happy, and surprise for all but two pair combinations.

The second half of the chapter shows the dynamic nature of eyebrow height across sentences when charted in a contour across time. These contours demonstrate that eyebrows raise and lower to create distinctions between sentence types through lexical attachment and two additional types of spread, and that these distinctions remain across emotional states in the data.

In Chapter 5, “Conclusions and Implications”, the data is situated into the theoretical context discussed in Chapter 2. I contend that the layering of upper face nonmanual functions proposed by Wilbur is an insightful observation and I then expand this to argue for a further layering of ASL nonmanuals, where not only each channel can function separately, but also within one channel such as eyebrows there can be multiple functions. I analogize the findings to pitch in some tone languages, where the lexical tone can co-occur with grammatical intonation, and also prosodic emotional intonation can co-occur without removing these grammatical distinctions. For questions, I argue that in ASL,

eyebrow height can represent syntax, grammatical intonation, and emotional prosody with one raising or lowering. Finally, specific improvements to curricula are recommended in order to better support acquisition of ASL for Deaf learners and also to improve curricula for interpreting programs and lessen misunderstanding of ASL questions.

CHAPTER 2

EYEBROWS IN AMERICAN SIGN LANGUAGE

2.1 Introduction

This chapter summarizes research on raised and lowered eyebrows in signed language literature with a focus on ASL. Section 2.2, “Eyebrows in ASL: Raising or Lowering across Constituents” examines patterns of eyebrow movement in ASL.

Section 2.3, “The Debate: Does Eyebrow Height Represent Syntax or Intonation?”, introduces the theoretical debate on nonmanual interpretation from an examination of eyebrows in ASL questions. Eyebrow analysis is established as a central point in the debate. At issue is whether nonmanuals are syntactic in nature or whether they can be compared to the intonation of English. This section summarizes ASL research on raised and lowered eyebrows in questions from first a syntactic perspective and then an intonational perspective. It also considers a third proposal from ASL literature in which eyebrows can be syntactic while the other upper face nonmanuals can simultaneously function as intonation and prosody.

Section 2.4, “Co-Occurring Nonmanuals in American Sign Language”, discusses the co-occurrence of nonmanuals in ASL. First, this section reviews

literature on co-occurring linguistic nonmanual markers, and next the co-occurrence of linguistic nonmanuals with the paralinguistic effect of actions similar to 'whispering' in ASL. Finally, this section reviews the combination of and difference between affective and linguistic nonmanuals, including research on the left hemisphere activation for linguistic nonmanuals and right hemisphere activation for emotional facial expressions. Also discussed are the differences in production between emotion and grammar on the face, including onset and offset, spread of the nonmanual, and the physical space between the independent channels.

Section 2.5, "Methodologies for Analyzing Linguistic and Affective Eyebrows in Questions" investigates work on both static and dynamic features of eyebrows in ASL. First, this section discusses of SignStream ™ transcription software, and then data on eyebrow movements using Facial Action Coding Software, coupled with a theory in the literature on the overlap of affect and grammar in questions of a different signed language. This section also presents research on the importance of displaying brow movement across entire sentences in a contour chart form. These foundational studies in this section are the basis for this dissertation, which presents the first experimental measurements of eyebrow height in ASL questions.

In section 2.6, "An Extended Proposal for Nonmanuals: Eyebrows as Both Intonation and Syntax", it is argued that much of the research presenting the two opposing perspectives for eyebrow interpretation are not mutually

exclusive, but instead are acting in tandem, as framed in this new approach. A new proposal on nonmanual interpretation is then presented which further extends the third proposal for nonmanuals discussed in section 2.3. Not only can nonmanuals concurrently function as independent channels, but in addition, one single change in eyebrow height can function simultaneously as syntax, grammatical intonation, and affective intonation in ASL questions. The data from this study will show evidence to support this new account. As technology has limited brow analysis to impressionistic approaches, past works have resulted in only qualitative descriptions until now. I argue that a new depth of detail will resolve many of the theoretical differences.

2.2 Eyebrows in ASL: Raising or Lowering across Constituents

Eyebrows serve linguistic functions across several different types of constituents in ASL. For example, eyebrows distinguish conditionals (Liddell 1986, McIntire, Reilly, & Bellugi 1987, Reilly, McIntire & Bellugi 1990). Eyebrows over the conditional are raised and then the conditional is separated as a constituent by a sudden change or drop in the nonmanual marker, where the eyebrows lower to neutral, the facial muscles relax (release of nasolabial contraction), and the head nods (Siple 1978).

As one of the sets for this research contains a sentence-initial topic, it is important also to examine the role of eyebrows in ASL topics. Aarons 1994 examines three types of nonmanual markings that occur with either moved or

base-generated topics in ASL. All three markings include raised eyebrows, but differ in head tilt or nod and eye movements.

The first, tm1 (topic marking group 1), is only used with a moved topic, part of an argument, and can be contrastive focus with a limited set of new information, as shown in 1(Aarons 1994; 158).

(1) FOUR WOMEN LIVE IN HOUSE IX. $\overset{\text{tm1}}{\text{MARY}_i}$, JOHN LOVE t_i
'Four women live in that house over there. *Mary*, John loves.'

Tm1 only occurs over the sign MARY, the topicalized portion, and includes raised eyebrows, head slightly tilted back and to the side, wide eyes, and head moving down and forward.

Tm2 occurs only with base-generated topics that can be co-referential with an argument, changing the discourse topic while introducing new information, seen in 2 (Aarons 1994; 160).

(2) $\overset{\text{tm2}}{\text{VEGETABLE}}$, JOHN LIKE CORN
'As for vegetables, John likes corn.'

Tm2 in 2 is only produced over the sign VEGETABLE and includes raised eyebrows, the head moving farther back and to the side, eyes very wide, and the head moving down and forward.

Tm3 also appears only with base-generated topics that are always co-referential with an argument, but can only be used with known referents, seen in 3 (Aarons 1994; 164).

(3)
tm3
MARY$_i$, JOHN LOVE IX-3rd$_i$
'(You know) Mary, John loves her.'

These tm3 topic markings are considered to introduce a new major discourse topic. Tm3 only occurs over the sign MARY in 3 and includes raised eyebrows, the head jerking up and down, forward, the upper lip raised, mouth opened, a fixed gaze, and a series of rapid slight head nods that precede a pause and the rest of the sentence.

2.2.1 ASL Questions: Eyebrows Raise for Yes/No Questions, Lower for Wh-Questions

ASL research shows eyebrows to position in three linguistic manners during ASL questions: furrowed (bf) or lowered, neutral brows, and raised (br). As discussed in Chapter 1, the terms furrowed and lowered are not interchangeable, but both terms are often described for the same question type. Their differences will be further discussed in the results and discussion chapters, but for the purpose of this dissertation the focus is on brow lowering.

Neutral eyebrows occur with assertions, lowered eyebrows occur with wh-(content) questions, and yes/no (polar) questions include raised eyebrows (Baker-Shenk 1983, 1986, Petronio & Lillo-Martin 1997, Neidle et al. 1997).

2.2.2 The Particle of Indefiniteness in both Wh- and Yes/no ASL Questions

Eyebrows have also been observed raising and lowering over the particle of indefiniteness (Conlin et al. 2003). This will be important to understand for the investigation because this particle appears several times in the data.

This particle appears as and is often mistaken for the sign WHAT, with the palms up and all five fingers extended out. The sign WHAT moves side to side, while this particle generally produces a single outward movement (Conlin et al. 2003). This particle is often one handed, and frequently occurs in ASL questions, especially after the final wh-word in a wh-question, but can also occur in yes/no questions. Conlin et al. 2003 noticed brow furrowing with this particle in wh-questions, and also brow raising in yes/no questions. They consider the particle to express a degree of uncertainty or indefiniteness and to widen the domain of focus in discourse, but the exact nature of the eyebrow movement in this particle has not yet been explored.

2.3 The Debate: Does Eyebrow Height Represent Syntax or Intonation?

Researchers are currently debating the interpretation of upper face nonmanuals in American Sign Language and signed languages in general.

Many of the foundational studies on ASL upper face nonmanuals consider them representations of syntax, but there are increasingly more works suggesting that instead, upper face nonmanuals should be compared to intonation in English. This section summarizes both sides of the debate through the literature on eyebrows in ASL, and then examines another claim that suggests eyebrows function as syntax while other upper face nonmanual channels can function separately to convey information about semantics, prosody, or possibly morphology of the language. The understanding of these nonmanuals is crucial because, as this section shows, their interpretation informs the analysis of ASL structure presented in past work (Aarons et al. 1992, Aarons 1994).

2.3.1 Eyebrows in ASL Questions: A Syntactic Perspective

The traditional analysis of nonmanuals including eyebrows in ASL is that they reflect the syntax and serve as facial morphemes, particles, or clitics (Stokoe 1978; Baker and Padden 1978; Liddell 1980; Baker-Shenk 1983; Kegl 1986; Neidle et al. 2000). Perhaps the most extensive examination of eyebrows in ASL can be found in Wilbur 1994b, 1995, 1999, Wilbur and Patschke 1999, and Wilbur 2000, 2003. Wilbur and Patschke 1999 examined eyebrow movement in search of a unified account, and concluded only a syntactic analysis encompasses all occurrences of raised and lowered eyebrows in ASL. While Wilbur considers many upper face ASL nonmanuals to be intonational or prosodic (e.g. eyeblinks, Wilbur 1994b), for one treatment of all eyebrow movement she put aside the common assumption that raised

eyebrows could be explained based on information packaging (e.g. Coulter 1978), due to what she calls contradictory evidence of brow raising in the domain of pragmatic non-assertions. For example, she notes that the three types of nonmanual marking for two different topics in ASL (Aarons 1994) clearly show ASL brows raised over both non-asserted and new information, therefore countering the assumption that br serves only one of these functions.

Wilbur and Patschke 1999 conclude that all eyebrow raising and lowering can be explained in one syntactic account where brows are raised only when marking structures in A bar (ie. non-argument) and not A (argument position). In this explanation for eyebrow position, all br (brow raised) marked clauses are associated with [-wh]-operators (Wilbur 1995a, 1996), and br only spans across the checking domain of the operator. For an example of this raising and lowering distinction, in 6 (Boster 1996) we see br over the topic and bf (furrowed eyebrows) over the wh-question.

(6)

br _____ bf

BOOK, YOU WANT WH-MANY

In 6, when a noun is fronted and therefore topicalized (Boster 1996), it receives br-marking, but the remaining wh-question clause receives bf-marking (Lillo-Martin and Fischer 1992). Notice that the topic br over BOOK only extends over the topic, and the bf eyebrow lowering begins after this topic.

From a general discussion on brow raising and lowering, we can now move to a focus on question types in ASL literature. In ASL, these raised and lowered eyebrows are crucial for differentiating interrogatives from declaratives. Both wh- and yes/no questions have obligatory eyebrow movements as a part of the set of nonmanuals for the question type (e.g. Baker-Shenk 1983).

2.3.1.1 Yes/No Questions: Raised Eyebrows as Syntax

In ASL, the only way to signal a yes/no question is through nonmanual markers. The yes/no question nonmanuals include raised eyebrows and a slight head tilt forward (Baker-Shenk 1983).

2.3.1.1.1 The Domain of Raised Eyebrows in Yes/No Questions

The consensus in ASL literature is that these obligatory raised eyebrows in yes/no questions are not associated with any particular manual sign (e.g Emmorey 2002, Aarons 1994). For Aarons (1994) and others, yes/no questions are considered to show the obligatory nonmanual marking over the c-command domain of the Comp, and it is considered to spread obligatorily over the entire IP because it is not associated with any lexical material in Comp.

While the nonmanual is the obligatory signal for a yes/no question, there is a question marker in ASL that can be optionally added to the sentence, and sometimes occurs for pragmatic effect. Aarons 1994 and others note the nonmanuals remain unchanged with or without this question marker. Neidle et al 2000 states the nonmanual information could occur over only the sentence-final question marker, but if this question marker is at the beginning, the

intensity (or degree of raising) will remain the same through the entire sentence. They consider this difference in intensity and distribution to support a syntactic analysis and to be contrary to the interpretation of yes/no nonmanual markings as intonation.

For a yes/no question that contains a sentence-initial topic, Aarons 1994 and others consider the yes/no nonmanual marking to occur only after the topic as seen in 4, and to be ungrammatical if spread over the entire topic-comment structure, as seen in 5 (examples 4 and 5, Aarons 1994; 76).

(4)

$\overline{\text{JOHN}_i}^{t}$, $\overline{\text{IX-3rd}_i \text{ LIKE CHOCOLATE}}^{y/n}$

'As for John, does he like chocolate?'

(5)

* $\overline{\text{JOHN}}^{t}$, IX-3rd LIKE CHOCOLATE $\overline{\qquad\qquad\qquad\qquad}^{y/n}$

Example 4 shows a topic over JOHN followed by a yes/no question over the remaining portion of the sentence. The topic marking is considered dropped after JOHN. Note that both topics and yes/no questions contain raised eyebrows. Example 5 shows an ungrammatical sentence, where the yes/no nonmanual feature set, including raised eyebrows, spreads over the topic portion.

2.3.1.2 Wh-questions: Lowered Eyebrows as Syntax

Wh-questions receive the majority of syntactic examination on ASL questions. The wh-question nonmanual marking is said to include lowered eyebrows, squinted eyes, slight head tilt and a headshake (Baker-Shenk 1983). Wh-words in ASL include WHEN, WHERE, WHY, and WHO, among other signs. Descriptive accounts of ASL grammar generally consider wh-question words to occur at the end of a sentence (e.g. Baker and Cokely 1980). Perlmutter 1991 states that wh-words are sentence final in ASL. Coulter 1979 notes wh-words are found at both sentence-initial and sentence-final position, while Kegl and Wilbur 1976 argues that the wh-word can occur *in situ*, at the end of wh-questions, and have a copy at the beginning of wh-questions.

Aarons et al. (1992) argues that the wh-word may move or remain *in situ*, and that the spread of nonmanual marking differs in each case, demonstrating the importance of understanding subtle eyebrow movements. While the consensus in the literature is that the wh-phrase does not need to move, when it does, there is disagreement about the direction of this wh-movement in American Sign Language.

Syntactic research on eyebrow lowering in wh-questions outlines the expected spread of this wh-marking, and researchers generally agree that this spread provides insight into the hierarchical organization of the language (Aarons et al. 1992) and that the wh-spread can help linguists determine the syntactic structure of sentences (e.g. Aarons 1994). The spread, intensity, and

nature of these nonmanuals over the wh-words is the subject of heated debate in current ASL literature.

2.3.1.2.1 Wh Rightward Movement in ASL

There are two main approaches to movement of wh-words in ASL syntax, rightward and leftward movement. Neidle et al 2000 continues the position of rightward movement based on prior work (Neidle, Kegl, Bahan, Aarons, and MacLaughlin 1997; Neidle, McLaughlin, Lee, Bahan, and Kegl 1998) which argues that wh-phrases appear as the rightward specifier of the CP position. For this analysis in sentences with two wh-words, the initial wh-phrase may be a type of topic, and the sentence-final position is the regular landing site for a wh-element. In this rightward analysis, Bahan 1996 and Neidle et al 2000 consider the nonmanual marker to be determined by the syntactic position of the +wh feature. These authors note the greatest intensity of nonmanual markers (e.g. eyebrow lowering) over wh material will be at the right edge of a sentence, and then may optionally spread to the left, seen without spread in 7 and with spread in 8 (examples 7 and 8, Aarons 1994; 98).

(7) JOHN BUY YESTERDAY $\overline{\text{WHAT}}^{\text{wh}}$

(8) $\overline{\text{JOHN BUY WHAT YESTERDAY}}^{\text{wh}}$

'What did John buy yesterday?'

In 7, the wh-question marking of lowered eyebrows occurs only over the sign WHAT, and does not spread leftward across the remaining portion of the sentence, while in 8 spread optionally occurs.

If a wh-word occurs initially, however, or occurs outside of the spec of CP sentence-final position, the spread is obligatory, as in 9 (Aarons 1994; 106).

(9) WHO BUY BOOK^{wh}

(10) * ^{wh}WHO BUY BOOK

'Who bought a book?'

In 9, the wh-question marking spans the entire sentence, creating 10 (Aarons 1994; 106) without spread as ungrammatical. Bahan 1996 and Neidle et al 2000 also state that the intensity of the nonmanual marker decreases with distance from the +wh feature. If these measures of intensity could be charted, then for example, 8 would show the lowered eyebrows less 'intense' or with a lesser degree of lowering over JOHN and with a greater degree of lowering over WHAT in comparison. YESTERDAY would then show the greatest degree of lowering because it is at the right edge, considered the position of greatest intensity to these authors.

In fact, it is this rise in intensity towards sentence-final position that is also one argument for a syntactic analysis of eyebrow movement in ASL questions. Spoken language intonation generally shows pitch and intensity declination over the scope of a constituent (Ohala 1978, Bolinger 1978).

Instead, these studies show impressions of inclination or rising strength for the nonmanual towards the syntactic trigger, in the case of wh-questions the wh-word.

ASL also allows a wh-question to appear with no overt wh-word, signaled only through the nonmanuals as seen in 11 and 12.

(11) ___wh
NAME

"What is your name?"

(12) _____wh
NAME WHAT

"What is your name?"

In 11 and 12 these two grammatical examples show wh-questions with both an overt (in 12) and non-overt wh-word (in 11). In 11, the lowered eyebrows marked "wh" occur over the sign and create a non-overt wh-element.

Eyebrows in questions with a sentence-initial topic are also part of the discussion. For topics overlapping onto wh-questions, Neidle et al. (2000) argue through their analysis that the canonical rightward wh nonmanual marker is distinct from the topic wh-marker that occurs when a wh-word is in initial position, which may then include some combination of wh marking and topic marking (Aarons 1994). They also argue that wh topics, unlike other topics, are not followed by a pause. Aarons demonstrates in 13, 14, and 15 (Aarons 1994; 124) ASL topics in wh-questions.

(13)

t wh
VEGETABLE, WHO PREFER SPINACH

'As for vegetables, who prefers spinach?'

(14)

wh
WHO VEGETABLE PREFER SPINACH WHO

(15)

wh t wh
WHO, VEGETABLE, PREFER SPINACH WHO

'Who as for vegetables prefers spinach?'

Aarons 1994 observes that it is possible for wh-marking to spread over topics but only when a wh-element is also in initial position. Example 13 shows VEGETABLE occupying topic position, and a wh-element occurring in sentence-final position. In this syntactic analysis, the wh-marking cannot spread over the topic. In 14, however, the sentence-initial wh-element, considered a topic in this rightward movement perspective, allows the wh-marking to optionally spread across the entire sentence. Aarons 1994 suggests that this spread obscures the topic marking on the non wh-topic, in the case of 15, VEGETABLE.

This rightward proposal for wh-movement, where the wh-element is in a rightward position and may receive an initial copy as a wh-topic, has been criticized by Lillo-Martin (1990, 1992) and in Petronio and Lillo-Martin 1997, where a leftward movement is alternatively proposed.

2.3.1.2.2 Wh Leftward Movement in ASL

In the leftward analysis, the sentence-final wh position requires a special interpretation as a focus position, and the wh-phrase in sentence-initial position is in Spec, CP. This leftward movement results in a more prosodic interpretation of nonmanual functions, where wh-doubles are also focus doubles with [+focus, +wh] (Petronio 1993). Not only are there published positions for both rightward and leftward analyses[2], but there are also replies to each position, and both sides call into question the data being examined. Some of the data used by Petronio and Lillo-Martin (1997) for their leftward analysis have been criticized and judged ungrammatical by native signers assisting Aarons et al. 1992 and Neidle et al 2000, compounding the disagreement. Conversely, some of the data used by Aarons et al. 1992 and Neidle et al 2000 are disputed as to grammaticality by Sandler and Lillo-Martin 2006.

Sandler and Lillo-Martin 2006 suggests that both a leftward and rightward movement analysis of wh-questions in ASL assumes the distribution is based on syntactic factors, which they argue against in their writings. For example, both Neidle et al 2000 and Sandler and Lillo-Martin 2006 have different explanations for why the raised or lowered eyebrows do not spread across into the sentence-initial topics in ASL questions. While Neidle et al 2000 provides the syntactic analysis described previously, Sandler and Lillo-Martin

[2] See e.g. Lillo-Martin 1990, 1991, 1992, Petronio 1993, Neidle et al. 1997, Petronio and Lillo-Martin 1997, Neidle et al. 1998, Neidle et al. 2000, for both rightward and leftward movement positions and responses to criticisms

(2006) believe instead that the intonational phrasing separates the topic from the latter question constituent, suggesting this is further evidence for an intonational interpretation. The next section examines just such an alternative, in which the contention is that instead of syntax, raised and lowered eyebrows represent intonation.

2.3.2 Eyebrows in ASL: An Intonational Perspective

Are all upper face nonmanuals (including eyebrows) a representation of intonation rather than syntax? In the earliest years of ASL research, Baker 1976 mentions the confusion among researchers on correlation of spoken intonation to any element in signed languages, whether manual or nonmanual. Today, many consider nonmanuals that extend across a series of manual signs as analogous to English intonation.

The upper face nonmanual channels include eye gaze, eye aperture or squint, and eyebrow movements, among others. These nonmanuals are considered to function similar to pitch and as a part of the ASL intonation system in Frishberg 1978, Wilbur 1991, 1994, and Wilbur & Patschke 1998. Wilbur 2000 and Brentari and Crossley 2002 consider this upper face domain to correspond to prosody and intonation across the clause. The lower face nonmanuals are then considered to layer simultaneously with the upper face when produced over the same signs (Wilbur 2003).

To describe these upper nonmanuals as a group, Sandler 1999 introduces the term *superarticulation*. This term represents their contention of

an extra-linguistic or super-segmental nature of nonmanuals in Israeli Sign Language, furthered in Nespor and Sandler 1999. The superarticulation perspective is then extended to signed languages in general. For example, Nespor and Vogel (1986) consider these nonmanuals to create the rhythm and melody of signed languages.

These nonmanuals are compared to English prosody and intonation by several researchers of different signed languages including ISL, ASL, and BSL (e.g. Selkirk 1984; Nespor & Vogel 1986; Reilly et al.1990, Brentari 1998, Atkinson et al. 2004; Wilbur 1991, 1996, 2000; and Veinberg 1993).

Sandler and Lillo-Martin 2006 argues that eyebrows raising or lowering in ASL questions represent intonational tunes, and that a pragmatic force creates the question nonmanual marker, not the syntax. The belief is this occurs similar to the highs and lows of intonation[3] that create different types of illocutionary force and result in different interpretations of a sentence.

Sandler 1999 argues this point with the famous story where a professor wrote on the board WOMAN WITHOUT HER MAN IS NOTHING. The students were told to insert punctuation into the statement. The men wrote “Woman, without her man, is nothing.” while the women wrote “Woman! Without her, man is nothing.” This example of different interpretations illustrates the importance of intonation to languages such as English, and also the importance of what

[3] For more on intonation see e.g. Pierrehumbert and Hirschberg 1990, Ladd 1996, McCarthy and Prince 1993, and Nespor and Vogel 1986. See Hayes and Lahiri 1991 for more on Intonational Phrases.

these authors consider facial intonation in ASL, the upper face nonmanual channels, including eyebrows.

Nespor and Sandler (1999) studying Israeli Sign Language (ISL) observe that all facial expressions are suddenly dropped or changed at the ends of what they consider intonational phrases, further supporting their contention that nonmanuals in signed languages are equivalent to rises and falls of pitch in spoken languages. For ASL a similar drop has been noted for the eyes, where voluntary eye blinks signal the ends of phrases, and are also said to convey semantic prominence (e.g. Baker and Padden 1978, Wilbur 1994, Brentari 1998).

2.3.2.1 Yes/No Questions: Raised Eyebrows as Intonation

When Baker-Shenk (1976) first examined yes/no questions, she observed a strong correspondence of raised eyebrows to yes/no questions and labeled the eyebrow position as raised, but also recorded that 30% percent of sentences did not show these obligatory raised eyebrows. With numerous exceptions to this eyebrow rule noted in ASL literature, many researchers have turned to investigate whether the raised eyebrows are not reflections of syntax at all, but instead reflect intonation. Another nonmanual that co-occurs with eyebrow movement in yes/no questions includes a head tilt, and this also has received a prosodic interpretation in the literature. Wilbur and Patschke 1998 notes that a forward head tilt in yes/no questions suggests inclusion of the addressee, while a backwards head tilt indicates exclusion of the addressee.

As referenced in Meir and Sandler 2004, an Israeli Sign Language example demonstrates this intonational perspective for a yes/no question. In spoken Hebrew, intonation minimally distinguishes both yes/no questions and statements. In ISL, they argue, the facial expression also makes this minimal distinction, and helps interpret the utterance through its spread in the same manner as intonation in spoken languages. The example in 16 (Meir and Sandler 2004) shows the scope of the yes/no marking that contributes to the analysis of these raised eyebrows as intonation.

_____y/n

(16) Index2 LIKE ICE CREAM VANILLA OR CHOCOLATE?

"Do you like vanilla ice cream or chocolate ice cream?"

Sandler and Lillo-Martin (2006) among others suggest it is the illocutionary force with the intent of a real question that motivates the yes/no nonmanual eyebrows in 16 to stay raised over the first portion of the sentence. The second part of the sentence does not receive the marking because it is a statement, offering another option. These authors contend this extends to ASL yes/no question structure as well. They consider this to be evidence that raised eyebrows are a representation of the intonational tune or melody of ASL, and that the nonmanual marker does not follow the confined structural boundaries of syntax, but instead requires a larger unit of analysis and domain, leading to a prosodic interpretation.

In yes/no questions many contend that raised eyebrows impart the notion of presupposition, and given or otherwise not asserted information (e.g. Coulter 1979). As discussed in the previous section on the syntactic position, however, information packing was shown to not account for all brow raises (e.g. Wilbur and Patschke 1999, Wilbur 2000, 2003).

Are the raised eyebrows in yes/no questions a reflection of eyebrows that are raised with the rising intonation in spoken language? Flecha Garcia (2001) researched the intonation of English speakers and found the eyebrows do not rise or lower corresponding to the rises and falls of pitch. There was only a 37% correlation for questioning intonation rises, and eyebrows went up considerably more often to instruct than to query.

Are the raised eyebrows in yes/no questions universal to signed languages? Yes/no questions do involve raised eyebrows in several examined sign languages including British Sign Language (Sutton-Spence and Woll 1999), Sign Language of the Netherlands (Coerts 1992), Danish Sign Language (Engberg-Pedersen 1993), and Israeli Sign Language (Nespor and Sandler 1999). These raised eyebrows were also seen for the signed languages studied in a cross-linguistic analysis of questions in signed language (Zeshan 2004).

Raised eyebrows, however, are not a universal phenomenon in signed language questions. For example, Croatian Sign Language lowers the eyebrows to signal yes/no questions (Kuhn and Wilbur 2006), and Austrian Sign

Language is not considered to use brow position at all, but instead to rely on other nonmanuals for yes/no questions (Hunger, Schalber, and Wilbur 2000; Schalber, Hunger, Sarac, Alibasic, and Wilbur 1999). Also, for raised eyebrows in topics, Zeshan (2004) found that signed languages often require raised eyebrows similar to ASL, but that in Indo-Pakistani Sign Language, it was the absence of this nonmanual that signaled the topic.

2.3.2.2 Wh Questions: Lowered Eyebrows as Intonation

Sandler and Lillo-Martin 2006 claims that the widespread assumption of wh-question nonmanuals as realizations of syntax should be reconsidered and replaced as realizations of intonation. The arguments are made for Israeli Sign Language (ISL) but the theory behind these arguments applies to ASL as well. Meir and Sandler 2004 suggests that facial expressions in ISL questions, for example, are separable from the syntax of the questions. The contention is that for a wh-question in non-interrogative contexts, a different facial expression is used.

One example, referenced in Sandler and Lillo-Martin 2006, is when guests at a party notice one of their friends hurry to the door and exit. The host comments to the friends about the person who left, saying “Why did he leave like that!”. Their contention is that instead of furrowed eyebrows over this wh-word, there is only an expression of amazement, because the intent is not to pose a content question. Another example translated from ISL (Meir and Sandler 2004) is “Why did you just walk out of my store with that shirt without

paying!" Sandler and Lillo-Martin 2006 show a clipped image of a signer with an expression they claim does not contain the furrowed eyebrows expected of a wh-question, but instead displays an emotional expression[4].

On wh-questions, Sandler and Lillo-Martin also suggest that sentences which have the pragmatic force of a wh-question but do not contain a wh-word are further evidence that eyebrows lower because of the illocutionary intent of the sentence, not the syntax. For example, in the sentence in 17 (Sandler and Lillo-Martin 2006):

(17)
_____wh
AGE INDEX2
"How old are you?"

For these authors, this sentence receives the lowered eyebrows driven by the intention of the interlocutor rather than the structure of the language.

Both the syntactic and intonational positions on the linguistics of the upper face nonmanual channels make some convincing arguments, but present apparently conflicting analyses. The following discussion centers on a third alternative for the other upper face nonmanuals, where eyebrows are still

[4] While conducting the data analysis for this dissertation I noticed that while their images appeared emotional and without brow furrowing as they claim, they also appeared to contain a degree of slightly lowered eyebrows. Instead of simply making this claim here based on my impressions, this is addressed as an ancillary comparison through the data, to see whether a degree of lowered eyebrows remains despite the addition of emotion in a similar sentence in ASL.

syntax but then other upper face channels simultaneously carry different functions.

2.3.3 A Third Proposal on Nonmanuals: Eyebrows as Syntax and Other Upper Face Nonmanuals Simultaneously as Intonation

Wilbur 2000 and 2003 presents a theory of nonmanual layering in American Sign Language where each individual nonmanual channel can simultaneously function independent of the other in the language. This view still supports the syntactic account for eyebrow behavior, but expands the upper face nonmanual debate for the other upper face channels. Wilbur explains how different morphological, syntactic, prosodic, and semantic functions can co-occur when distributed to distinct channels.

Wilbur 2000 extends a layered analysis of signed language to nonmanuals in ASL, such that one nonmanual channel can function differently than another nonmanual channel simultaneously. For example, the eyebrows could serve as syntax (e.g. Wilbur and Patschke 1999, Wilbur 2000) and the eye blinks could be intonation (e.g. Baker and Paden 1978, Wilbur 1994), even though both the brow and eye movements occur with the same manual signs. To investigate this third proposal, and to lay a foundation for my new proposal that further extends this idea that nonmanual channels can each function independently, it is important to first examine how researchers approach the co-occurrence of nonmanual channels in ASL.

2.4 Co-Occurring Nonmanuals in American Sign Language

Little is known about the interaction of nonmanuals when they overlap in ASL, but research increasingly highlights the importance of these complex co-occurrences to the language. This section examines theories on how such nonmanuals can combine as separate channels and how they interact with each other. After a brief review of linguistic and paralinguistic nonmanual combinations, the section will review theories on how linguistic nonmanuals co-occur with affect in ASL.

2.4.1 Simultaneous Linguistic Nonmanual Markers

In one of her seminal works on details of nonmanuals, Baker-Shenk (1983) suggested that nonmanual markers co-occur based on constraints which, if examined in detail, would reveal patterns. Some nonmanuals could be optional in certain contexts, for example, but when chosen, could trigger the obligatory appearance of other nonmanuals. She theorized that these combinations could interact under unknown constraints (Baker and Padden 1978).

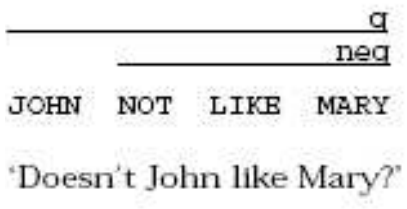
Research is just beginning into these potential interactions and the idea that when two grammatical nonmanual markers co-occur, the production of one or more nonmanuals is altered. One such observation in the literature is that a topic overlapped with a wh-question alters the facial combination (Aarons 1994), seen in 18 (Aarons 1994; 128).

(18) wh/t
WHAT JOHN BUY wh WHAT
'What, what did John buy?'

We see in 18 that the initial wh-word has a "wh/t" that represents a combined "wh" (wh-question, lowered eyebrows) with a "t" (topic, raised eyebrows) nonmanual marking. According to Aarons, eyebrows will retain their slight lowering in this combination, which is then further combined with tightened cheek muscles and the head tilted back, influenced by the topic.

In another example, Bahan (1996) illustrates how a negative yes/no question is produced. Negation includes a side-to-side headshake, lowered eyebrows, and squinted eyes. When a negative marker set and a yes/no question marker set (including raised eyebrows) are combined, the yes/no question eyebrows are still raised but the gap between the brows narrows, the head may shake side-to-side, the upper body and head lean forward slightly, and the upper lip is raised (Liddell 1978, 1980, Wilbur 1979, Baker-Shenk 1983, Aarons et al. 1992). This overlap is indicated below with "neg" showing the scope of the negative marker and "q" showing the scope of the yes/no nonmanual movement seen in 19 (Bahan 1996).

(19)



In 19, the question continues over the entire sentence but the nonmanual set for negation is modified and occurs only under the scope of negation.

2.4.2 Combinations of Linguistic and Paralinguistic/Non-Emotional Nonmanuals

In addition to linguistic nonmanual marker sets combining and influencing each other, paralinguistic effects can generate nonmanual expressions that also combine with linguistic nonmanuals. Research shows that paralinguistic effects can minimize linguistic facial movement, such as what occurs during whisper mode (Bahan 1996). When signers are trying to whisper a conversation, they stand roughly side by side with their backs to people so others in the room cannot see the signs. They sign in a more confined space directly in front of the body, and automatically omit or minimize the otherwise required nonmanual markers. For example, eye gaze to establish referents for agreement marking is omitted during whisper mode. In any other context the omission of this eye gaze would be ungrammatical, but it is considered acceptable in this whispered context (Bahan 1996).

2.4.3 Combinations of Affective and Linguistic Nonmanuals

The rest of this section examines how emotion is added to question eyebrows in ASL, and how both affective and linguistic nonmanuals are expressed in distinct patterns.

2.4.3.1 Lateralized Hemisphere Activation of Emotion and Grammar

Grammatical and affective nonmanuals are separate entities in ASL (e.g. Baker and Padden 1978; Coulter 1978, 1979; Liddell 1978). Research in spoken languages (Segalowitz and Bryden 1983) establishes that both emotional information and linguistic information are controlled by separate hemispheres of the brain. Linguistic centers of the brain are located mostly in the left hemisphere, while the paralinguistic centers that control emotional aspects of communication are found in the right hemisphere (e.g. Corina, et al. 1999).

In addition to spoken language research, imaging the brain hemispheres during signing (e.g. Bellugi et al. 1989) shows that the facial movements for linguistic purposes are also processed differently in the brain than movements for affective purposes. While analyzing native Deaf signers and the area of the brain which were activated during signs, Bellugi et al. 1989 found that during signs such as the example of GOOD (Figure 2.1a) which is nonmanual movement for an entirely emotional purpose, the expected result of additional right hemisphere activity was seen, correlating with emotions in spoken language. Conversely, when signs such as DISCUSS (Figure 2.1b) were used,

which contains a purely grammatical nonmanual marker with no emotion involved, the left hemisphere was active, correlating with linguistic content in spoken language (Bellugi et al. 1989).

(a) (b)

Figure 2.1 (a) emotional expression in GOOD and (b) non-emotional linguistic expression in $\frac{\text{bl}}{\text{DISCUSS}}$

Figures 2.1a-b (images from consultants in this current research) are two illustrations of nonmanual markers from videotaped subjects for this dissertation. Figure 2.1a shows an emotional expression for the sign GOOD, with no linguistic nonmanual marker attached. Figure 2.1b shows a linguistic nonmanual marker 'bl' attached to the sign DISCUSS with outward pursed lips and with a neutral emotion. These examples demonstrate how ASL Deaf

signers make use of neural substrate areas that function in non-emotion speech during grammatical nonmanual movement, utilizing the side of the brain which controls grammatical production (Bellugi, et al. 1989).

Examination of impairment to both hemispheres shows that the visual modality relies on the left hemisphere to process language in a similar manner as spoken language, while studies on the acquisition of nonmanuals reveal emotional facial expressions occur first, and linguistic expressions show learning patterns and later acquisition of canonical functions (Anderson and Reilly 1997, 1998; Reilly 2000; Reilly & Bellugi 1996, Reilly et al. 1991, Reilly & McIntire 1992).

Grossman (2001) provides even more support for hemisphere lateralization of nonmanuals. She made fMRI reports for both hearing non-signers and Deaf signers during expressions of emotional statements, and also neutral questions in ASL. Her study was the first to examine hemisphere activation when participants did not view the hand at all, but instead only saw the face. The results show Deaf subjects had extra activation in the left hemisphere when viewing linguistic question nonmanuals on the face, and a similar right activation during emotion as seen in hearing non-signers.

2.4.3.2 Distinct Production of Affect and Grammar in ASL Nonmanuals

Research on affective face perception in spoken language debates whether a set of facial expressions are perceived holistically as one unit, or as a bundle of independent features that create the emotional expression (de Gelder

1998). In (de Gelder et al. 1996), angry and fear were compared to see if these expressions could be recognized from the full face, upper face only, and lower face only. For both the full face and upper face, the emotions were categorically identified, but the lower face did not allow subjects to interpret the expressions consistently. This suggests that the upper face, which includes the eyebrow region, carries much of the emotional content for these emotions. Eyebrows are known for playing a significant role in emotional production, and emotions are generally considered to include universal involuntary expressions (Ekman 1992; Ekman and Friesen 1978; Izard 1971).

With both emotional and linguistic meaning carried in the eyebrow channel in ASL, the language uses specific features to maintain a separate production for these facial elements. When a yes/no question with raised eyebrows is signed in ASL, and when the signer is angry at the same time, how will the raised eyebrows be influenced? One example is an expression of anger, which includes a tensed mouth and lowered eyebrows (Ekman 1992). When emotions use similar facial muscles as the linguistic expressions, as in this example, how does ASL show these distinctions?

2.4.3.2.1 Design Features of Nonmanuals Help Maintain Simultaneously Independent Channels

Anger results in lowered eyebrows, but so do wh-questions. To help maintain these distinctions, there are differences in the production of either affect or linguistic nonmanuals in ASL. Wilbur (2000, 2003) explained the three

key design features from the literature on ASL that help nonmanuals function distinctly:

timing (Baker-Shenk 1983, Baker and Padden 1978)

coordination with syntactic constituents (e.g Baker-Shenk 1983)

and spatial distribution of the nonmanual channels (Wilbur 2000, 2003).

First, affective or paralinguistic facial expressions and linguistic facial expressions can involve different timing factors (Baker-Shenk 1983). For example, an affective facial marker may begin slightly before the sign, while a linguistic marker will begin abruptly and concurrently with a given sign, illustrating again the distinct existence and function of these two uses of facial expressions in ASL. Thus, one movement can be used for both grammar and affect.

The second design feature (Wilbur 2003) first noted in Baker-Shenk 1983 and examined by others such as Bahan 1996, is through onsets and offsets that link with a particular sign or scope of an entire constituent. One example is the lowered eyebrows over wh-questions, and the scope of this lowering over a wh-phrase. Veinberg and Wilbur 1990 researched the linguistic nonmanual connection to scope through emotion and negation in ASL. The negative headshake in ASL, a grammatical nonmanual, begins and ends abruptly either over the negative sign or over the entire constituent that is negated (Veinberg and Wilbur 1990). Emotional negative headshakes in non-

signers, however, begin and end gradually, and seem dissociated from English syntax (Veinberg and Wilbur 1990).

The third design feature noted by Wilbur (2000, 2003) is the spread of potential nonmanual channels throughout the upper body, head and face. This allows independent channels to function separately.

The next section discusses key approaches to examining such nonmanual features, and the findings of works using different methodologies on ASL questions or emotions.

2.5 Methodologies for Analyzing Linguistic and Affective Eyebrows in Questions

To explain functions of these subtle differences and combinations in nonmanuals, ASL literature often provides examples of entire sentences in discussion, but may only look at static impressions of peak realization, onset, and offset when reporting data from videotapes. Discussions from Baker-Shenk (1983), Bahan (1996) and others show the importance of not only focusing on these key static moments in analysis, but also looking at nonmanuals across entire constituents. These authors recorded dynamic information as nonmanuals changed throughout constituents.

2.5.1 SignStream ™

As both nonmanual research and technology has developed, computer software programs allow a more consistent recording of transcriptions for these data. One such program is SignStream ™ (Neidle 2001), innovative software

application created to allow ASL digital transcriptions of both manual and nonmanual movements, and then to make these available to other researchers on the internet.

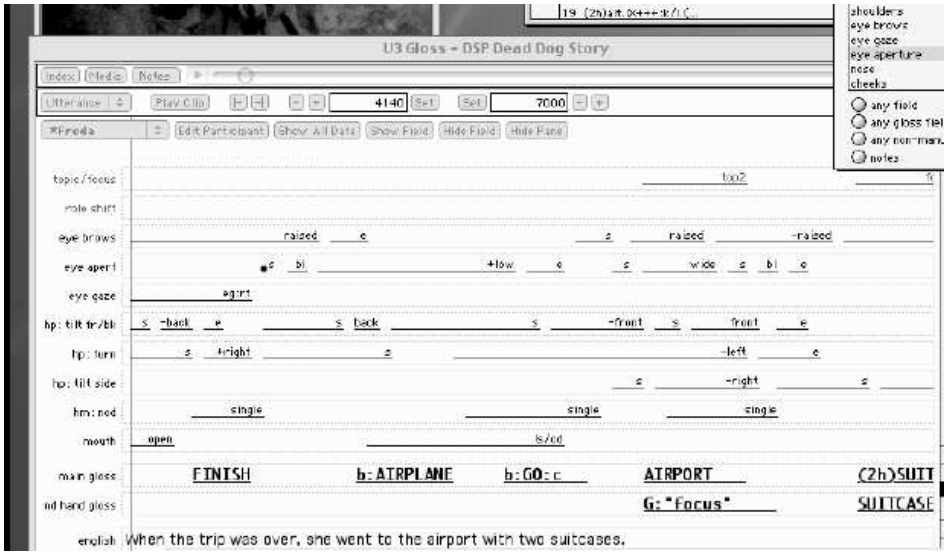


Figure 2.2 SignStream™ transcription portion from ASLLRP, Neidle 2001

Following the standard in ASL research, coders record signs on one line, and then simultaneously record each nonmanual channel on a different line. This multi-level analysis allows all the observed information to be recorded and aligned to the same point in a video recording. Data is recorded as qualitative labels of intensity. For eyebrows, this includes an impressionistic evaluation of eyebrow levels from highest to lowest as: raised, raised -, lowered, and lowered – for the most lowered eyebrows.

These labels are then recorded based on the opinion of the observer viewing the eyebrow movement in the videotaped frames. SignStream ™ is a valuable tool for seeing complex patterns of nonmanuals, but events must contain a minimum of two video frames, and require space between each label, which results in a lesser degree of precision for researchers interested in focusing on the critical and often subtle details of nonmanual changes.

2.5.2 Facial Action Coding System

The standard in ASL nonmanual research is the Facial Action Coding System (Ekman and Friesen 1978) or FACS. Baker-Shenk (1983) first applied FACS to ASL, and signed language researchers continue to benefit from this system. The method applies to facial expressions of all types, and records labels of muscle movements based on impressions of facial actions. Eyebrows, for example, receive an Action Unit 1 (AU 1) for inner brow raise, AU 2 for outer brow raise, and AU 1+2 for both inner and outer brow raise. AU 4 represents furrowed or lowered brow levels. Baker-Shenk determined that ASL yes/no questions employ raised eyebrows AU 1+2, and wh-questions use furrowed eyebrows AU 4. FACS is a valuable tool that allows researchers to note qualitative observations through a common label set. For example, Ekman 1979 identifies the emotion anger to display AU 4, and surprise to display AU 1+2. From these affective and linguistic FACS observations, we see that surprise and yes/no questions have similar brow movements, as well as anger and wh-questions.

While Action Units are helpful for a general analysis, for a more in depth examination of eyebrow behavior, a more precise tool is needed. The label AU 4, for example, is given if the brows are lowered, drawn together, or both lowered and drawn together (Ekman 1978), and there is no way to record the difference in height alone[5]. In fact, the creators of FACS suggest AU 4 comprise of five components in different combinations. For example, AU 4 generally lowers the eyebrow, but it is possible for only the inner portion to lower, only the inner and central portion of the eyebrow to lower, or for it to appear the entire brow lowered (Ekman et al. 2002). The eyebrow may also pull closer together, called brow furrowing. It is also is possible for brow lowering to occur with no brow furrowing in an AU 4. The FACS coding manual states there is currently no way to separate out these distinctions with the current system, as all of these possibilities are labeled AU 4. In ASL literature, brow furrowing is the label generally given for wh-questions, and a lowered brow is just assumed to follow, with the terms brow lowering and furrowing sometimes even erroneously interchanged.

After completing the data collection and beginning to examine the results, I discovered that de Vos 2006 was also investigating affect added to questions, but in a different sign language, Sign Language of the Netherlands or Nederlandse Gebarentaal (NGT), and instead of eyebrow height she used the traditional method just discussed, FACS. In this first study of emotion

[5] FACS does allow researchers to record impressions of intensity along with the AU labels.

added to questions for any signed language, she examined eyebrow muscle movements, and found that for NGT, which also is said to have eyebrows raised in yes/no questions, AU 1+2 and often AU 4 all occur in yes/no questions. She also found some variations in AU when emotion was added to neutral questions. For example, for a surprise yes/no question 6 out of 20 times AU 1+2 was used exclusively. She also noted angry as a more intense AU 4. From these and other AU recordings she contends that in NGT affect "wins" or overcomes grammar some of the time (forcing the grammar out of the eyebrows), grammar "wins" or overcomes affect some of the time, and a third "phonetic sum" exists some of the time, where both affect and grammar are changed for a combined effect.

De Vos (2006) contends that generally it is either the linguistic or the affective expression that is seen through the eyebrows at any given moment and not both, based on the emotion or question type signed in NGT. She therefore concludes there is no nonmanual layering for NGT eyebrows, and contends that whatever linguistic function may be lost by the emotion overcoming it is taken over by other articulators on the face. She then counters the position of Wilbur 2000 and 2003, discussed previously as a third proposal for nonmanual interpretation, wherein Wilbur states layering of nonmanuals does indeed occur in signed languages.

I believe, however, de Vos is expressing at least partial agreement with Wilbur without realizing it when she recognizes that eyebrows can serve one

function and other articulators take over the different functions simultaneously, as already discussed in Wilbur 2000. The difference may be that de Vos appears to suggest emotion cannot overlap with linguistic nonmanuals without frequently suppressing them. The results from de Vos 2006, however, affirm the assumptions that emotion does influence ASL grammar, and provide further support to the importance of eyebrows in signed languages. Her findings also generate many more questions. Can more consistent patterns be seen with a different approach? Could analysis of eyebrow height show more consistent patterns?

2.5.3 Contour Charting of Eyebrow Behavior in ASL

ASL researchers have indicated the flow of Nonmanuals across constituents in a contour form, drawing a line curving up or down based on nonmanual movement of impressions (e.g. Neidle et al. 1996, Wilbur 1994). Grossman (2001) demonstrated a new method for displaying the subtle and dynamic changes across a period of timed recording further showing that a contour presentation of dynamic features can help to better understand nonmanual functions. She examined multiple nonmanuals in ASL including eyebrows for their raised or lowered states across frames. Grossman (2001) and later Grossman and Kegl (2006) took the impressions of eyebrow levels similar to those often recorded in SignStream™ and assigned a numeric value to these impressions in order to graph the results in a contour chart.

These contour approaches allow us to view the dynamic flow of eyebrow levels in ASL sentences, and these contours allow for stronger examinations of what is happening on the face in ASL. Grossman 2001 and Grossman and Kegl 2006 assigned the highest raised eyebrows from impressions the label Raised 2, less raised as Raised, then Neutral, and finally for the lowest eyebrows, the label Lowered, as seen in figure 2.3, based on SignStream ™ conventions.

Facial Features				
SignStream label for feature events	Eye aperture	Eyebrows	Cheeks	Mouth
	Wide 8	Raised2 12	Tensed2 6	Smile 6.5
	Neutral 7	Raised 11	Tensed 5	Smile only left 6
	Squint 6	Neutral 10	Neutral 4	Open 5.5
	Squint2 5	Lowered 9		Frown 5
	Squint3 4			Intense 4.5
	Upper lid down 3			Neutral 4
	Blink1			Raised upper lip 3.5
				Right lip up 3
				Pursed lips mm 2.5
				Pursed lips Mm-tight 2
				Pursed lips Oo 1.5
				Pursed lips Oo-tight 1

Figure 2.3 Example of numeric representation based on eyebrow movement. partial listing, from Grossman and Kegl 2006

Each label of eyebrow height then received a number from 12 (highest) to 9 (lowest) based on these eyebrow impressions. They also charted other nonmanuals that occurred simultaneously, such as the cheeks (#4-6), and eye aperture (#1-8) seen in Figure 2.3. The idea was to record eyebrow changes

over a period of time based on numeric values of impressions, as introduced in Grossman 2001, and seen in figure 2.4 from Grossman 2006.

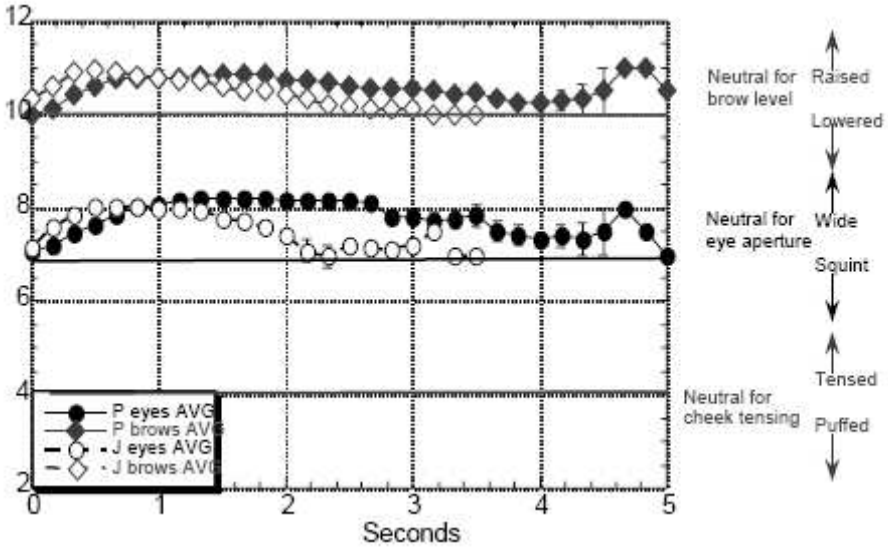


Figure 2.4 Examples of eyebrow height (top two lines) and eye aperture changes (middle two lines), of two signers in a surprise statement, from Grossman and Kegl 2006.

Seen here in figure 2.4 is the brow position for eyebrows given a two point range based on impressions. Impressions for these eyebrow labels in the example of figure 2.4 would be recorded as 10 or 11, and then statistical averaging of 20 sentence samples produced several points that generate an average contour that flows within this range, seen in figure 2.4 for a surprise statement.

In figure 2.4, the emotion surprise is shown as having raised eyebrows, and the lower portion of the graph shows the eye aperture. The data in Grossman and Kegl 2006 showed no occurrences where eyebrows raised and

eye aperture decreased or vice versa. This pattern of similar eye aperture and eyebrow movement can be seen above as the lines flow up and down together. The study also concluded that there are virtually no changes in eyebrow movement during a neutral sentence.

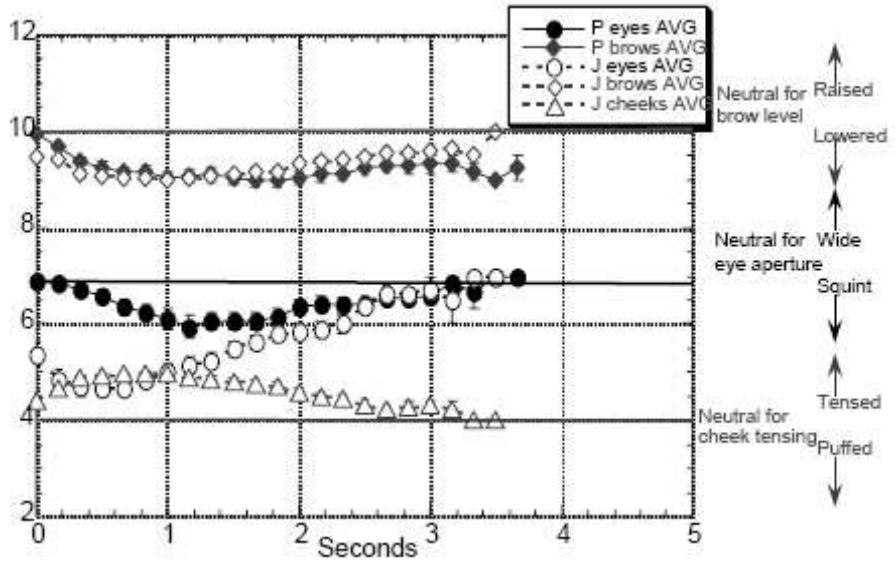


Figure 2.5 Eyebrow levels of two signers for angry, quizzical, and wh-questions based on impressions of movement, from Grossman and Kegl 2006

Grossman 2001 and then Grossman and Kegl 2006 examined nonmanuals in ASL yes/no questions and wh-questions, declarative emotional statements, and non-emotional non-grammatical expressions. This work included eyebrow analysis and focused on the production of several nonmanuals simultaneously across a domain. Grossman 2001 showed that no one point in the sentence contains a peak realization for all features of nonmanual expressions, and found that overall, surprise statements and yes/no

question expressions had raised eyebrows and wider eyes, while angry statements and wh-questions had lowered brows and squinted eyes.

Anger had faster and stronger squints than wh-questions. For either angry statements or wh-questions, both signers rise to an apex for eyebrow movement within approximately the first third of the sentence, but at different rates for each signer as one arrived sooner than the other.

Grossman and Kegl 2006 noted that subjective impressions were used in the study, and objective measurements of eyebrow movement in similar detail was unfortunately not possible given the current technology and methods for comparing against facial features. This present work, however, expands on their approach by introducing and applying a new experimental method to ASL that is now able to meet this challenge.

The contoured numbering approach in Grossman 2001 recognizes the importance of quantified data, and represents finer detail than previously seen in ASL facial analysis. This ground-breaking work inspired the examination of data in this current work not only through statistical tests of single measurements, but also through contour charts of eyebrow height across time. I am heavily indebted to the standard set by these previous works, which was then extended to the methodology in this current work, a new approach that now allows researchers to objectively measure eyebrow height. The results allow the first quantitative examination of ASL eyebrow height, and provides for

a new account of further layering of the eyebrow nonmanual channel, with insight into why interpreters misunderstand ASL questions.

2.6 An Extended Proposal for Nonmanuals: Eyebrows as both Intonation and Syntax

The assumption in the current debate is that eyebrows must represent *either* syntax or intonation across ASL questions. Instead, rather than a mutually exclusive set where either the intonational or syntactic interpretation can be correct, what if eyebrows can simultaneously layer to represent both syntax *and* intonation?

The data suggest these functions indeed co-occur. Not only can eyebrows function differently than the rest of the upper face, but also eyebrow height can simultaneously function in multiple ways along a single dimension, change in height.

The findings of the current study not only support Wilbur's layering perspective, but also require a new theory, an expansion of the idea that upper face nonmanuals can each function differently while co-occurring over the same lexical signs. The proposal introduced in this dissertation is that both sides of the debate can be correct simultaneously, not only through different co-occurring nonmanual channels, but also through one channel with simultaneously multiple functions. The data show that eyebrow height simultaneously functions as paralinguistic emotional intonation, grammatical

intonation, and syntax in ASL. The theoretical implication is charted in figure 2.6.

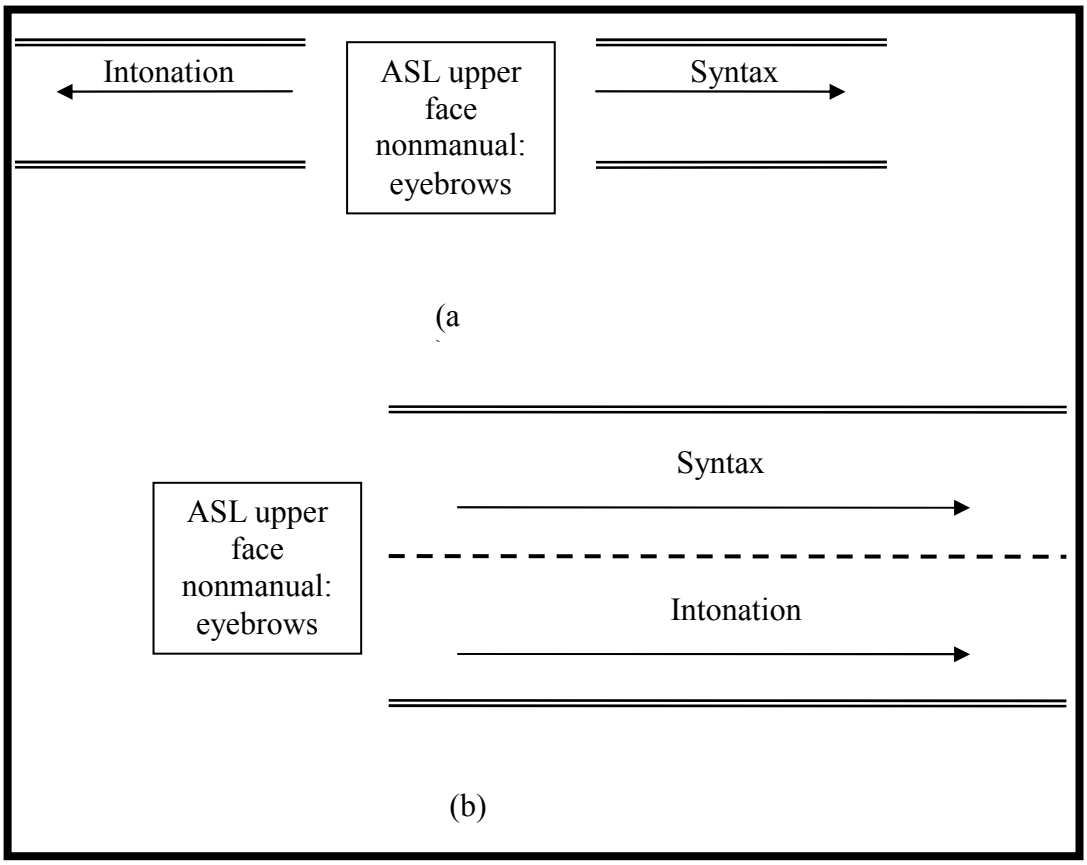


Figure 2.6 Graphical representation of (a) perception of the current debate and (b) a new approach to much of the contrasting information

Figure 2.6a shows the current assumptions that analysis is either one or the other, while 2.6b shows my contention that both syntax and intonation are components of eyebrow movement in ASL. It may not be possible to arrive at a consensus on all aspects of the debate, but this expanded theoretical framework allows a more unified approach to the upper face nonmanuals.

These apparent divergent paths are not as opposite as it appears. The current literature on both sides suggests mutually exclusive views that take investigators in different directions. I suggest that rather than two different paths, much of the literature on eyebrows represents two lanes going forward on one larger road.

The idea of nonmanual layering is central to the new proposal on eyebrows in this dissertation. This new theory draws on comparisons to spoken languages because examples of similar layering are found in both signed and spoken languages. There remains some disagreement in ASL research, however, on whether signed languages are uniquely layered, so it is necessary to provide a brief summary of the discussions on layering as they pertain to nonmanuals in order to show that all natural languages are capable of complex layering, regardless of modality. This bears directly on the data that show ASL nonmanuals are layered with even more complexity than previously described.

2.6.1 *How Emotion Shares Linguistic Space in ASL Nonmanuals*

This next section shows how both spoken and signed languages layer, which lays the foundation for this new expanded theory on eyebrows and the larger area of upper face nonmanuals.

2.6.1.1 The Claim in Literature that Signed Languages are Layered While Spoken Languages are Limited

Liddell (e.g. 2003) considers signed languages to be unique in their layering, while spoken languages are limited in their ability to make simultaneous or overlapping articulatory contrasts. He suggests that the tongue

has only limited movements, such as vowels that are either high, low, front, back, or mid, and he argues that the throat is only one single articulator. These "limits" are then compared to the multiple articulators in signed languages, including the various nonmanual channels. Sandler 1999 furthers the discussion of signed languages as unique by stating that the throat is capable of only one articulation at a time, while signed languages have an entire array of nonmanuals that can simultaneously layer.

ASL and other signed languages do have a large repertoire of potentially simultaneous articulators, but it is important to emphasize in the ASL literature that spoken languages can also have systems rich with overlapping articulators that function similar to signed languages (e.g. Wilbur 2000).

2.6.1.2 Counter-Evidence through Complex Layering in Spoken Languages

While the visual modality is especially suited for layering, some spoken languages incorporate a comparable system of signal overlap. Linguistic research has long considered spoken languages to layer. Spoken languages can simultaneously alter voice quality types, vowel qualities, nasalization, emotional and grammatical pitch contours or instances of tones, and other features which combine to signal differences in meaning and to create *minimal pair* distinctions. For example, in Dinka of Sudan, voice quality, vowel quality, syllable duration, and tonal alterations can simultaneously interact in phonological patterns (Edmondson, Esling et al. 2003). These distinct voice qualities are complex, employing both the glottic and epiglottic planes in Dinka

to create modal voice, breathy voice, tense voice, and hollow voice (Edmondson, Esling et al. 2003).

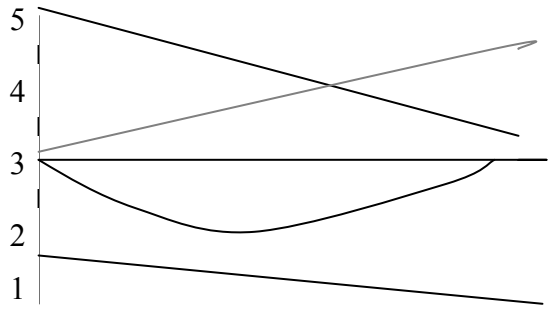
While the throat is a single apparatus, instead of limiting spoken languages, the multiple mechanisms inside the throat can create a rich system of simultaneous articulations. For example, spoken languages can use a rich system of phonetic tools such as plain epiglottal stops, glottal stops, and epiglottal stops (Edmondson and Esling 2006). Another example of the complexity of spoken language articulators is Somali's voiceless epiglottal trill in word final position (Armstrong 1934). The aryepiglottic folds can control acoustic sources through alterations of the aryepiglottic constrictor mechanism while the epiglottis trills against the back pharyngeal wall (Edmondson and Esling 2006), and both the glottal vocal folds and the aryepiglottic folds can simultaneously oscillate during harsh vocal register at low pitch (Edmondson and Esling 2006).

Tone languages can also provide insight into how emotion is added to linguistic nonmanuals in ASL questions. Specifically, my theory that eyebrow height represents both intonation and syntax with one raised or lowered eyebrow can analogize to adding emotional intonation onto a tone in tone languages, explained in the following discussion.

2.6.1.3 Affective and Linguistic Pitch in Tone Languages

How does pitch function in tone languages? Tones function in tone space, which is the pitch range for tone languages when they produce their

potentially highest highs to the potentially lowest lows (Ross et al. 1992). While there is some variation for speakers and languages, the tone space corresponds to the natural range of voicing in speech, about one octave or 12 semitones (YR Chao 1930). Tone letters are conventionally labeled with the numerals 1-5 (5 is high). To demonstrate, Figure 2.7 represents the five tones in Thai.



Kha 35 'to trade'

Kha 53 'to kill'

Kha 33 'cogongrass'

Kha 323 'leg'

Kha 21 'galangal'

Figure 2.7 Diagram of the five tone shapes of Central Thai (Standard as in Bangkok), generated from Praat.

Figure 2.7 shows the range of tone contours for Thai, where minimal pairs are created with the same lexical information with different tone contours attached.

Thai tone shapes are:

(a) 53 a fall from the highest-to-mid trajectory

(b) 35 a rise from mid-to-high

(c) 33 a mid-level trajectory

(d) 323 a mid-dipping trajectory

(e) 21 a mid-low to low-falling trajectory

In the Thai example of Figure 2.7, each segmental shape is identical and only varies in the tone. Producing the pith shape incorrectly could convey the sense of 'kill' rather than 'trade'. In tone languages, therefore, the pitch trajectory and segmental material are inextricably bound together lexically. Such lexical tones not only create minimal pairs, but they can also impact constituents for purposes such as creating 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).

Emotion alters this obligatory linguistic and syntactic tone in tone languages, yet this gradient movement of pitch still remains within a distinct linguistic category of tone space. Research in both Thai (Gandour et al 1995) and Taiwanese (Ross, Edmondson et al. 1992) indicates that while the tone at level 4, for example, is attached to the word, this tone can be varied by the speaker for emotion within a certain range or latitude, such that it still conveys the same tone of 4 (Ross, Edmondson et al. 1992). If it is produced too low, it sounds like a 3. If produced too high, it sounds like a 5. But within this range, the speaker can vary the tone to convey emotion. What Ross et al. 1992 term *tone latitude* is used in this tone language to incorporate emotion, while simultaneously conveying the underlying attached structural component of the tone required for the understanding of the word itself.

Tone languages, then, can have a lexical tone over a word and simultaneously express emotional intonation through the same use of pitch. Additionally, some tone languages can also incorporate grammatical intonation such as focus and other prosodic cues that are then simultaneously overlapped onto this lexical tone (e.g. Lindau 1986, Laniran 1992).

2.6.1.4 Affective and Linguistic Eyebrow Height Compared to Pitch in Tone Languages

I argue that ASL nonmanuals show some similarities to 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 the upper face nonmanual eyebrow channel, the data will show ASL eyebrow height attaches to lexical items in questions which triggers a syntactic raising or lowering across the entire constituent, and allows emotional states to influence this eyebrow height.

This composite is similar to how tone functions because the data will show emotional states do not remove the syntactic and grammatical intonation distinctions that simultaneously co-occur with one alteration in eyebrow height, much the same way as emotional alterations in pitch do not remove the syntactic tone distinctions created through pitch. The combination for tone has been famously proposed by Y.R. Chao (1968; 39) in his wave and ripples model. “The best answer is to compare syllabic tone and sentences with small ripples riding on large waves (though occasionally the ripples may be ‘larger’ than the waves).”

2.7 Summary: Questions Remaining from the Literature

From the current debate, there are several disputed missing pieces that could help us better understand the ASL nonmanual puzzle, and why ASL questions are so often misunderstood by learners of the language. Do eyebrows raise and lower in a consistent pattern over question types, or not? Do wh-words receive lowered eyebrows over every occurrence, or only based on the speaker intent? What exactly triggers the spread of the eyebrow height? These and other questions continue to be the subject of disagreement based on current data. Is there a way to see greater detail of eyebrow height for potentially new information? Until now, new detail through objective measurements of eyebrow height remained to be investigated. Also, a detailed examination of eyebrow height had not been made for questions with added emotion for ASL nor for any signed language. As discussed, de Vos 2006 analyzed for NGT emotion onto questions, but for FACS muscle movements, not eyebrow height.

While qualitative impressions can continue to provide excellent generalizations about nonmanuals, quantitative methods are now available to every researcher and should be added to the approaches in nonmanual research. Many, but not all, of the key points of contention in the debate over the upper face are caused by impressionistic data and can be resolved from measured data and by re-analyzing results in light of this new theory of multiple functions within one nonmanual channel. As the theoretical focus becomes

clearer it is hoped new pedagogical approaches to nonmanuals will improve ASL curricula. This study contributes to this focus with some suggestions for more effective instruction on eyebrows in ASL questions.

When an angry expression that triggers lowered eyebrows is added to a yes/no question with raised eyebrows, what happens to eyebrow height? What about when a surprise expression that triggers raised eyebrows is added to a wh-question that has lowered eyebrows? Can a quantitative analysis provide new clues? The next chapter considers these questions with a discussion on the methodology for this investigation.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The purpose of the study is to explore eyebrow height in American Sign Language questions. The goal is to determine if the raising and lowering of eyebrows separates the different question types from one another, and if it is also possible to distinguish between the affective and emotional uses of the eyebrows through quantitative measurements. For this study, consultants signed yes/no questions, wh-questions, and statements in neutral and four emotional states: happy, sad, angry, and surprise. The videotapes were then analyzed and hand coded with a digital tool to measure precise changes in eyebrow height for each sentence. This chapter presents details of the methodology for the research.

3.2 Selection of Consultants

An email announcement was sent out through the Deaf Network Listserv, and interested individuals contacted me for participation. Deaf consultants were screened through emails and accepted into the study if American Sign Language was their first language, if they had Deaf parents in their home as

they grew up, and if they began signing ASL from a young age. Participants were provided $50 for their two hours of help, as approved by the Institutional Review Board.

3.3 Selection of Signed Sentences

For this study, each signed sentence is called a sentence, and each larger sentence unit that is signed in several ways is called a sentence set. The sentence sets were each signed as three types: a yes/no question, a wh-question, and as a statement, and then each type was signed in four emotional states and neutral.

The scripted sentence sets for this research were similar to those I used in prior studies to investigate relative ranking of emotions in spoken languages. For example, in Weast 2006, similar types of sentences were used to elicit declarative statements in Korean to determine the relative ranking of pitch when altered for affect, and these similar sentences and their pitch contours were then compared to Russian and English.

The ASL sentence sets for this study were each based on simple sentences, with the exception of Set 3 which includes a sentence-initial topic in order to also see how topics overlap onto questions with emotion. Sentence sets and sentence set types were created by a native Deaf consultant, and then each native Deaf consultant also verified the sentence sets and individual sentences were natural ASL during data collection. Consultants were then able

to make limited modifications during signing. This modified elicited approach and the sentence sets and set types are further discussed in 3.4 Data Collection.

3.4 Data Collection

This section reviews the data collection procedures established for this study, with a discussion on natural vs. elicited data.

3.4.1 Environment and Camera Placement

Data was collected in the same university library conference room for every consultant. Consultants were seated comfortably in this quiet room, away from any visual or auditory distractions. 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 signer's nose. A back-up videotape recorder was situated behind and slightly above the primary camera, but no videotapes malfunctioned so these back up tapes were not used in data analysis. The consultants were videotaped from approximately waist level so as to include the entire sign space.

Consultants were instructed to relax, sit back in their chairs, and to sign comfortably. They were shielded from onlookers during the data collection. Consultants knew the face was important for the videotape, but did not know the specific goals of the research. Before signing the scripted sentences, they were given the opportunity to sign two short narrative stories of their own

creation, to help them become comfortable with the camera. These signers were also videotaped answering questions to confirm their eligibility. Both the interview and the narratives were recorded and used in the data analysis to confirm a range of eyebrow movement in naturally occurring settings for each consultant.

While the entire signing space was videotaped, during analysis, only the small facial area was viewed to be consistent with the practice of other studies in facial coding. Other research designs (Grossman, 2001, Grossman and Kegl 2006), used more than one camera, and zoomed an additional camera in to the face only, to be used in data analysis. The design for this dissertation study accomplished this same objective but used only one video camera. Instead of having a separate camera that excludes the signs from view, the data were coded by obscuring the computer screen so only the face was visible during recording of the facial measurements. After data analysis was completed, the target was verified by returning to the time stamp and viewing the covered card on screen.

3.4.2 Presentation of Sentence Sets and Set Types

During data collection, the sentence sets were presented on a sheet of paper with an ASL gloss of the signs but without the linguistic conventions of written nonmanual markers. The glosses were also casual so they could be understood, so for example in Table 3.1 the pronoun YOU in Set 2 is not glossed as IX-2p, as would be traditional in literature, but instead as YOU, more

familiar to the average individual. The sentence sets and set types are listed below in Table 3.1.

Table 3.1 Stimulus Sentences in ASL Glosses and English Translation

Set	Sentence Set Type	ASL Transcriptions	English Translations
Set 1	Statement:	NOW RAIN	It is raining now.
Set 1	Yes/No Q:	NOW RAIN	Is it raining now?
Set 1	WH-Question:	WHERE RAIN WHERE	Where is it raining at?
Set 2	Statement:	YOU EAT ~~FINISH~~	You (already) ate.
Set 2	Yes/No Q:	YOU EAT ~~FINISH~~	Did you (already) eat?
Set 2	WH-Question:	WHAT EAT WHAT	What did you eat?
Set 3	Statement:	GIRL (point) HAIR RED GO-OUT	The red-headed girl went out.
Set 3	Yes/No Q:	GIRL (point) HAIR RED GO-OUT	Did the red-headed girl go out?
Set 3	WH-Question:	WHEN GIRL (point) HAIR RED GO-OUT WHEN	When did the red-headed girl go out?

Table 3.1 above shows the three sentence sets included in the final analysis. Set 2 included the sign FINISH but it is crossed out in Table 3.1 because in the modified script procedure consultants frequently replaced it with a repeated pronoun instead.

Sentence sets were then signed in each of three set types, as a statement, a yes/no question, and a WH-question. These set types were then each signed in five states, HAPPY, SAD, NEUTRAL, SURPRISE, and ANGRY. So, for example, Set 1 was signed by each consultant 15 instances: 5 yes/no

questions, 5 statements, and 5 wh-questions. For each instance, sentences were signed in three renditions. For example, for the 5 yes/no questions, each emotional question was signed three times: three times in neutral, three times in angry, etc.

3.4.3 Issues with Natural and Elicited Data in ASL Research

Data collection in ASL is traditionally either natural or elicited. Collecting natural data is the ideal for linguistic research, but to collect ASL data, signers must be videotaped. When signers are aware of the videotaping, however, this can alter the naturalness of the data in the same manner as noted by Labov (1970, 1972) about data collection in general. Signers are not only aware of the videotaping, but they must also stay within view of the camera, further limiting the natural feeling of the setting.

Elicited data is usually scripted with an ASL gloss or representation of signs on paper. Scripted data is then created and judged grammatical by a native signer. In the field of ASL research, these scripts are often then practiced by these consultants before signing, but for this current research I intentionally avoided this practicing, and conducted the data collection as described below.

3.4.4 This Study: Both Natural Data and a Modified Elicited Data Approach

Both natural data and scripted data were collected. The natural signing portion provided a control to compare the range of eyebrow height during natural conversation and narratives to the range of eyebrow height in elicited

data. The narrative portion attempted to elicit emotion with natural unscripted signing by asking signers to tell about a time when they were lost or when they almost got into a car accident, and to also sign about some time when they had fun while realizing it was dangerous or scary, such as parasailing or skiing.

While these narratives are a rich source of linguistic information, for this study natural data alone could not provide the necessary comparisons to address the research goals. The focus of this research was specifically to observe how emotion overlaps with different question types, so it was imperative to examine similar data in different emotions and questions to allow for an accurate comparison. Also, it was crucial that signers remain focused on the camera as if to an interlocutor in order to take accurate eyebrow measurements. This position required scripted data rather than data recorded from naturally occurring conversation.

3.4.4.1 Elicited Data Collection

After the initial unscripted signing, consultants each signed six target sentence sets using the emotions HAPPY, SAD, ANGRY, SURPRISE, and also signed each in NEUTRAL. Each consultant signed fifteen sentences for each sentence set, with 5 sentences signed as a yes/no question for each of these five emotions, 5 signed as a WH-question for each emotion, and 5 signed as a statement for each emotion. The six sentence sets contain a total of 45 sentences per consultant. With six consultants, this resulted in a total of 540 sentences for the data. As discussed in the data analysis section, only the first

three sentence sets were selected for analysis[6], which resulted in 270 sentences for the final data of this investigation.

3.4.4.1.1 Modified Script Procedure

In this method of data collection, consultants were not given any instructions for producing nonmanuals, and did not practice their sentences before videotaping. Consultants were given a written gloss of the signs in the sentence, judged as grammatical sentences by their own native intuition. They were also able to select their preferred sign for each wh-word. I did not instruct consultants on what to do with their faces through marks on these glosses because I wanted to observe as natural facial expressions as possible and not expressions based on a written guide. Since ASL is not a written language, most Deaf signers do not know the linguistic transcription system, so the absence of markings does not generally give any information about what to add or not add on the face while signing. There was the possibility that a consultant would be aware of transcriptions and that by omitting any markings, the consultant could have produced a flat face, but this did not occur in the data. Instead, regular patterns for eyebrow height occurred.

The consultants helped select the glosses and each consultant verified each sentence represented native ASL before signing. During data collection, the statements and yes/no questions were sorted randomly so that later the

[6] English translation of the three other sentence sets not analyzed, include the statements "You like motorcycles", "You're getting married", and "Those boys are twins". These were also signed in both question types.

coder would not know which one was being analyzed based on the order. Each consultant also signed the various sentences for each sentence set in different sequences so there would not be a learned order to influence data analysis.

For each sentence, subjects were reminded to omit any emotive words such as the sign for HAPPY, SURPRISE, or ANGRY, and to avoid using the question marker that is optionally added to the end of a yes/no question, in the fashion of Baker and Padden (1978), to ensure the information was maximally on the face.

During an initial pilot study of two Deaf native consultants, I did not provide any context description for the sentence sets, but I found this problematic. Consultants would ask me to give them ideas for how an emotional state fits with the sentence, and when I signed it, I realized I used emotional facial expressions and sometimes even emotional signs without intending to do so. This could influence the degree of emotional intensity produced by consultants if they attempt to copy what they see, or my signs could influence their sign choice if they thought I was producing some "target" sentence. For the data collection for this study with six new consultants, however, I made sure not to sign the sentences at all, and to provide a context for each emotion prior to signing the set, repeated for each consultant. This allowed signers to start and finish the entire set without my signs influencing the collection.

In this method, each sentence set was given a possible context. For example, scenario ideas for It is raining now included planning a fun picnic but now it rains (sad), leaving the car window open with important papers inside the car and now it rains (angry), thinking it was sunny and leaving a room without windows to suddenly see that it is raining (surprise), or maybe dreading the chore of mowing the lawn but realizing it is not possible now because it is raining (happy). Standardizing the scenario in this manner helped frame similar interpretations of sentence sets. Prior to signing the sentence set, consultants were given opportunity to ask questions about why they might feel a certain emotion for each sentence if needed, and when they were ready and felt comfortable with situating a scenario in their mind for each emotion, they started signing the sentences.

While signing, subjects saw a flashcard that indicated whether it was time to sign a yes/no question or a statement, and which emotion was to be signed. The card simply listed the emotion name, and the word “Question” or “Statement”, also in the same manner as Baker and Padden (1978).

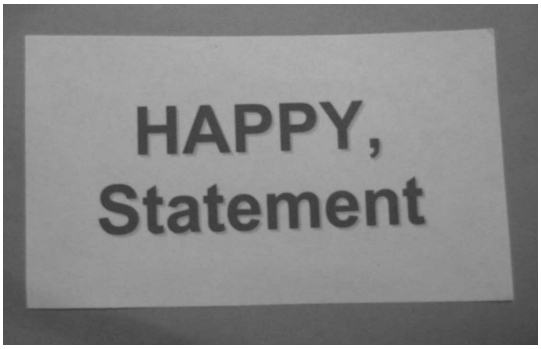


Figure 3.1 Sample Card Seen by Consultants Listing Emotion and Sentence-Type

Figure 3.1 shows a sample card that was held for consultants to view during signing. Consultants then took the sentence set and set-type glosses and created a rendition using the emotion and sentence-type listed on the card. Consultants were allowed to change the sentence slightly as long as they used the signs in the sentence. This resulted in repeated pronouns, verbs, or other lexical items depending on signer preference, and allowed more natural responses because, once they know the general signs for the sentence type, the signers did not have to stare at a piece of paper for each sentence. The subjects then signed three renditions of each sentence. After all the yes/no question and statement sentences were signed, the five wh-question sentences were signed with the emotions again in random order.

While each consultant signed the sentences, a small card appeared in the lower right portion of the screen (to the signer's lower left), slightly behind the consultant so as not to be distracting during the signing.

Figure 3.2 A surprise statement signed by one of the consultants, signing RAIN, with the card inserted behind and to the left of the signer.

Seen in figure 3.2, the card was color coded to indicate the target emotion, and included a symbol to indicate the type of sentence signed. Later, as each rendition was selected and time-coded for analysis, this card provided verification for the coder as to the intended sentence type and emotion. During the analysis itself, however, the card was obscured so the coder would not know the target emotion or sentence type.

3.4.4.2 Viewing Videotapes to Verify Target Emotions and Sentence Types

After approximately one hour to one and one half hours, the signing portion for each consultant was completed. Next, each consultant viewed their own signing to verify that they produced the target emotions and sentence type. Consultants viewed a Flatron Wide monitor using Adobe Premiere 6.0 software,

with a Compaq Presario Notebook computer. Finally, each subject viewed the signs of 1-2 other subjects as an ancillary comparison, still through Adobe Premiere 6.0, and recorded an impression of whether each sentence was a question or statement, and what emotion they felt was signed for each sentence. This was used as additional verification that the target emotions had been successfully achieved.

3.4.5 Avoiding Facial Obstructions and Selection of the Three Sets for Analysis

Another reason to use scripted data was to ensure that signs would not obstruct the face for a prolonged length of time. In nonmanual studies, researchers (e.g. Grossman and Kegl 2006) often specifically ask signers to suppress their signs to a smaller sign space as done when trying to carry on a semi-private conversation. This is in order to keep the face obstructions to a minimum, because signs in this mode are more closely produced in front of the chest in neutral space. This is an alternative approach, but for the purposes of this study, which focuses on extremely subtle eyebrow movements, it was determined that not only the signs but also the eyebrow movements might be muted to some degree.

To resolve this problem, the research procedure provided a large enough pool of data that sentence sets could be omitted from analysis if necessary. There were originally six sentence sets used to produce 3 renditions of 540 different sentences total from all six signers. In the final analysis three of the six sentence sets were selected for analysis, leaving 270 different sentences in the

data pool, seen in Table 4.1. For each sentence, approximately 15 different measurements were recorded by hand, providing a total of about 3500 pixel eyebrow measurements for the research project.

The three sentences were selected because they were the first three produced, and the declination effect for tired signers could have altered results of the 5th or 6th sentence. The 4th sentence was omitted because of signs which were naturally produced near the face and obscured too many frames from view. This was a sentence set with the sign BOY which was produced near upper the face, that did not prevent measurements in general, but did make it difficult to code exactly every three frames. The first three sentence sets selected only obscured the face briefly, and the data measures were able to be retrieved for the intended purpose, as addressed under the tools section.

3.5 Data Transfer

The videotaped data from the Panasonic Digital Video Camcorder PV-GS320 was connected to a Compaq Presario notebook and the material was transferred to the hard drive using Quick Movie Magic via a Firewire cable and connections.

3.6 Data Analysis

The focus of the research was to measure eyebrow raising and lowering in ASL through measurements on the face. To do this, eyebrow height was the

target measurement, in an effort to quantify the impressions of eyebrows raised or lowered that have been recorded from previous research. This section explores the development of this methodology and discusses what units I decided to use for measurements and what tool captured the measurements.

3.6.1 Difficulties in Eyebrow Measurements

The first step in the data analysis was to find a reliable way to measure eyebrow height against facial landmarks. Research into measurements of eyebrow movement often includes expensive computer technology aimed at face recognition and identification of muscle movement. The question of objective markings around the eyebrows creates different approaches for capturing the data. For the purpose of this research, examples of the most relevant systems are discussed below, and are then compared to the procedures and tool employed in this work.

Granstrom and House 2006 used markers placed on the face during video taping, seen in Figure 3.3 below.

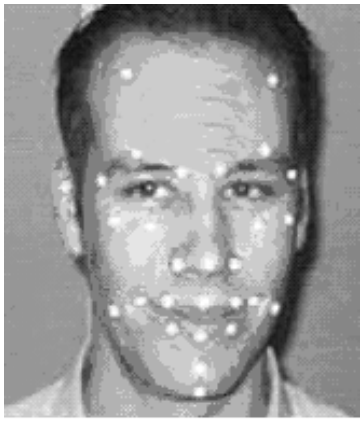
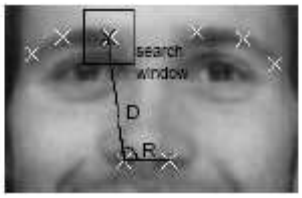


Figure 3.3 Facial markings to capture movement, Granstrom and House 2006

Figure 3.3 shows many points around the face used to help the computer find coordinates. One of these same reference points below the eye was used in this current study, described later in this section. For the current work, however, reference points based on edges of the eyebrows as in the image above are not sufficient, since hair could be trimmed, and more static features were needed.

Other studies focused on points along the eyebrow in relation to the nose, such as in Figure 3.4.



on one of the eyebrows.

Figure 3.4 Robust facial feature tracking from Bourel, Chibelushi, and Low 2000

Figure 3.4 above shows points along the eyebrow examined digitally to create measurements. This connection to the nose was determined to be less effective for the purpose of the current study, as discussed by Figure 3.6.

Some complex studies placed a face mesh on the subject during videotaping (Hong, Lee et al. 2006) to allow capture of numerous simultaneous muscle movements. Other studies examined multiple points on the face through complex software. One such promising work is at Purdue University's

Computer Vision for Recognition of American Sign Language project. This is one of several programs working on applying this Active Appearance Model (AAM) computer software to face recognition. Individuals train the computer to recognize points around the eyes and face, and then work to train the computer to follow these faces during signing. One example is in Figure 3.5 below.

Figure 3.5 Computer vision from Purdue University from the Active Appearance Model Face Plot

Figure 3.5 above shows a measurement from the center of the eye to about the midpoint of the eyebrow. The computer is trained to follow this movement, and the website shows an approximation that gives an overall idea of the facial changes. The AAM software is free, but the training and other technology can include considerable cost to an individual. This model was initially considered for the current research, but after working on the software, as well as consideration of financial concerns for training, I decided to search for a non-computerized measuring tool. Additionally, I concluded that the computer was still making approximations that did not track eyebrows consistently enough for such a detailed analysis as required by this work, such

as capturing measurements during eye blinks, among other requirements for this study.

Nevertheless, the current work owes much gratitude to the observations of this specific program at Purdue because of their example of initial work on their website, seen below in Figure 3.6.

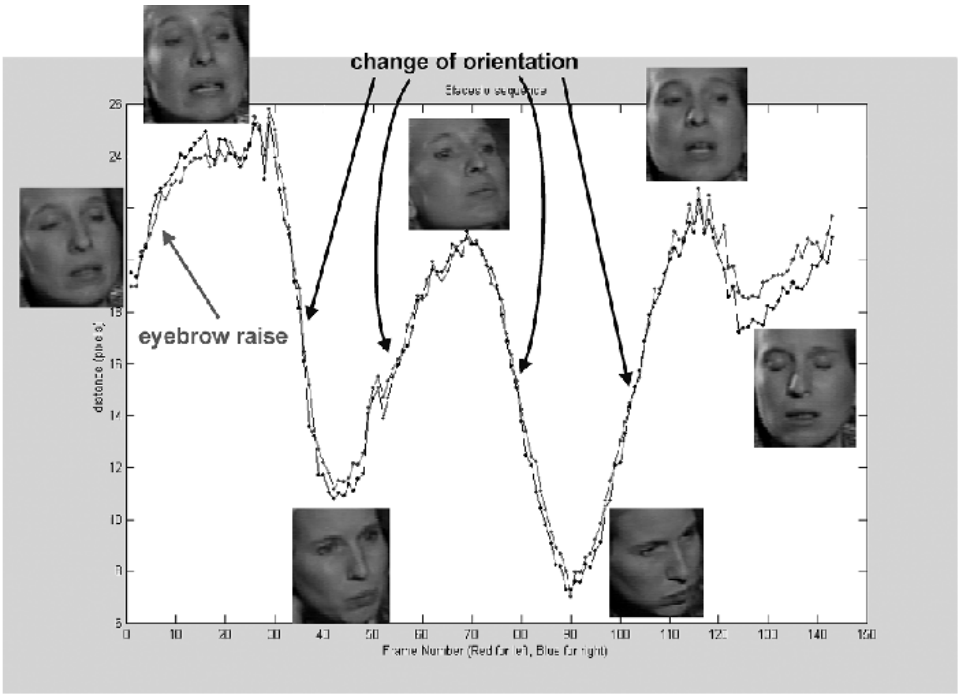


Figure 3.6 Computer Vision for recognition of American Sign Language, Purdue University

In Figure 3.6, a person is observed with changes in eyebrows over a period of time in conversation, measured by AAMs. When the online video image of data used to obtain these measurements is viewed, retrieved from the computer markings in Figure 3.5, it is evident that the eyebrows are sometimes not represented by the change of orientation plots. The general pattern still shows eyebrows raise and lower to differing degrees, and the Purdue project

created this sample image on their website as an example of what the investigators hope to allow their algorithms to measure automatically and efficiently. This image is a representation of the project goals for face tracking, and they also include tracking of hand movements.

For now, human coders can track facial movements more accurately by hand-coding measurements when focused on a frame-by-frame analysis of eyebrows, while, at the same time, the entire face is better captured by a computer, able to monitor a large number of points of reference on the face simultaneously. For the purpose of this study, then, hand-coding was preferred with current technology.

While the investigators at Purdue University say Figure 3.6 is only a preliminary representation of their face tracking ability, when searching for effective ways to measure eyebrows and emotion contrasted with grammar, I observed the differences in the ranges above and knew precise measurements were the key. This possibility of a future ability to track precise measurements for such research inspired the search for a way to do precise pixel measurements by hand now, for the current study.

Most of the facial measurements used in the current work refer to some of the facial landmarks discussed in the following study and presented in Figure 3.7.

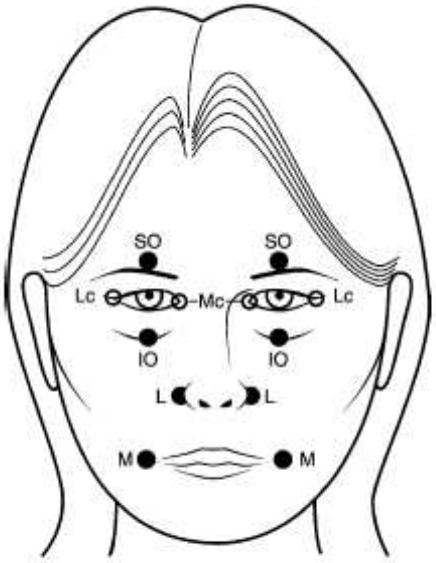


Fig. 1. Facial landmarks. *SO* immediately above eyebrow in mid-pupillary line, *IO* inferior skin fold below orbital rim in mid pupillary line, *L* point where nasal labial fold meets alar, *M* corner of mouth, *Lc* lateral canthus, *Mc* medial canthus. *NB* The periocular region is very sensitive and therefore Lc and Mc were visually identified, but not marked with adhesive dots

Figure 3.7 Facial landmarks from Clapham et al. 2006

In Figure 3.7, the facial markings show points that can be used to make objective facial measurements. This study compared practitioners using hand calipers to measure faces against coders who used digital photographs to make measurements in Adobe Photoshop. Calipers have been used frequently for facial measurements (outside the field of signed languages), and Clapham et al. 2006 investigated whether they were accurate in comparison to newer digital technology. The results of this comparison showed the most accurate

measurements were achieved within small domains of the facial topography, and caliper measurements across larger domains such as from the eye to the nose were less accurate when measured by hand, while digital measurements in Adobe Photoshop were more accurate for these distal measures. The measurements from SO to IO (Figure 3.7) were accurate in tests of variance with p-values <.05 for both hand and digital measurements, but correlation scores showed digital measurements were overall more accurate. This is suggested to be a factor of individuals moving or changing their expressions when a tool is physically placed over their faces.

For the current study, the combination of a caliper tool and digital still images of video frames proved to be an ideal combination. An online version of this caliper instrument is described below, which allows both caliper accuracy and digital still accuracy for more precise measurements.

3.6.2 Selection of Measurement Instrument and Training on the Tool

The current work shows that technology is now able to measure eyebrows in detail, and the results provide the first scientific measurements to determine if there are statistically significant distinctions between question types and statements, and emotions across signers. To this end, the Screen Calipers tool (explained below) was selected, and every eyebrow measurement was meticulously recorded by hand. In total, the 3500 measurements required approximately 170 hours to code, including 39 hours of training on the faces prior to coding.

The Screen Calipers tool (Iconico) was used to generate pixel measurements. Pixels are units of small dots relative to the screen size, measured in increments of 1 pixel (px) at a time. Researchers can replicate similar measures by using the screen size as discussed for the data, and using this same tool. Screen Calipers is a precise instrument for pixel-perfect measurements on any computer screen. It has applications for engineering, medicine, and other scientific projects, and can be calibrated to measure in different increments and units. The standard version is free, but I purchased the advanced upgrade to the basic software for the ability to move 360 degrees as needed for greater accuracy during head tilts. This affordable tool is only $30 as of this publication.

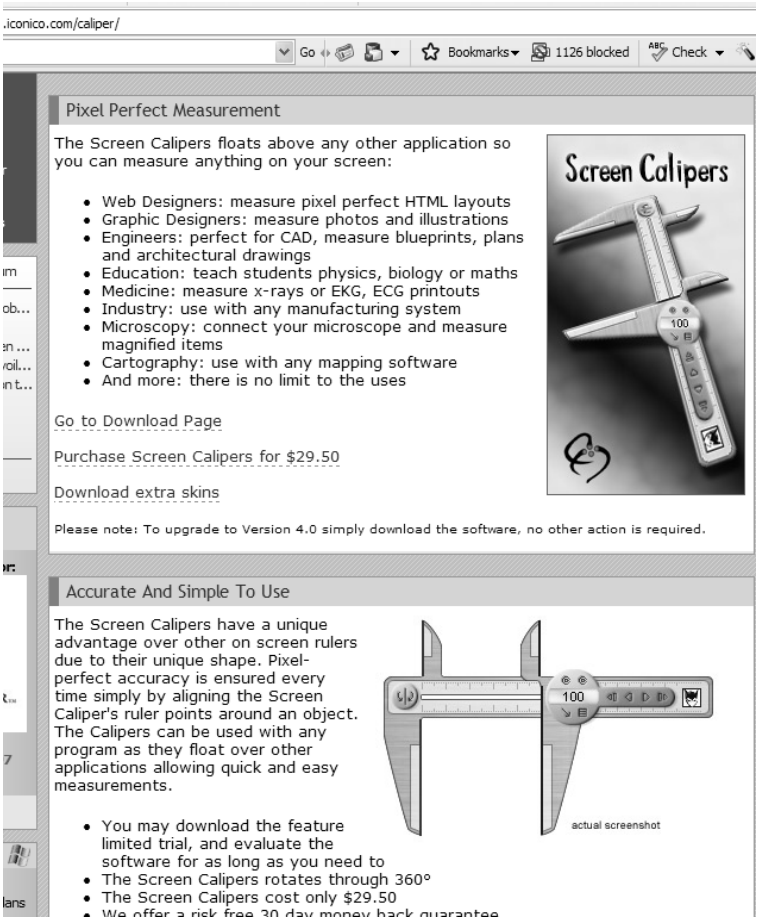
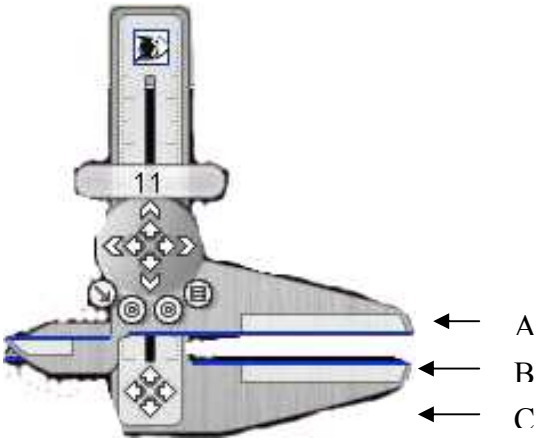
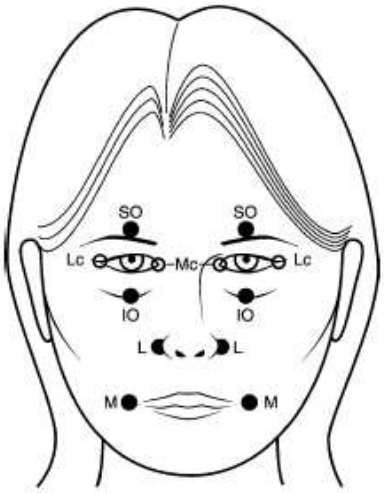


Figure 3.8 Screen Calipers website and image from Iconico.com

Figure 3.8 shows the Screen Calipers tool with 360 degree rotation that functions over any application on the computer screen, making it a versatile tool for any measuring needs. As the primary coder, I spent over 20 hours of initial training on the tool, practicing until random measurements yielded the same results when re-visited later. After this initial training, I had to spend about 2 hours of additional training for the next new consultant, and thereafter about 30 minutes of training was needed for each consultant to gain maximum

proficiency. The tool itself posed little problem for me, but applying it to a face objectively required time. The most time-consuming element was determining the exact points of reference for each specific face, an important component of an effective analysis. This research focuses specifically on measurements of eyebrows with respect to a set of reference points consistent for each signer and measurement in order to provide a comparison of the face uniformly across consultants in American Sign Language. The landmarks used for measurements are therefore crucial, and are described below in an enlarged example in Figure 3.9, with an image of the Screen Calipers tool near the image in Figure 3.7 from Clapham et al. (2006).





A: This corner was placed at the SO site

B: This line level was first aligned with the outer corner of the LC, and then the tip was placed at the midpoint of the eye when the eye was visible.

C: This corner contour was fit into the IO sac

Figure 3.9 Screen Calipers and facial landmarks

Figure 3.9 shows a visual representation of the eyebrow measurements. For each face, features were selected for a best fit on the similar landmarks as noted in Figure 3.7 to consistently place the tool. These landmarks are the SO (the middle upper eyebrow) and IO (the inferior skin fold below the orbital rim, in the middle edge of the infraorbital dark circles under the eye), with the lateral canthus or outer corner also used to situate the digital caliper tool. The goal was to measure from the bottom of the midpoint of the eyebrow to the point approximately at the level of the corner junction of the eye near the level of the lacrimal sac (measured from the outer part, the LC or lateral canthus), and the center of the pupil when looking straight ahead. The aperture corner of the tool was situated by the corner of the eye (B), and the lower end of the tool was situated at this IO sac (C), so accurate eyebrow measurements were possible whether the eyes were opened or closed, squinted or not. The upper line of the caliper tool (A) was placed at the SO site.

For each person, the Screen Calipers tool was used to measure this midpoint of the eyebrow and the center location as defined above. I practiced on each face until random samples were analyzed and repeated later with the same results based on the frame of reference established for each individual face. Once repeated measures were consistent (with an error of +/- 1 pixel less than 0.1% of the time), I was ready to record values. After each interruption from coding, it took between 5-10 minutes of re-training as determined by consistency of repeated measures.

For each sentence, I recorded measurements at intervals of at least 3 frames, and more often as necessary if the eyebrows were observed moving.

3.6.3 Selection of Renditions for Analysis

The first part of analysis was to select each rendition. There is a natural declination effect in phonetic analysis, not just in individual sentences, but also between renditions. The first rendition is often the strongest and the third starts to weaken in whatever effect, so following traditional phonetic analysis conventions, the second rendition was chosen unless it had to be discarded. Renditions were only discarded and a different one substituted if either the face was obstructed, a marker for question or emotion word was signed (which could then effect the extent to which emotion was shown on the face), or if the signer moved position briefly beyond what was figured in to analysis.

Because the face is not the only nonmanual channel, body movements had to be considered when assessing the reliability of data measurements for selection of sentences. Some elements of conversation such as yes/no questions are accompanied by a body lean. Consultants produced multiple renditions so that their gradient degrees of lean could be excluded if they were so extreme as to skew the measurement, and a different rendition could be chosen. A slight or typical body lean was tested for similar emotion against a non-body lean in same sentences of multiple subjects, and no pixel value influence was found. When the body lean was so extensive as to bring the signer's head over their knees, such as in an extra-excited version of

SURPRISE, this would produce a 1-2 pixel change, so these infrequent renditions were omitted in order to maintain accurate comparisons across sentences and signers. Over 98% of the time the second rendition was selected.

There is an optional question marker particle that can be affixed to the end of the sentence in a yes/no question, as discussed in Chapter 2, but its frequency of use varies by the signer's style and preference. The optional question marker can be emphatic and show eagerness to receive a response, or can be neutrally used to reinforce the nonmanual question signal. This question marker often accompanies a shift in expression to indicate doubt, changing the yes/no question to one overlapped with incredulity. For the purpose of this study, the question marker was not included in the sentences, and any renditions with a question marker were not selected.

To select the rendition, the exact time stamp was recorded from onset to offset. Onset was defined as the point where the sign reached its peak onset of production, often occurring following a blink, similar to the blinks observed in Grossman and Kegl (2006). Offset was the point where the emotion and sign began to decline to an end. As each rendition was selected, the card on the screen was viewed to ensure accuracy in recording the target emotion and sentence type of each sentence. This information was recorded in a separate column, later covered during the measurement phase of analysis so that I as the coder would not know the target emotion or sentence type.

3.6.4 Reliability of Coding

The subjects were viewed using a Compaq Presario notebook computer with a Flatron Wide Screen, and by enlarging the window in Adobe Premiere 6.0. A new project at 32 standard NTSC non-widescreen processing was opened and saved for all measurements of the one person so the counter numbers are consistent from rendition to rendition. The visible screenshot of the person seated 1.5 meters from the camera was 653 x 480 pixels in dimension on the screen. All but the face was covered on the computer screen, with the time stamp visible at the bottom of the window. I am the main coder who selected the renditions. I am a fluent hearing signer, signing ASL since age 5. I also received the highest score of ASL fluency on the Texas Assessment of Sign Communication-ASL, a measure of fluency conducted by native Deaf signers.

With computer technology it is possible to zoom in to the face to see as close a view as desired through Adobe Photoshop 3.0, but for the purpose of this study, I wanted to compare facial measurements relative to faces of other consultants, so the face needed to be the same size for each measurement. The screen was therefore expanded to the largest size possible, and all data were analyzed for each subject from the same screen size to ensure consistency in measurements. The exact measurements of the window as stated above were recorded and verified to be consistent for each saved file.

During analysis, I recorded measurements based on the video time stamp and without knowledge of the target emotion or sentence type for each sentence. As the primary coder, I recorded all measurements, and then a second non-signing coder trained on the tool and recorded a subset of measurements to provide additional verification of consistency in measurements of eyebrow movement.

3.6.5 Replicability of Measurements

The Screen Calipers tool provides an affordable and accessible method for objective measures against facial landmarks. On the question of replicability, while both coders made similar measurements in this study, it is possible in future studies that coders might train on the tool and produce different eyebrow ranges based on the exact manner in which they trained to align the tool to each face. These different ranges are still comparable across coders, however, because the proportionate range of eyebrow height should still be consistent. For example, if one coder shows Consultant X of a future study to range in pixel measurements from 2-14 pixels, and another coder shows a range of 4-16 pixels for the same consultant, there is still a consistent 12 pixel range observed from both coders. These values can then both be set to zero for a comparable analysis.

Conversely, while the six consultants in this study all produced eyebrow height ranges within 1-2 pixels of each other, it is possible that in a larger study or a study on a different facial or body feature there could be more variation of

ranges. In this case, values could be set to zero for comparisons of similar ranges. Finally, for different spreads of other facial features, the percent change could still be compared across individuals.

3.6.6 Statistical Tests for Results

The data was typed into Excel and then also placed into SPSS 14.0 GradPack version and SAS to generate charts for quantitative analysis. SAS constructed a Mixed Model based on the maximum, minimum, and onset values for each sentence out of a total of 270 sentences. Still images were captured in Adobe Premiere 6.0 and line drawing images were created using Adobe Photoshop Elements 3.0. Then, contour charts were generated using Excel. These include separating out wh-words that occur sentence-final, sentence-initial, and those that occur in both sentence-initial and sentence-final positions. The next chapter presents the results of this analysis.

CHAPTER 4

RESULTS

4.1 Introduction

This chapter presents the data and results of the study on eyebrow height in ASL questions and statements across four emotions and a neutral state. The first half of this chapter focuses on statistical results from a Mixed Model to show the interactions between question types and emotions, and the last half of this chapter focuses on contour charts of eyebrow height showing the dynamic changes across time in the sentences. This chapter addresses each research question, and then shows the details for eyebrow height patterns in ASL questions. The data show eyebrow height consistently distinguishes ASL sentence types through both timing and spread of raised and lowered eyebrows.

Section 4.2, “Organization of Statistical Data For Analysis” establishes the nature of the static data and demographics of Deaf consultants. Section 4.3, “Research Questions and Hypotheses” presents the goals of the study. Section 4.4, “Analysis of the Aggregate Data: 270 Sentences”, answers the research questions and examines the hypotheses. This includes the statistical results of a Mixed Model, and percentage changes in height for raised and lowered

eyebrows in both neutral and emotional question types and statements. Also, the categorical distinctions are highlighted between question types in the emotional states in the data.

Section 4.5, “Contour Data: Eyebrow Height by Frames”, displays contour charts of eyebrow height with data points in increments of every three frames (0.1 seconds per three frames), showing the dynamic changes in raised and lowered eyebrows for each sentence. The data also include a set (Set 3) with a sentence-initial topic in the question types and emotional states for analysis. The data show three types of wh-lowering spread in wh-questions, and similar spread in yes/no questions.

Section 4.6, “Comparisons for Intent in Questions: Categorical Distinctions Remain Despite Emotions”, addresses whether wh-words always receive lowered eyebrows, and discusses the difference between furrowed and lowered eyebrows in the data. Section 4.7, “Summary of Findings”, ends the chapter with a detailed overview of the results of the investigation.

4.2 Organization of Statistical Data Analysis

As discussed in the methodology, the data were analyzed for eyebrow height at least every three frames. Statistical analysis was performed on results of the onset, maximum (MAX), and minimum (MIN) height per sentence. Onset was generally the same as the maximum or highest pixel measurement. Statistically significant findings were generally the same for all three measures,

but maximum proved more determinative in some cases as discussed in detail in this section, so charts generally display the maximum values and means of maximum values.

4.2.1 Consultant Demographics

The six consultants were each at least second generation Deaf, with one consultant fourth generation Deaf. All consultants indicated ASL was their first language, and that they learned it from their parents and family at home from a young age. Consultants were ages 21-51, and there were two males and four females. All six had finished some college. Two consultants were current college students, three had graduated from Gallaudet University, and one of the consultants was a professor with an advanced degree.

4.2.2 Ranges of Eyebrow Height the Same in both Natural and Elicited Data

For comparison within signers, each consultant produced the same range of eyebrow height in the natural as well as elicited data, as expected. For comparisons across signers, before collecting the data I imagined that consultants would show great variety in pixel ranges because of different physiological variation across individuals. For example, it was assumed that one signer might range from 5-16 pixels when signing while another might range from 1-10 pixels. Instead, as seen in Table 4.1, all six consultants (C) ranged within 1-3 pixels of each other for both maximum and minimum height levels.

Table 4.1 Eyebrow Height Ranges for Each Signer from Both Natural and Elicited Data

	Minimum Eyebrow Height in Pixels	Maximum Eyebrow Height in Pixels
C1	1	13
C2	3	15
C3	1	13
C4	2	13
C5	1	13
C6	2	14

Table 4.1 shows the range in eyebrow height measurements for each consultant. 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. Consultants 1, 3, and 5 all range from 1-13 pixels for eyebrow height when signing. Consultant 4 has the same maximum of 13, but lowers to a minimum of only 2 pixels. Consultant 6 raises the minimum-maximum span by one pixel, going from 2-14, and finally Consultant 2 raises the span one further pixel, varying height from 3-15 pixels.

I initially planned to take the raw eyebrow height measurements and set every lowest consultant minimum value to zero. This would provide a zero baseline for comparison across subjects with large differences, and would limit

the results to only compare the range of production between signers rather than both the range and the physical eyebrow heights. Because of these similar ranges and raw scores, however, I decided against adjusting for physiological variation and instead performed more exact statistical tests by using only the raw pixel measurements. These raw values of eyebrow height are used in all statistical tests and contour charts in this dissertation.

4.3 Research Questions and Hypotheses

There are three research questions for this investigation. First, does eyebrow height play a role in misunderstandings of ASL questions? Second, to what degree does eyebrow height distinguish between question types in ASL? Third, how does the addition of emotion alter any linguistic eyebrow behavior in ASL questions?

Hypothesis 0 - (null hypothesis)	There is no change in eyebrow height across neutral questions or statements, nor across questions or statements in happy, sad, angry, and surprise states.
Hypothesis 1-	There are statistically significant distinctions from maximum and minimum eyebrow heights between question types, and also between questions and statements.
Hypothesis 2-	Despite the addition of emotion, these significant distinctions, if any, remain for all sentence types.
Hypothesis 3-	The question type determines the eyebrow height range, and emotions rank sentences only within this set range: emotions are expressed within the highest range for yes/no questions,

the middle range for statements, and lowest range for wh-questions.

4.4 Analysis of Aggregate Data: 270 Sentences

The boxplot in figure 4.1 is a visual representation of the means of the statistical data from a Mixed Methods test using SAS from all six consultants and 270 signed sentences (90 for each sentence type).

4.4.1 Research Question 1

In figure 4.1, each bar represents a sentence type. For each emotional column, the left edge is the range of means for all yes/no question maximum heights, the center bar represents statements, and the right edge of the column is for wh-questions. These bars show how high the eyebrows raise for each type or emotion in sentences. The minimum heights, or how low the eyebrows go in each sentence, also follow the same pattern, just with lower pixel values.

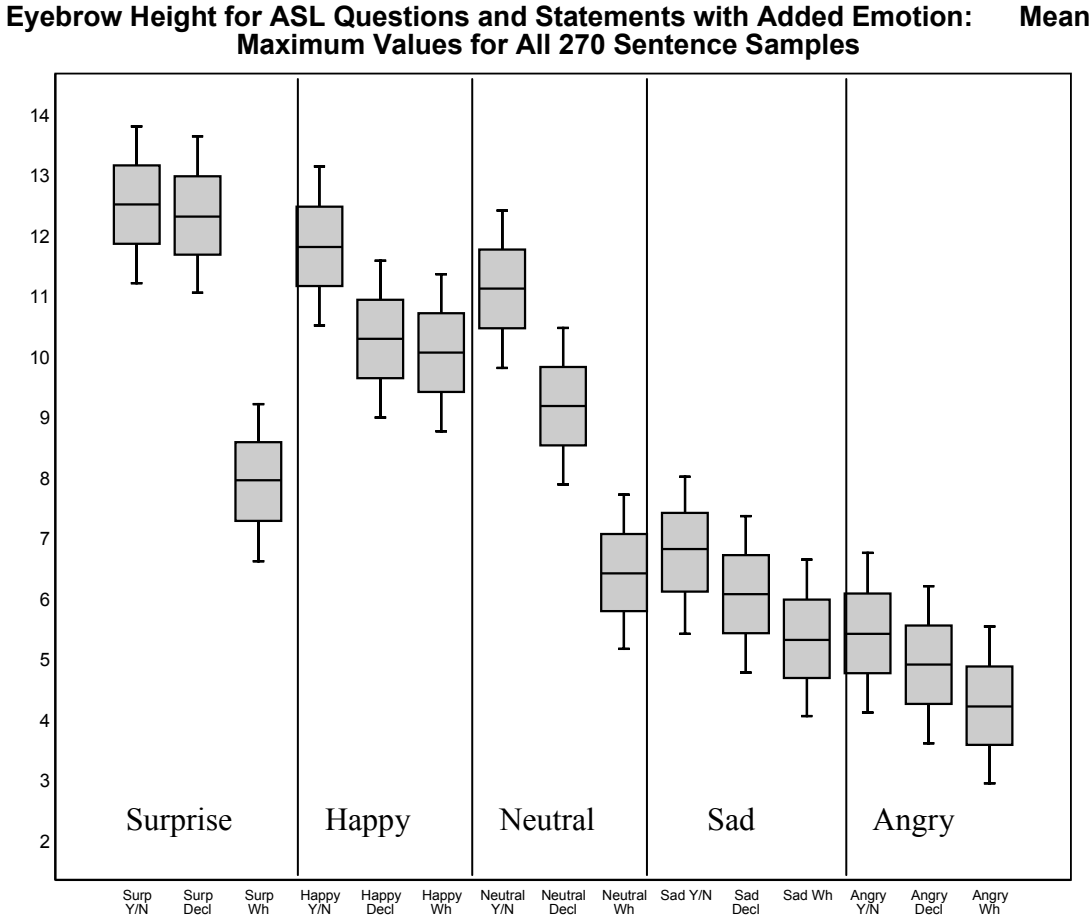


Figure 4.1 Eyebrow height for yes/no questions (Y/N), wh-questions (WH) and statements (DECL): Means across emotions for all 270 consultant sentences

Research Question 1: Does eyebrow height play a role in misunderstandings of ASL questions? When we look at the boxes in figure 4.1, immediately we see that the answer is yes, there are several ways eyebrow height contributes to misunderstandings in ASL questions. To answer this first question, I will discuss the overall patterns seen through figure 4.1.

One observation is that angry and sad are tightly distributed for all question types. An angry yes/no question (brows lower for angry, raise for the yes/no question) is about as low in height as a sad wh-question (where brows also lower). A sad wh-question is generally accompanied by brow furrowing in the data, so it could more easily be mistaken for an angry expression. A sentence could easily be misread because the same series of signs could produce both of these sentence-types by only changing the facial nonmanuals. For example, suppose a Deaf person is interviewed by an officer. Signing only SAY ME DO, this person could be sad and asking “What are you saying I did?”, distraught at being questioned by the police. This could then be mistaken for an angry yes/no question such as “Are you saying I did it?”, from the exact same signs, leading the interviewer to mistakenly conclude the Deaf person is defensive or confrontational.

Also from figure 4.1 we see that a sad statement is similar in range to a neutral wh-question, therefore a person could be asking a neutral content question but be misunderstood as making a sad statement based on how high the eyebrows rise in the sentence. In interpreting situations, Deaf individuals often must re-state questions in order to obtain information, or miss out on the content, all because the interpreter misinterprets the question as a statement.

If a question is stated as a statement by mistake this can cause problems, such as with the overlap in eyebrow height seen in figure 4.1 between a neutral yes/no question and a happy statement. For example, in a

business setting, an employer might tell a Deaf individual to “Finish the project today”. The Deaf person might then ask in a neutral state “When I’m finished, can I leave?” with the signs FINISH GO-OUT. An interpreter focused on overall eyebrow height alone might misunderstand this neutral question as a happy statement, and translate these same signs, with different perceived nonmanuals, to be said in a happy state as “When I’m finished, I’m leaving.” This interpretation would most certainly leave a negative impression on the employer, to the detriment of the career of the Deaf employee.

4.4.1.1 Misunderstandings Based on Expectations of Extreme Highs and Lows

Looking at the overall distribution in figure 4.1, it becomes apparent why traditional teaching, focused on neutral, often demonstrates raised or lowered eyebrows in questions with examples of usually the highest highs and lowest lows in videotexts. This teaching is based on the impressions from neutral, and the results show the reason for such an impression as the bars demonstrate a wider spread than the ranges for sentence types of emotions in the data.

The percent differences from neutral shows this in detail and reveals how high or low the eyebrows move for each sentence type and emotion. The neutral sentence types have the largest percent difference between each type, or the largest spread between each type, with a 21% increase in eyebrow height (+1.9 px) to change from a neutral statement to a neutral yes/no questions, and a 30% decrease in eyebrow height (-2.8 px) to change from a neutral statement to a neutral wh-question. The difference from neutral yes/no

questions to neutral wh-questions is a larger difference than for any other emotion, with a 42% change in eyebrow height between these neutral question types.

Now compare the large changes in neutral with a much more limited range of results for angry. Wh-questions lower only 14% on average from angry statements, (-0.7 px) and yes/no questions raise only 9% (+0.5 px). To compare all emotional states from neutral statements, however, question distinctions produce more variable results. In figure 4.2, the percent change from a neutral statement is listed for every emotion and sentence type.

Table 4.2 Percent Differential from Neutral Statement

	Statements	Yes/No Questions	Wh-Questions
Surprise	+3.1 px, 34%	+3.3 px, 36%	-1.3 px, 14%
Happy	+1.1 px, 12%	+2.6 px, 28%	+0.8 px, 9%
Neutral	9.2 px, baseline	+1.9 px, 21%	-2.8 px, 30%
Sad	-3.1 px, 34%	-2.4 px, 26%	-3.9 px, 42%
Angry	-4.3 px, 47%	-3.8 px, 41%	-5.0 px, 54%

Table 4.2 starts with a neutral statement as a base line at 9.2 pixels average across the data, and then shows the percent change and pixel values for raised or lowered eyebrows from neutral. For neutral, we notice that

eyebrows on average are not raised to the highest high value for yes/no questions, nor are they lowered to the lowest high value for wh-questions. Instead, there is a range of raised and lowered eyebrows, also visible in the boxes of figure 4.1.

When ASL learners or interpreters are expecting to see strongly raised eyebrows and strongly lowered eyebrows for the respective question types, then the learner may not readily catch the less dramatic changes encountered in the majority of sentences in emotional states. In fact, the three values in the squares for figure 4.2 show exceptions to this overall height rule. While yes/no questions show that eyebrows are generally raised from neutral in this question type, both sad and angry on average show a lower height than neutral, despite the interrogative nature of the question. They are both lowered less than sad and angry statements (and therefore raised relative to their respective statement values), but may still give the impression of an overall lowering from neutral. Also, while wh-questions generally pattern to lower the eyebrows from neutral conversation, for a happy emotional state, the eyebrow height is instead raised from neutral. This wh-question height is still not as high as the yes/no or statement height for the emotion, but it is still at a raised value from neutral.

The change in eyebrow height from neutral conversation ranges from a 54% change in eyebrow height to create an angry wh-question, to only a 9% change in eyebrow height from neutral for a happy wh-question. Sensing emotional states is a natural process, but these linguistic ranges of production

across emotions can blur the distinction between grammar and affect for ASL learners. The maximum and minimum levels of eyebrow height in a sentence do not consistently distinguish all questions and statements relative to neutral conversation. Instead, ASL questions raise or lower the brows by a percentage relative more to the emotional state of the conversation rather than to the brow height in a neutral statement.

The average brow levels only statistically distinguish yes/no from wh-questions, not either question type from statements. The highest high and lowest low point, then, can be an indicator of question type across emotional states, but not a definitive way to ensure comprehension of the correct sentence type. Consistent distinctions are still made through eyebrow height, however, and will be seen in section 4.5 on the contour chart data.

4.4.2 Research Question 2

Research Question 2: To what degree does eyebrow height distinguish between question types in ASL?

Eyebrow height makes many distinctions between question types in ASL. This section discusses differences based on the statistical results, and the next section will show distinctions over the sentence contour.

From the Difference of Least Squares Means tests, the statistical analysis shows that onset, maximum, and minimum values all distinguish yes/no questions from wh-questions with a statistically significant difference of $p<.05$ in the data across all emotions. Yes/no questions, therefore, are raised

higher than wh-questions, based on their position at the onset of the constituent, and also based on the highest high and lowest low height in the sentence. Between yes/no questions and statements, and wh-questions and statements, however, there was no difference for these static values, with p=.4173 and p=.0880 respectively. The exception to this is in Set 3 with a sentence-initial topic, where wh-questions are distinct from statements with a $p<.05$.

At this point we can also examine some of the hypotheses for the study. The null hypothesis, that there is no change in eyebrow height across neutral questions or statements, nor across questions or statements in happy, sad, angry, and surprise, can be rejected.

Hypothesis 1- There are statistically significant distinctions from maximum and minimum eyebrow heights between question types, and also between questions and statements.

We must fail to reject the first part of hypothesis 1, because there are statistically significant distinctions between question types, but we must reject the second part, because there is no statistically significant distinction between questions and statements in the static max and min data (with the exception of data with a sentence-initial topic, which then does distinguish wh-questions and statements).

Hypothesis 2- Despite the addition of emotion, these significant distinctions, if any, remain for all sentence types. We can fail to reject

hypothesis 2 because the distinctions that exist between question types do remain despite the addition of emotion. The remaining statistical data and contour charts will help clarify the exact nature of these and other distinctions made through eyebrow height.

4.4.3 Research Question 3

Research Question 3: How does the addition of emotion alter any linguistic eyebrow behavior in ASL questions? To further understand how emotion might impact questions in ASL, we examine hypothesis 3.

Hypothesis 3-The question type determines the eyebrow height range, and emotions rank sentences only within this set range: emotions are expressed within the highest range for yes/no questions, the middle range for statements, and lowest range for wh-questions. The data organized in the reverse of my assumption, therefore H3 must be rejected. The emotions do not fit within a yes/no or wh-question range, but instead, the emotions determine the eyebrow height range, and then the question types make categorical grammatical distinctions between each other within this emotional range, as explained below.

4.4.4 Yes/No and Wh-Question Eyebrow Height across Emotions: Assumptions

Prior to data analysis I assumed that the raised eyebrows in yes/no questions would stay raised within the upper one third range for eyebrow height of a signer but vary within this range based on the emotions. For example, for yes/no questions, neutral raised eyebrows would be further raised for positive

emotions surprise and happy, and lowered from neutral for negative emotions angry and sad, but still within the upper range of yes/no question height. Conversely, I assumed the lowered eyebrows in wh-questions would remain within the lowest third of the range of eyebrow height for a given signer, and that positive emotions would show eyebrow heights in the upper part of this lowered range, while negative emotions would fall within the lowest pixel values for wh-questions. Also, statements would fall in between these question types, and the emotions would vary within this statement range. Figure 4.3 shows my initial assumptions of how eyebrow height would be organized across sentence types when emotion was added to the statements and questions.

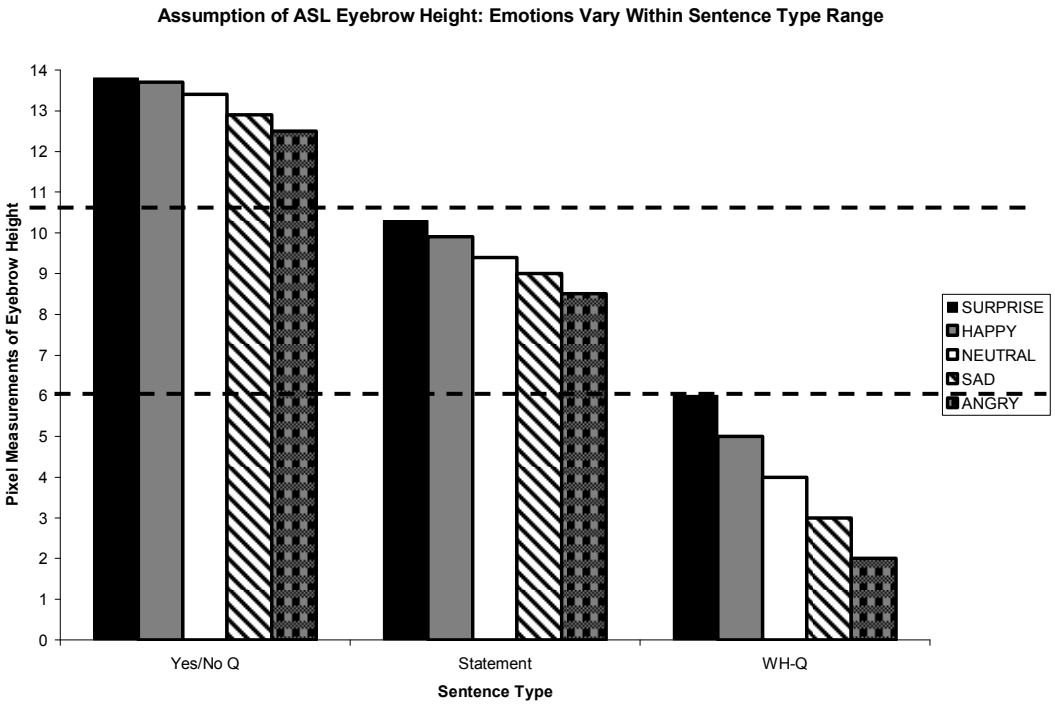


Figure 4.2 Assumption of eyebrow height organization in ASL by sentence type and emotion

In Figure 4.2, the horizontal lines represent approximate levels where I assumed categorical distinctions might occur between question types, regardless of emotional state. I expected sentence types to maintain these ranges and emotion to influence eyebrow height only within the sentence type ranges. These assumptions are based on the teaching of eyebrows "raised" in yes/no questions and "lowered" in wh-questions, where often extreme examples are displayed, with eyebrows furrowed and very low in height for wh-questions, and eyebrows raised to maximum for yes/no questions. If the data fit with the assumptions in figure 4.2, therefore, effective lessons on ASL questions should follow traditional teaching that demonstrates extreme raised and lowered eyebrows, regardless of emotions. In this case, emotions would influence the eyebrow height, if at all, only inside the raised or lowered levels.

4.4.5 Yes/No and Wh-Question Eyebrow Height across Emotions: The Data

Instead, the data show the organization is the reverse of figure 4.2. Eyebrows do organize between the sentence types and the emotions, but in a reverse manner than what was predicted based on eyebrow height. Figure 4.3 shows how the data organize eyebrow height for ASL sentence types when emotion is added to neutral statements and questions.

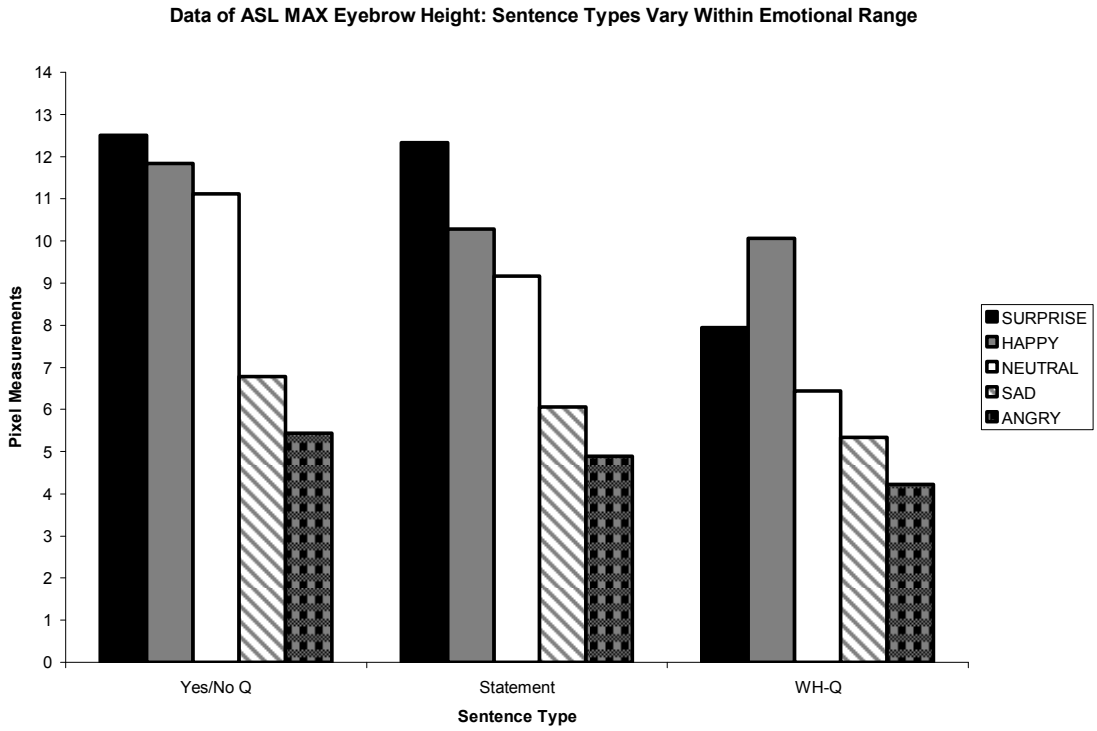


Figure 4.3 Results from the data: Sentence types vary within emotional range

Rather than emotions varying within a range of sentence types for eyebrow height, the data show sentence types varying within emotional ranges of eyebrow height. Figure 4.2 shows the mean maximum values across all 270 sentences. The yes/no question maximum values were always higher than the wh-question maximum values for a given emotion, and the wh-question measurements of maximum height were always in the lowest range for each emotion when compared to yes/no questions in this aggregate mean data. Statements were between these question types. Furthermore, the individual data in section 4.3 also show the maximum values for each sentence often

following this pattern, where yes/no questions raise the highest, then statements, then wh-questions that raise to the lowest maximum, but not 100% of the time.

4.4.5.1 Categorical Distinctions: Sad and Angry Separate from Positive Emotions

Eyebrow height makes categorical distinctions to rank the negative emotions sad and angry together as lower than the other emotions, as seen in figure 4.4. These type by emotion results show a $p<.05$ difference exists between sad and angry and all emotions above the dotted line, with the exception of the two center values in the box. Except for these two, the emotions happy, surprise and neutral are all statistically ranked with a $p<.05$ from sad and angry, in all sentence types. There were several other categorical separations between the questions and statements across different emotions, but no clear pattern emerged from these further distinctions. These data are listed in Appendix A. Figure 4.4 shows this categorical ranking of negative emotions from positive emotions.

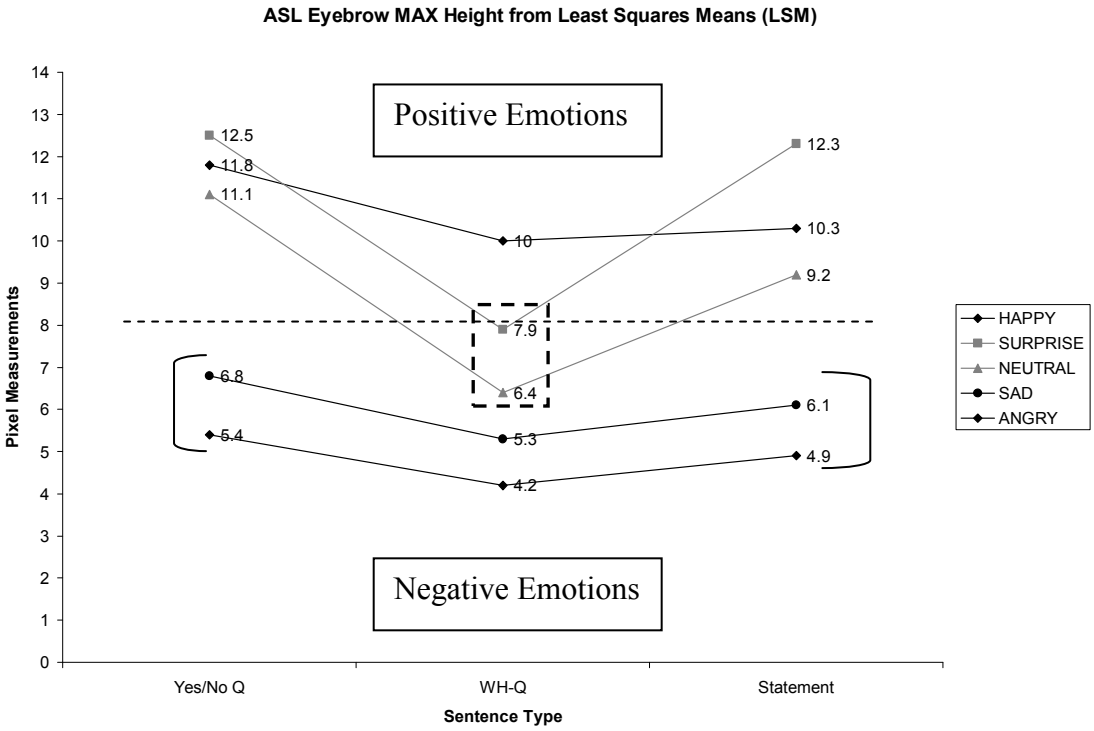


Figure 4.4 Categorical distinctions: Sad and angry different from positive emotions

Figure 4.4 shows the difference in mean eyebrow maximum values for eyebrow height. Minimum and onset values are also the same categorically for the three sentence types across the same data set of emotions.

There are type-by-emotion interactions which demonstrate emotions do indeed influence the linguistic question distinctions. All five emotions are statistically significant $p<.05$ from each other, except for surprise and happy. Surprise and happy show no difference ($p=.9632$). Angry and Sad show $p=.0010$, and all other emotions show $p<.0001$ from each other. Therefore, there is generally no difference between angry and sad for eyebrow height, but

these negative emotions do show a statistical difference between most of the positive emotions.

The two values in the box in figure 4.4 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 difference for all of the comparisons except two, therefore they had to be excluded from the grouping. The two instances where these values did not categorically rank were when these wh-questions for surprise and neutral were compared against neutral statements and when they were compared to each other. It is possible a larger study could resolve these exceptions and show they too will fit into the categorical ranking.

The type-by-emotion data for topics in Set 3 is now listed separately here for a comparison. These results of eyebrow height over the initial topic are not included in the static images assessed figure 4.4. For the maximum, onset, and minimum values over topics, only a few emotions were different from each other statistically over the topics, but no clear pattern emerged, suggesting that the ranking of emotions is not as salient in topics, and the linguistic topic marker impacts sentences differently than the linguistic question marker of eyebrow height. For topics, only negative emotions create any difference: happy and angry, happy and sad, surprise and angry, surprise and sad, neutral and angry, and sad and angry are all different from each other, but all other pairs show no statistical difference over topics in the data. This is in contrast to Sets 1, 2, and

the non-topic maximum for Set 3, where all emotions are statistically different from each other in all cases except for happy and surprise.

4.4.6 The Mixed Model Test

These statistical results display the Least Squares Means from the Mixed Model analysis of MAX values for sentences from Set 1, Set 2, and Set 3 after the topic portion

From a Type 3 Tests of Fixed Effects, there was no type-by-set (type * set) interaction, so for the MAX values in Sets 1, 2, and 3 (with maximums after the topic portion for Set 3) there was a type-by-emotion effect of $p<.0001$. For the topic portion, however, there was no type-by-emotion effect ($p>.05$). There was also no emotion-by-set (emotion * set) interaction.

Also, there was no difference or sentence effect in results between sets 1 and 2 and sets 1 and 3. Set 2 and 3 showed a $p<.028$ difference. This is potentially an effect of the topic in initial position in Set 3. The max value was recorded after the topic, and it is possible the height of raised eyebrows over the topic constituent resulted in an alteration or overall slight rise in height over the comment portion. If this were true, it means this difference created by the topic would not be as strong between sentence sets 1 and 3.

4.4.7 Overall Means for Eyebrows in all 270 Sentences, and for all Emotional States

Table 4.3 shows the range of means for each sentence type and each emotional eyebrow height across sentences.

Table 4.3 (Least Squares Means MIN and MAX) Ranges of Means for All Subjects

	Lower Means	Upper Means
Y/N	8.0	9.5
Statement	7.0	8.5
Wh-Q	5.4	6.8
Surprise	9.4	10.9
Happy	9.0	10.7
Neutral	7.5	8.9
Sad	4.7	6.1
Angry	3.4	4.9

Table 4.3 shows the overall ranges for each effect, either sentence type or emotion. The mean values of yes/no questions range from 8 to 9.5 pixels in eyebrow height. Means for statements range from 7 to 8.5, and wh-questions from 5.4 to 6.8. These values represent averages in order to make a control comparison for eyebrow height, as seen in figure 4.5.

4.4.8 Control Comparison: Eyebrows from Six Deaf Signers Different than Hearing Non-Signer

A control comparison was also conducted of one hearing non-signer speaking the sets to test whether the sentence type categorical distinctions between yes/no and wh-questions would exist in eyebrow height of speakers in spoken languages too as some type of universal effect, or whether it was

indeed a linguistic phenomenon in ASL. As assumed, this effect was not seen for hearing non-signers (HNS) speaking English. Figure 4.5 shows the mean values for the HNS compared to means of all six Deaf signing consultants.

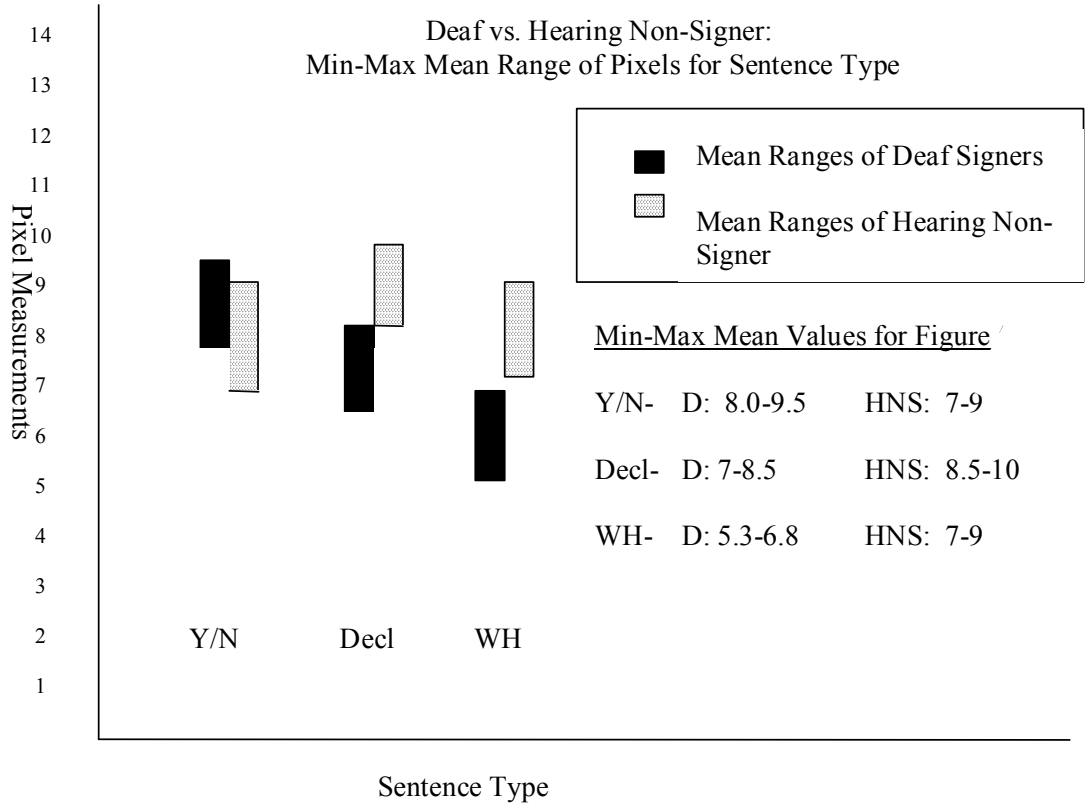


Figure 4.5 Control comparison, Deaf vs. hearing non-signer eyebrow heights

Figure 4.5 shows the total mean for all emotional states for each question type. The results from the six Deaf Consultants are in black, and the one hearing non-signer (HNS) is the patterned result. In these data, the hearing non-signer statements are on average 1.5-2 pixels higher than both question types, and both question types show no difference in average eyebrow

height. In contrast, all Deaf signers on average across all emotions maintain about 1 pixel higher for yes/no questions than statements, and 1.5-3 pixel difference between statements and wh-questions. This shows that Deaf signers make distinctions between question types in a manner not seen in eyebrow height of the hearing non-signer.

Another finding in this comparison is that while HNS do not make the same question distinctions for linguistic eyebrow height as Deaf signers, HNS do make the same emotional distinctions across all sentence types. The universal nature of emotions (Ekman 1972) are apparent in these data, as hearing speakers of English show the negative emotions sad and angry statistically lower than (most) other positive emotions, in a similar way as the Deaf signers rank emotions through eyebrow height. This is further evidence of the difference between language and emotion on the face in ASL.

4.4.9 Control Comparison: Eyebrow Movement in a Hearing Non-Signer vs. Pitch

An ancillary comparison was also conducted for control to determine if the hearing non-signer eyebrows are raising and lowering according to the rises and falls in spoken English intonation. The results are in figure 4.6.

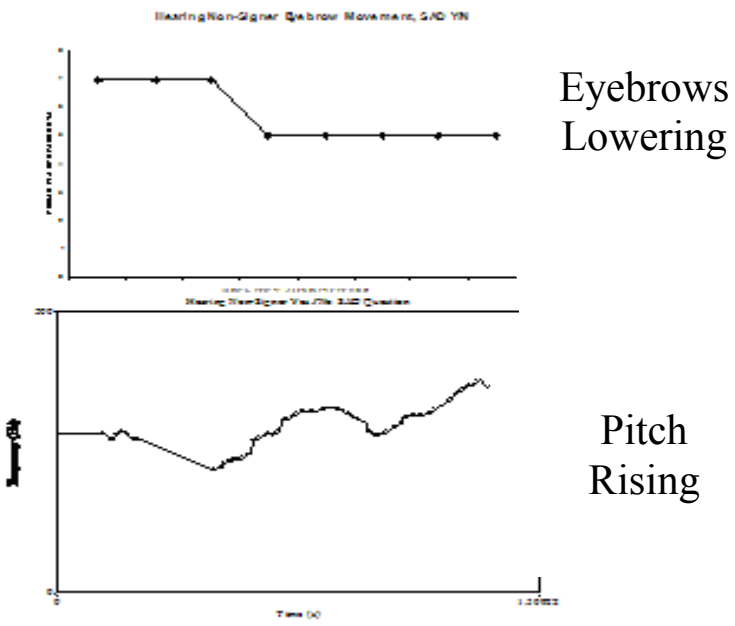


Figure 4.6 Control comparison: Hearing non-signer eyebrows do not correlate with pitch

In figure 4.6, we see the results of an extraction I performed using Praat to generate the pitch contour of an English yes/no question in a sad state with a rising intonation while eyebrows show a falling declination. This demonstrates that contours for eyebrow heights are not only different between hearing speakers and Deaf signers, the eyebrow heights are also different from the rises and falls in pitch for speakers of English.

4.5 Contour Data: Eyebrow Heights by Frames

In addition to aggregate statistical data based on single values such as maximum and minimum eyebrow height, I also charted eyebrow height at least

every three frames in order to present contour charts over a timed series. This included over 3500 pixel measurements from 270 sentences. This section summarizes the findings from the contour data, beginning with statements from Consultant 1 in Figure 4.7.

Contour charts are all set to a 14 pixel range on the y axis, for consistent comparisons across charts. The x-axis timeline is set to consistent intervals of one tenth (0.1) of a second per unit (3 frames per unit). The number of these units, however, varies based on the length of the sentences for each chart. Because these contours allow an examination of dynamic changes across the entire sentence, it is important to fit the entire sentence into charts, so this variable timeline length along the x-axis allows consistent comparisons of entire sentence contours.

The patterns discussed in this section appear in all six signers unless otherwise specified. There are differences in the number of pixels raised or lowered based on individual signing style, but the overall movement still patterns in similar ways. To see the role of eyebrow height beyond just the maximum and minimum values, we need to examine the pattern across the sentences.

4.5.1. Eyebrow Height Changes at Lexical Boundary or With Lexical Movements

One observation from the data concerns the timing of eyebrow changes. Eyebrow height changes regularly keep in timing with lexical movements. When a new sign begins there is often a transition frame, but the new eyebrow

height, when shifting, always coincides with the onset of the new sign, or with the onset or completion of a specific part of the sign movement. For example, shifting from RAIN to NOW, when the hands rise from the lowered RAIN position to form the initial hand shapes for NOW, the transition begins, and as the hands rise when forming the NOW hand shape, before lowering in NOW, eyebrows often raise at least one pixel.

Once the sign NOW finishes its move to a waist level position, at the precise frame of arrival, the eyebrows frequently lower. I say frequently because this is not an obligatory movement. One reason the eyebrows lower over the second part of NOW is because of stress or an emphasis on the sign. This type of stress generates a more rapid movement with increased tension (Wilbur 1994), seen in the data when the signer wanted to stress this particular sign. Also while the eyebrows may lower at this precise moment, in other instances, the eyebrows raise as the sign is lowered to waist position, such as during the end of a yes/no question.

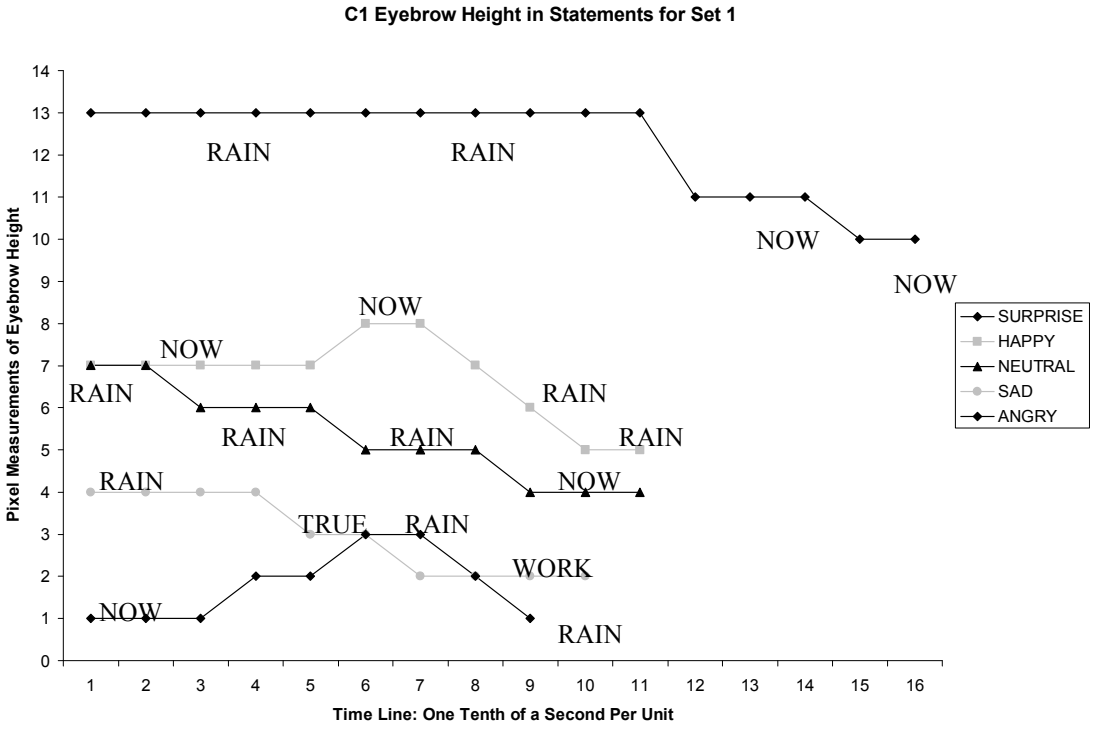
While the above examples occur intermittently, one lexical attachment of lowered eyebrows occurs with regularity: the lowering over every instance of the fingerspelled loan sign #WHEN. This sign is used by two consultants as their preferred wh-word for Set 3. For both consultants, the eyebrow height made a sudden shift of at least 1 pixel lower over the final part of the sign, the letter N. This occurred in every appearance of the sign in the data, including not only the fifteen analyzed sentences from Set 3 for each consultant, but also

in each of the three renditions from which the analyzed set was selected. This lexical attachment of eyebrow lowering, as it patterns in the data, is then bound to the sign in much the same way as the tongue protrusion is bound to the sign NOT-YET discussed in Chapter 1.

Another example of eyebrow height shifting at lexemes is seen in the expression angry in figure 4.6. The compound sign TRUE+WORK shows eyebrow height changing at exactly the moment of sign production for each sign, from TRUE at 3 pixels, to the first WORK at 2 pixels, and the repeated WORK at 1 pixel.

4.5.2 Contours in Statements

Figure 4.7 from Consultant 1 shows statements for Set 1 across four emotional states and neutral. One general observation in the data is that the positive emotions happy and surprise tend to produce the longest sentences, while angry tends to produce the shortest sentences.



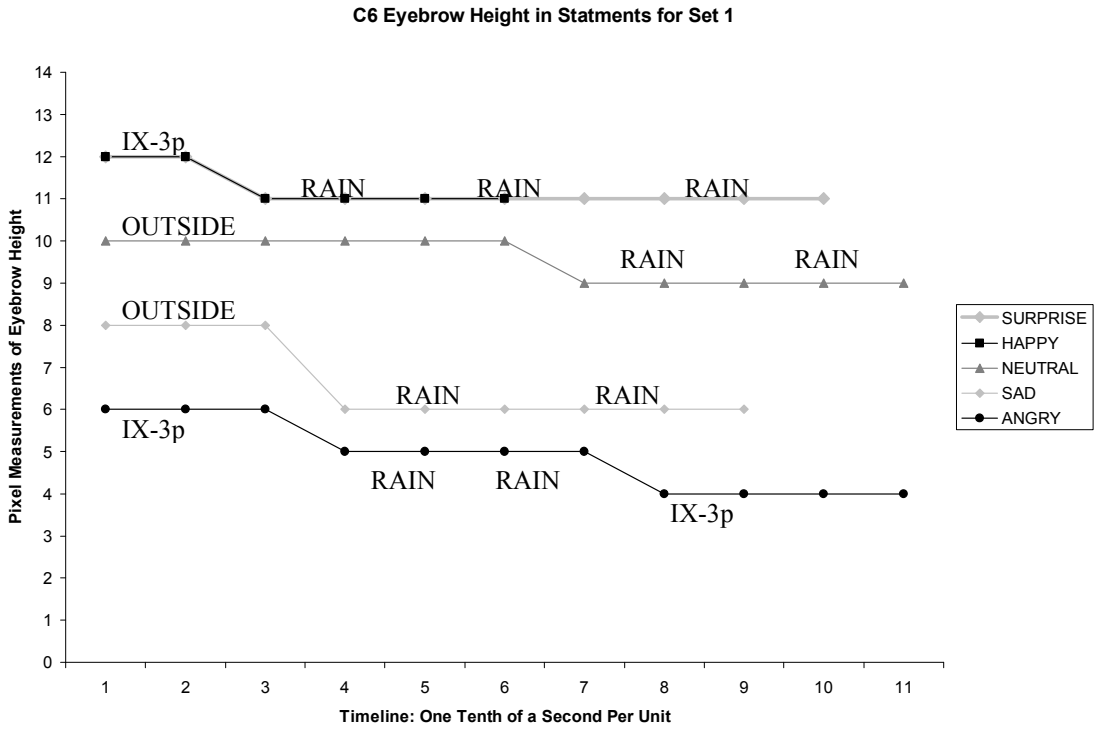
English translation: “It is raining now.”

Figure 4.7 C1 Eyebrow height in statements for Set 1: Declination effect

Figure 4.7 shows declarative examples with statements from Set 1. This chart shows five sentences. With few exceptions, the 270 sentences, including these five in figure 4.7, each started and ended with an eye blink, as discussed in the ASL literature (Baker and Padden 1978, Brentari 1998). Every point on the contour represents three frames. This chart is representative of patterns observed in contours over all statements in the data. Contour lines range from highest to lowest based on these emotions, but with this detailed examination, further detail is now seen.

The first observation is a declination effect, where the sentences begin at or near the highest value in eyebrow height, and then gradually arrive at the lowest height in sentence-final position. Also, notice that both happy and angry have a rise in sentence-medial position. This often occurs in statements, (but not in both question types where instead a lowering is observed). There may be a rise sentence-medial in most statements, but there will always be at least a 1 pixel fall (and often a 2-3 pixel fall) by the end of statements in the data.

Statements also have the greatest range of height in general, as both question types are produced in tighter distribution in comparison (a smaller pixel range for sentences). Consultant 1 is a female signer, so figure 4.8 includes an example from a male signer, Consultant 6.



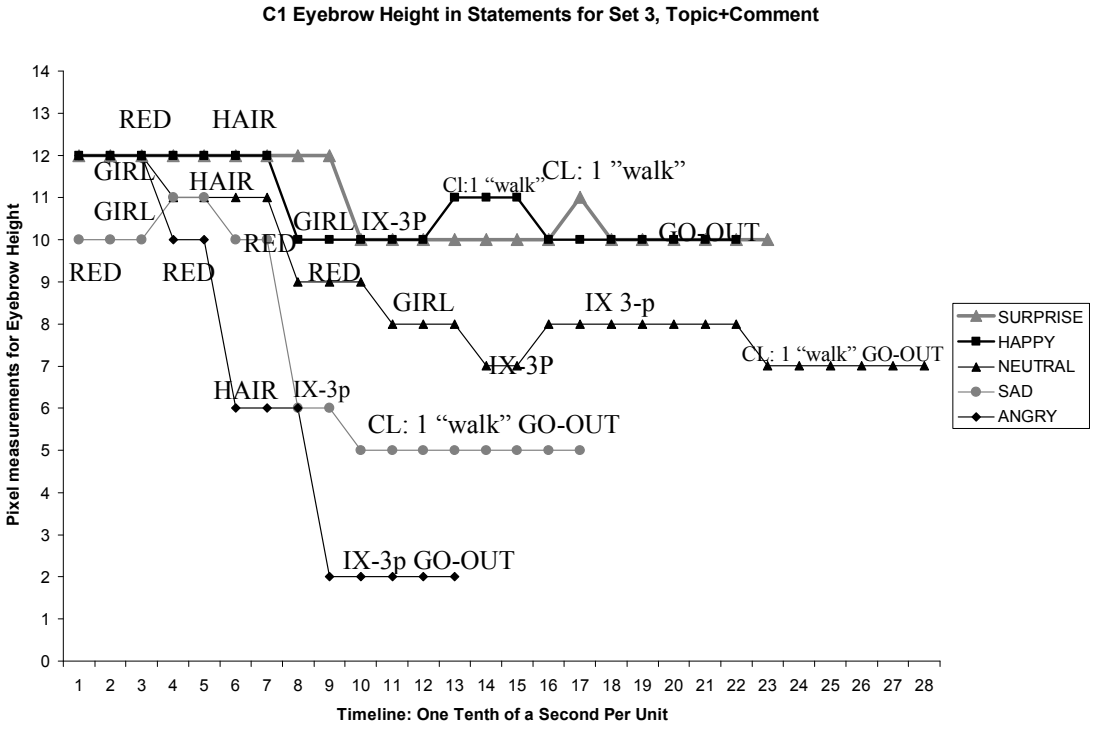
English Translation: “It is raining outside/there.”

Figure 4.8 C6 Eyebrow height in statements for Set 1, Declination effect

Figure 4.8 shows the same Set 1 statements as Figure 4.6 but with a male signer. Notice there is still a lowering or declination effect over the sentence of at least 1 pixel difference (and often two pixels). Signers may have variations in arriving at maximums or minimums, but the patterns are still comparable across signers. This consultant in figure 4.8 shows a declination effect across all emotions, and also changes in eyebrow height that consistently correlate with lexical boundaries or lexical movement.

4.5.2.1 Statements with Sentence-Initial Topics

Topics occur in sentence-initial position in ASL, and set 3 includes a sentence-initial topic.



English Translation: "The red-headed girl is going out."

Figure 4.9 C1, Set 3 Eyebrow height in statements with sentence-initial topics

Figure 4.9 shows a yes/no question with a sentence-initial topic. Topics employ raised eyebrows, shown by the tight three-pixel distribution in sentence-initial position (10-12 pixels) for all five sentences, and the abrupt drop after the topic construction for the emotions. Most of Set 3 sentences maintained near-maximum raised eyebrow height during these topic constructions. When the

topic is over, the comment portion shows a similar declination as seen in statements without a sentence-initial topic.

4.5.3 Contours for Wh-Questions: Three Types of Wh-Lowering

Contour charting of eyebrow height reveals patterns not seen for questions in the statistical tests discussed in Section 4.4. With these dynamic measurements, a more complete picture emerges. For wh-questions, this includes differences in eyebrow height based on the position of and presence or absence of wh-words in the sentence, and reveals three types of wh-lowering: lexical wh-lowering, narrow spread of wh-lowering, and broad spread of wh-lowering. These are seen through a closer look at wh-questions with wh-words in either sentence-initial position, sentence-final position, or in bracing with both positions, and when seen in these positions with a sentence-initial topic.

4.5.3.1 Distribution of Wh-Question Words in the Data

The modified data elicitation allowed signers to finish each sentence as they felt most comfortable. Signers could choose which wh-word sign to use when a particular word has multiple possible signs (such as WHEN). Signers were also able to slightly add to or modify the script as long as the key signs were included. This resulted in all three types of wh-question positions for wh-words: an initial wh-word as the only wh-word in the sentence, sentences with only a wh-word in sentence-final position, or a bracing form with sentence-initial and sentence-final wh-words. Although the scripted sheet presented the sentence sets in the bracing form, which could have resulted in more of this

type, instead, in the data more than half of the sentences were not in bracing form.

Of 90 wh-question samples, C6 signed wh-questions with only a sentence-final wh-word in 11 out of 15 of his wh-questions. 40 of the total set of wh-questions across all consultants were signed with bracing wh-words, and 39 sentences were signed with only a sentence-initial wh-word.

4.5.3.2 Wh-Questions: Broad Spread of Wh-Lowering

The contour flow of eyebrow height in wh-questions shows a strikingly different pattern than those in statements. In wh-questions, unlike statements, we see no sentence-medial large rises in height (although there may still be an occasional lexical rise and fall of about 1 pixel over individual signs as discussed in section 4.5.1). The declination seen in statements is only present in wh-questions to a degree, such as between wh-elements in the sentence or seen sometimes when the same wh-word is repeated and the second wh-word is slightly lowered.

The overall contour or broad spread of wh-questions is depressed from the overall level of statements for the same emotions. This overall depressed contour level is also further divided by emotions, as it is already established through the statistical data that sad and angry categorically distinguish from most positive emotion combinations through eyebrow height. This overall lowering tends to rank emotions, but can vary from sentence to sentence.

Often eyebrow height patterns such that for a give emotion, the wh-question is signed at a lower pixel range than each emotional counterpart in statements. This difference does not, however, occur all of the time. Sometimes, as discussed about the percent change exceptions, question values are reversed from the expected. This is not only true for the highest and lowest heights, but for the overall broad range in eyebrow height. The pattern exists, but this broad spread of wh-lowering can be intentionally varied by signers.

There are, however, patterns beyond this broad spread that are instead obligatory, and that make consistent distinctions between questions for eyebrow height. These are seen in lexical lowering and narrow spread for wh-lowering.

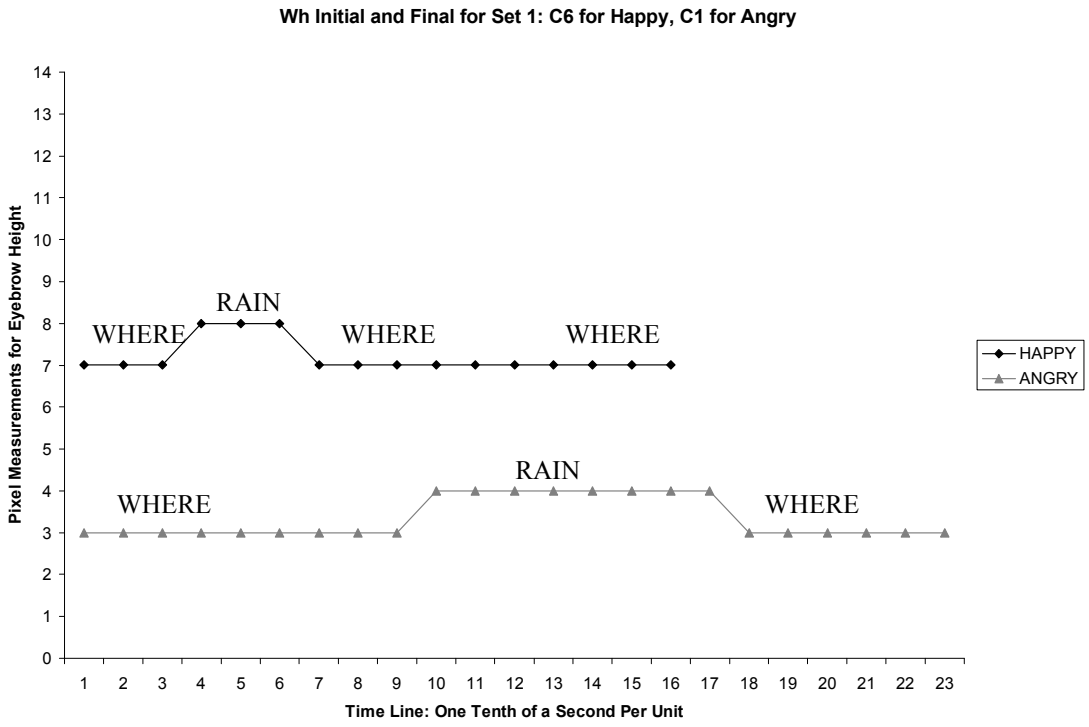
4.5.3.3 Lexical Lowering: Anchored to Wh-Words in the Data

The contour charts beginning with figure 4.10 show the first glimpse at a lexical lowering anchored to wh-words that is a part of the wh-word itself. This lexical signature of lowering by at least 1 pixel is attached to every wh-word throughout the entire wh-question data (90 sentences out of 270 are wh-questions). This includes Set 3 which has a sentence-initial topic. Even when the wh-word occurs within a topic, it still receives this lexical lowering. Also, this lowering is attached to wh-words in any position in the sentence.

Not only is there a lexical lowering over every wh-word, there is also at least a one pixel lowering over an element at the end of the wh-constituent: 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. In the data, this non-overt element that received wh-lowering was either a verb, a pronoun, or infrequently the particle of indefiniteness. In contrast, when an initial wh-word is omitted, there is no lexical lowering assigned to any element in initial position.

Figure 4.10 shows a sample from both C1 (angry) and C6 (happy) to demonstrate the lexical lowering over the wh-word in bracing form.

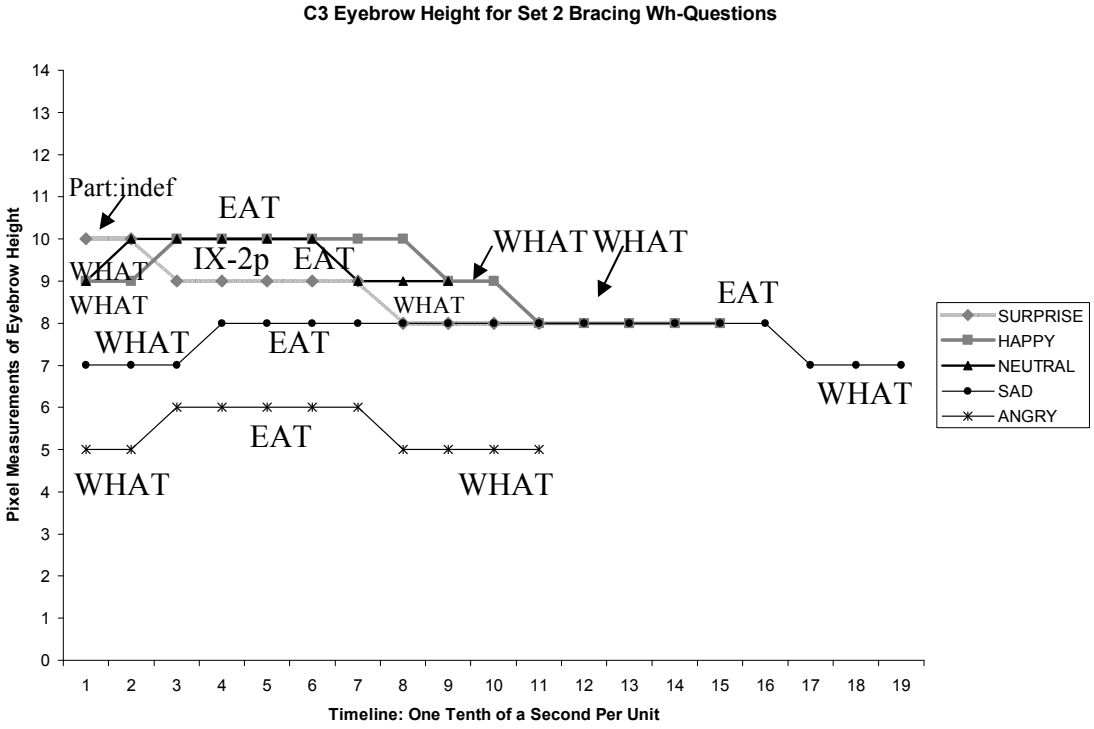


English Translation: “Where is it raining?”

Figure 4.10 C6 happy and C1 angry, wh-words initial and final for Set 1

Figure 4.10 shows two examples of wh-word bracing in sentence-initial and sentence-final positions. The peak value (lowest height) for the lowering does occur at the right edge of the sentence, but can also be repeated when a sentence-initial wh-word occurs. For wh-questions in the data, the lexical attachment occurs with at least and very often only a one pixel lowering. In figure 4.10, we see a lowering over the wh-word such that after it is signed sentence-initial, there is a rise of at least 1 pixel in eyebrow height, and then when the wh-word is signed sentence-final there is a drop of at least 1 pixel (and often exactly 1 pixel) over the sign.

Also, in figure 4.10 the sign RAIN stays at the wh-question overall lowered height for the sentence (broad spread), and at the emotional eyebrow level for the sentence, but then the eyebrows further lower by at least one pixel to sign the wh-element. Specifically, the happy wh-question in figure 4.10 ranges from 7-8 px (pixels), while the happy statement for the same consultant ranges from 11-12 px. Conversely, angry shows one of the examples of an occasional lack of distinct broad spread, where the wh-question range is from 3-4 px, but the angry statement for this same consultant ranges from 1-3 px in height. Figure 4.11 shows a full set example of wh-words from Consultant 3, with bracing for all but one emotion. The same patterns are observed in this example, demonstrating the consistency across signers.



English Translation: “What did you eat?”

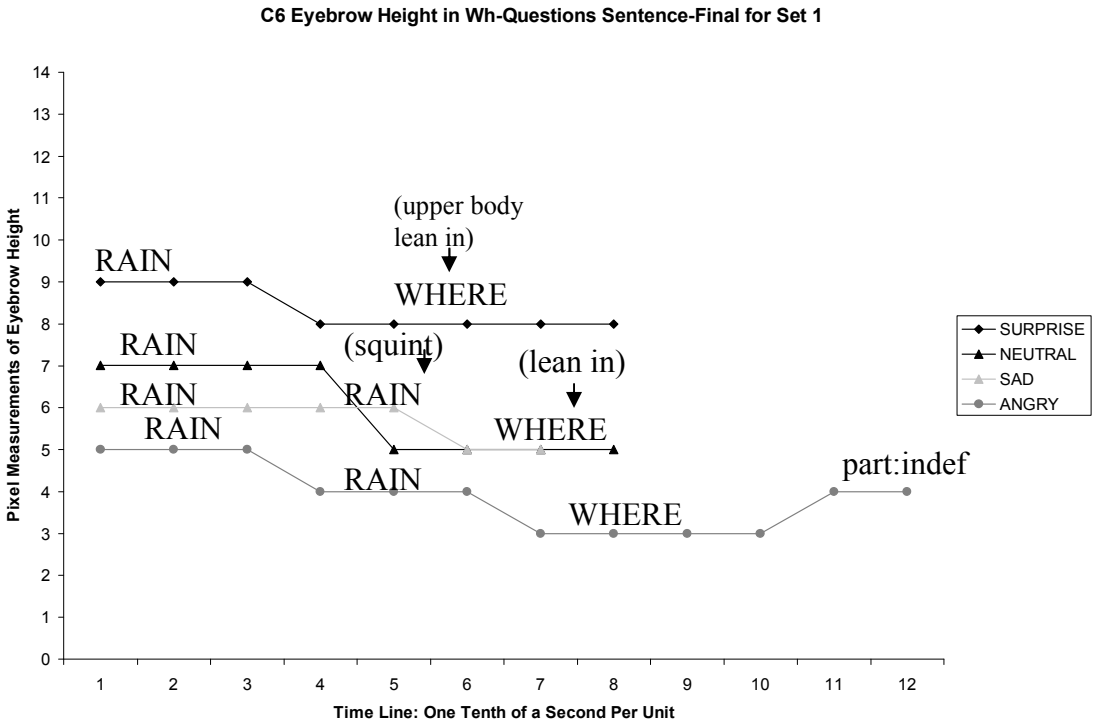
Figure 4.11 C3 eyebrow height for Set 2 bracing wh-questions

In figure 4.11, we see Set 2 for Consultant 3 with the same lexical lowering over wh-words. Neutral begins at 9 px over WHAT, then 10 px over EAT, until going down for WHAT at the end. Happy signs WHAT at a 9 px, then the pronoun YOU and EAT are at 10 px, then the final question sign WHAT at 9 px, and the repeat sign WHAT at a lower 8 px. Surprise begins with the particle of indefiniteness which is not lowered and therefore not bracing the sentence in this emotion, but the sentence-final WHAT is lowered. There is a clear lexical lowering over the wh-words in both sentence-initial and sentence-final position.

The emotions vary the height range of the sentences, but these lexical distinctions remain. Emotional categorization is seen in figure 4.11 as surprise, happy and neutral all grouped closely between 9-10 pixels, while sad and angry are lower. Also, the overall levels of ranges (broad spread) are generally lower in this wh-question set than the comparative emotional statements.

4.5.3.4 Narrow Spread of Wh-Lowering: Tight Distribution Between Wh-Elements

Figure 4.10 and 4.11 show a tight distribution where the constituent between the wh-words only raises about one pixel. This is an additional lowering or what this work terms a narrow spread, that occurs in wh-bracing forms and does not occur without an initial wh-word. To demonstrate, in figure 4.12, we see more wh-questions, but this time with only a sentence-final wh-word.



English Translation: “Where is it raining?”

Figure 4.12 C6 eyebrow height in wh-questions sentence-final for Set 1

Figure 4.12 shows the other four wh-questions for Set 1 from signer C6 that are produced with only a sentence-final wh-word. With no sentence-initial wh-word, there is no narrow spread and therefore a greater range of eyebrow height for sentences when compared to figures 4.10 and 4.11.

Sentences still show a lexical lowering over each wh-word of at least one pixel, with neutral lowering two pixels. These examples show that wh-question can also have a declination effect, seen with the repeating of RAIN in different lowered heights for angry. Similar patterns are observed as in other wh-

questions with lexical raising and lowering that follows with sign transitions. The beginning of the sentence is at the highest value for the sentence, because there is no sentence-initial wh-word to trigger a lowering. Even though there is no wh-word at the beginning of the sentence, however, the entire sentence still often receives broad spread of wh-lowering within a wh-question range relative to neutral for each emotion.

Angry also adds what has been identified as a particle of indefiniteness (Conlin et al. 2003) to the end of the sentence. This acts similar to a tag question or a “huh” gesture in this sentence, and has the same “5” hand shape and outward movement mentioned by these authors for the particle (discussed in Chapter 2). The meaning could be translated as “Where is it raining, huh?” or “Where is it raining, do you know?” This similarity to a yes/no construction results in a one pixel increase over the sign in this instance. There are several other times in the data, however, where a sentence-final wh-word is non-overt (omitted), and the lexical lowering occurs over this particle, which is then functioning as a wh-element, in the same way as verbs or pronouns that also receive this sentence-final lowering.

When the wh-word is sentence-medial, in 85 out of 90 wh-questions the wh-words are lower than the signs immediately adjacent to them on both sides. In the other five out of 90, 3 wh-words lower by 1 pixel and then the following pronoun is also at this lowered level. These three occur in the same sentence set across two different signers, so it is possible that the pronoun is somehow

attached to the wh-word, or some other effect lowers the eyebrows over the pronoun.

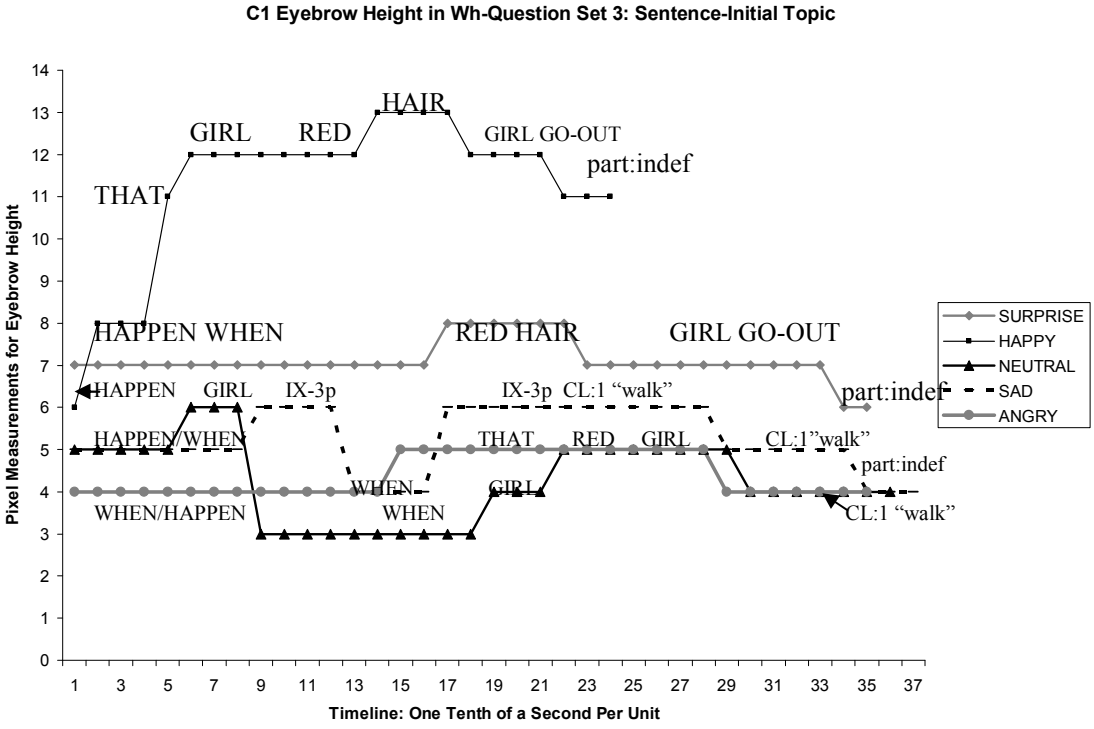
For the other 2 of 90 wh-questions, the wh-word is lower than the following sign, as that following sign raises by one pixel, but the sign before the wh-word is at the same level as the wh-word. Both instances occur from the same signer, and both in the same sentence, Set 2. Both wh-words follow the verb EAT. In these cases, the verb appears to be stressed, signed faster and with more tension, which could possibly account for its lowering, masking the difference between the verb and the wh-word at the left edge, while the distinction remains at the right edge of the sign. Other non-prosodic explanations for these two exceptions may very well appear in future studies as well. Regardless, the wh-word is still lowered and therefore all wh-words lower across all 90 wh-questions in the data.

4.5.3.5 Narrow Spread of Wh-Lowering: Scope of Spread in Topics

Figure 4.13 shows wh-questions with a sentence-initial topic and wh-words in sentence-initial positions, while figure 4.14 only shows wh-words in sentence-final position.

Figure 4.13 and 4.14 show all three types of spread for wh-lowering: broad, lexical, and narrow spread. First, the broad spread exists relative to statements and yes/no questions for each emotion, but this general pattern of lowering varies in its consistency and degree of intensity. Second, the lexical spread lowers over all occurrences of wh-words. Third, narrow spread is seen

when the sentence-initial wh-word further lowers the constituent, while this extra lowering does not exist without the sentence-initial wh-word. While the topic in a wh-question will have a slight lowering from overall broad spread, this further narrow spread does not lower into the topic constituent unless the sentence carries a sentence-initial wh-word, seen in figure 4.13.



English Translation: "When did the red-headed girl go out?"

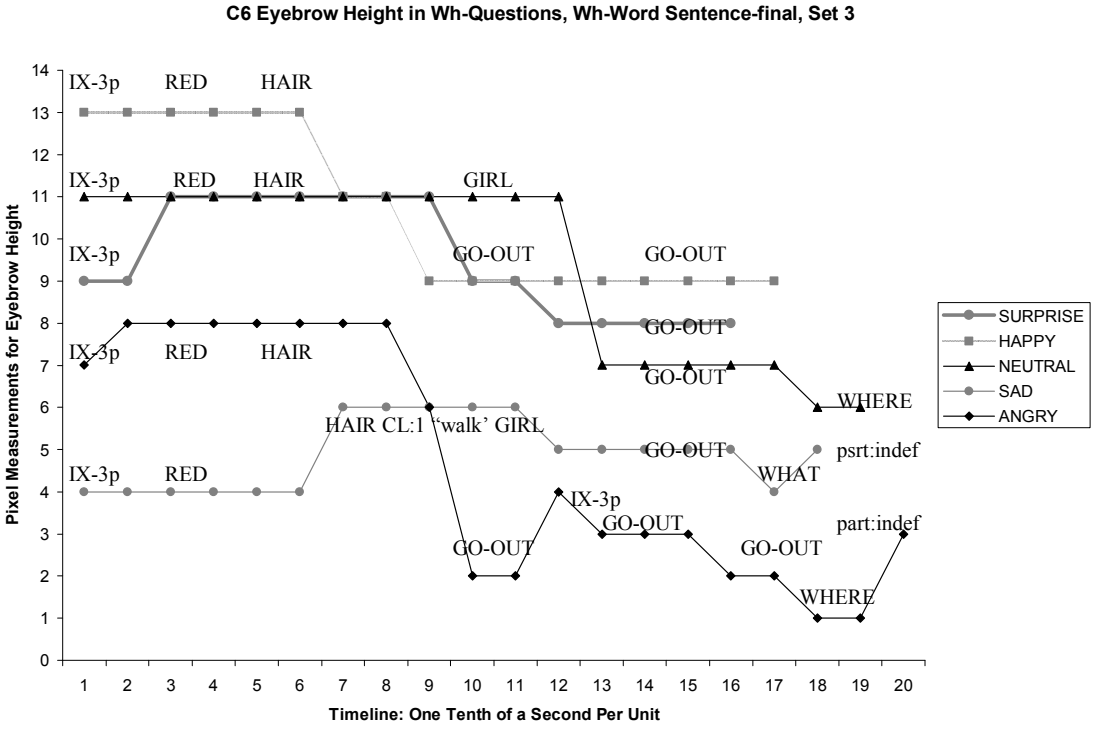
Figure 4.13 C1 eyebrow height in wh-questions with a sentence-initial topic, Set 3

To compare topics across sentence types, for the same consultant C1, in figure 4.13 wh-questions, topics lower to between 4-8 pixels. In figure 4.9, topic

statements range from 10-12 pixels, while in figure 4.17 yes/no questions, topics are further raised to range from 11-13 pixels.

The initial wh-word creates a low height sentence-initial for all emotions, but within a tight distribution of four pixels (between 4-8 pixels high). The topic then rises at different timed units in the timeline, to a raised value that is lower than the heights attained in non-wh topics. The lexical lowering remains for both sentence-initial and sentence-final wh-elements. In sentence-initial position the sign glossed as WHEN was signed by these consultants using their preferred sign HAPPEN. Sentence-final position has no overt wh-words, but there is still a lexical lowering, seen consistent across all wh-questions in the data. In figure 4.13, this lexical lowering is over either the classifier of a person walking, or over the particle of indefiniteness.

Figure 4.14 shows wh-questions with sentence-initial topics that do not have a wh-word at the beginning of the sentence. These non-braced forms are assumed in previous work to not contain wh-spread.



English Translation: "Where did the red-headed girl go out to/for what?"

Figure 4.14 C6 eyebrow height in wh-questions with topics and no initial wh-word

A striking dip in value is observed after the topic constituent in figure 4.14, as in other Set 3 examples. While figure 4.13 begins with a wh-word, figure 4.14 does not begin with a wh-word, and therefore does not begin with a lexical lowering. Just as non-topic wh-questions without initial wh-words do not show a lexical lowering in sentence-initial position, these topic wh-questions without initial wh-words also do not require lexical lowering in sentence initial position. For both angry and surprise, there is a sentence-initial lowering, but this is not a consistent pattern in the wh-question data for sentence-initial position without wh-words. Future study may determine whether this is an

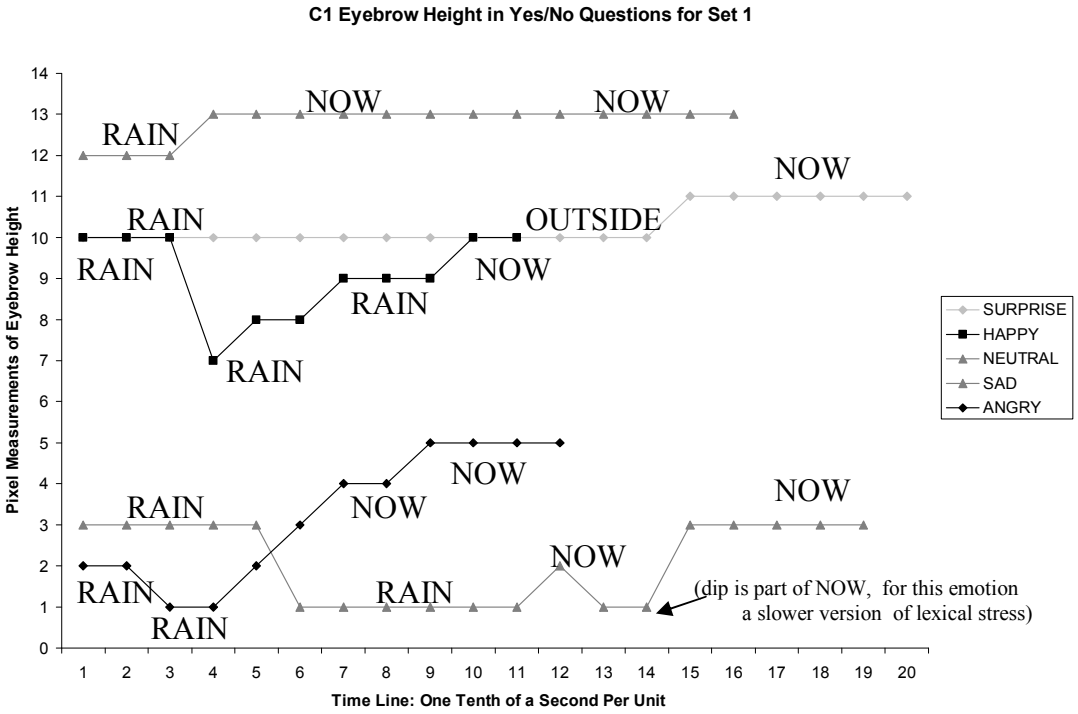
effect of the emotion, but regardless of its purpose, it does not trigger the overall lowering that occurs when a wh-word occurs in sentence-initial position.

In contrast to the sentence-initial raised positions seen in the data, all wh-questions without a sentence-final wh-word do require a lexical lowering in sentence-final position, including sentences that begin with a topic. For example, surprise in figure 4.14, the lexical lowering in the absence of a wh-sign lowers over the sign GO-OUT. Also, when the particle of indefiniteness is added after the sentence-final wh-word, and the eyebrows are then raised over the particle that is acting as a tag question, this further demonstrates the lexical lowering attached to the wh-word.

4.5.4 Contour Charts of Yes/No Questions

Yes/no questions also exhibit patterns of distinction for eyebrow height through contour charts of the data. The sentence-medial rise that frequently occurs in statements is not only missing in wh-questions, it is also missing in yes/no questions. Yes/no questions instead either show a steady rise to a sentence-final level, or a lexical lowering in the sentence prior to a final rise. This lexical lowering, once it raises in the next sign, will repeat if the sign is later repeated in the data. Yes/no questions show an overall broad spread of wh-raising over the entire constituent that is variable relative to emotions and other sentence-types in a similar way as the broad spread in wh-questions. Yes/no questions then show a consistent pattern of narrow spread that distinguishes

them through eyebrow height by raising at least 1 pixel by sentence-final position. These distinctions will now be demonstrated through contour data.



English Translation: “Is it raining now?”

Figure 4.15 C1 eyebrow height in yes/no questions for Set 1

4.5.4.1 Broad Spread of Raising in Yes/No Questions

Yes/no questions reveal frequent overall raised ranges (broad spread) relative to each emotional state, seen in the ranges for each emotional question in figure 4.15. In figure 4.15, we see one of the infrequent instances when neutral was the highest height, showing the broad spread height is variable. For most of the 90 yes/no questions neutral was between the positive and

negative emotions, but in this case, the rise for neutral yes/no questions was stronger for this one signer than the four emotional states.

This is also a good representation of how signers can vary. While most order the emotions from highest to lowest as happy, surprise, neutral, sad, and angry, categorically only the negative emotions are distinct from most of the others for maximum and minimum values. This is also seen in the contour ranges by emotion, as sometimes happy, surprise, and neutral are not raised relative to statements, seen in the data as not distinct from question to statements.

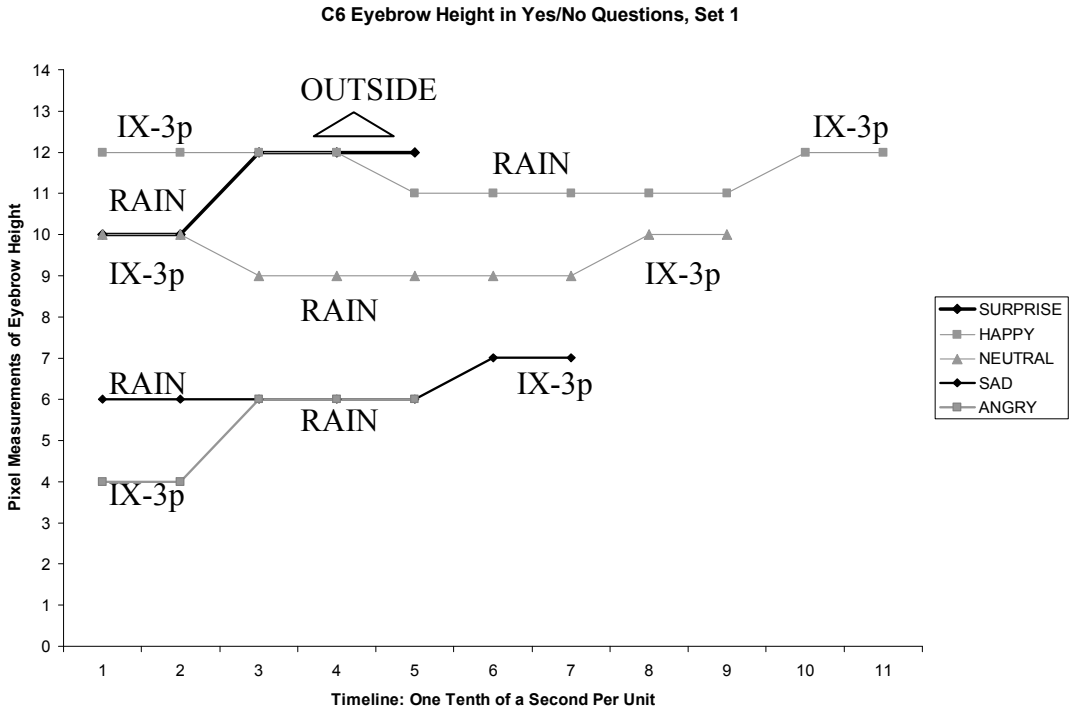
4.5.4.2 Narrow Spread of Raising in Yes/No Questions

While the maximum and minimum values only show a limited distinction through eyebrow height, the contour data show further distinctions that do separate yes/no questions from statements across all data. One such distinction is in what this work terms narrow spread, where there is a rise of at least one pixel by sentence-final position. The individual sentences all raise by the final sign in a yes/no question, as seen in the example from Set 1 in figure 4.15. Sometimes, such as in neutral for figure 4.15, this raising occurs prior to the final sign and if so, remains elevated until the end of the sentence. This final level is sometimes the highest level in a yes/no sentence, but other times, as in the sad example in figure 4.15, this sentence-final level is at the same or lower height than the sentence-initial level. There is still a raising of at least one pixel, however, as the sentence will lower eyebrow height before a final rise.

This obligatory pattern occurs across all signers in the data, attached to the yes/no constituent.

4.5.4.3 Lexical Lowering in Yes/No Questions over Different Signs

A lexical lowering occurs in the first instance of the sign that receives the lowering, where it is repeated or produced through a lowering dip until the next sign is produced. If after another sign, the lowered sign is repeated, it will again receive this lexical lowering in the data. When the lowering is near sentence-final position, it leads into the sentence-final raise, but the lowering is not always in sentence-final position. This lowering is seen in figure 4.16.



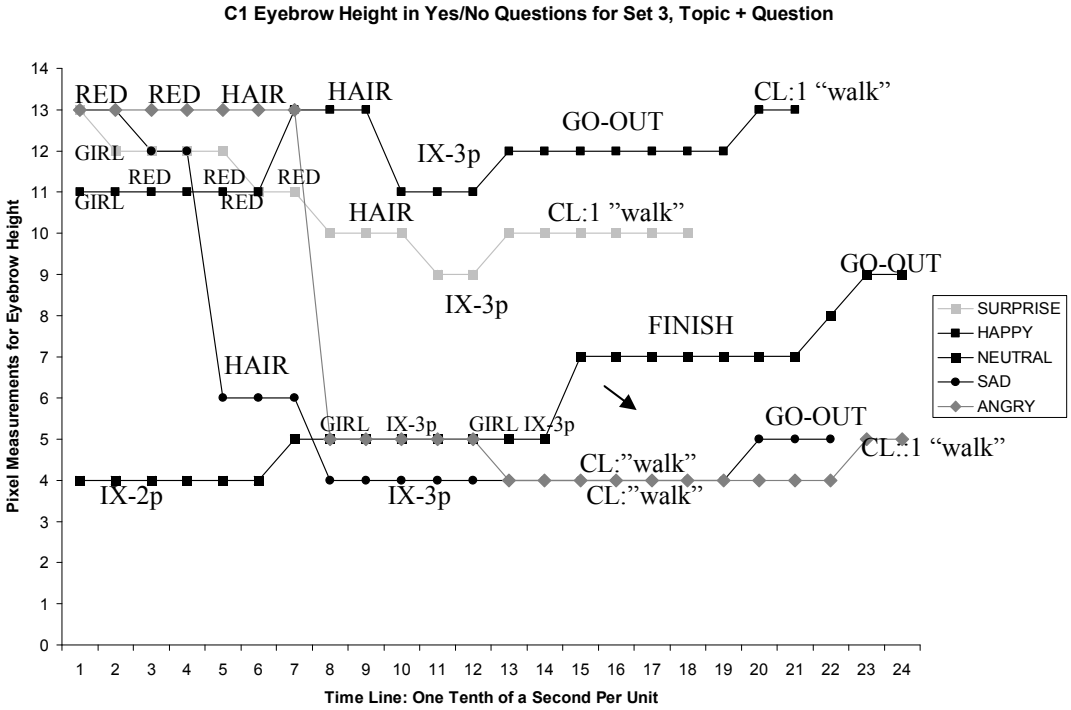
English Translation: “Is it raining?”

Figure 4.16 Eyebrow height in yes/no questions, C6 Set 1

For Set 1, the lowest level occurs over a dip on the sign RAIN. This lexical lowering is either already present sentence-initially, or the sign is produced at an emotional level and then receives the lowering. One example is happy in figure 4.16, where rain is lowered.

4.5.4.4 Yes/No Questions with Sentence-Initial Topics

It is not always the verb that receives the lowering, however, as seen in angry in figure 4.16, where the pronoun is lowered in sentence-initial position. Notice that if the lowered sign is repeated only as the sentence-final sign, then the narrow spread forces it to be raised in sentence-final position. This lexical lowering could be an effect of the sentence-final raise, or could be an independent phenomenon. This data set shows the existence of the lowering, and further details on the nature and occurrences of this effect is left to future research.



English Translation: "Is the red-headed girl going out?"

Figure 4.17 C1 eyebrow height in yes/no questions for Set 3, topic+question

These yes/no questions in figure 4.17 also show the same narrow spread for raised eyebrows of at least 1 pixel that once it occurs, remains until sentence-final position. This is seen in figure 4.17 as a consistent pattern when the yes/no questions contains a topic. Also, the lexical lowering that occurs in yes/no questions without topics is also seen in these sentences with topics, though sometimes this can be masked by the sudden drop from the topic. For surprise, happy, and angry, after the drop a further lowering occurs, making this pattern visible.

Figure 4.14 shows a tight distribution of contours sentence-initial over topics, within an 11-13 pixel range for the four emotional states. Then, a striking drop occurs, and a sentence-medial lowering (followed by raising). This "u-shaped" pattern in yes/no questions that does not occur in statements occurs in these yes/no questions even when preceded by a sentence-initial topic.

Additionally in figure 4.17, we see that the neutral topic is at a strikingly different level. Instead of the near maximum height, this topic is lowered from all neutral baselines across sentence types, not an expected behavior for topics that are considered to require raised eyebrows. This occurred in only a few examples, but across different signers. While only eyebrow height was measured in this analysis, it was observed that these separate topic markings for eyebrow height, when seen in the data, are generally accompanied by squinted eyes. It is possible that this nonmanual is signaling some other type of information, such as shared information for the topic marking set 3 (Aarons 1994) discussed in Chapter 2.

4.6 Comparisons for Intent in Questions: Categorical Distinctions Remain Despite Emotions

To address the contention from Sandler and Lillo-Martin 2006 and others that wh-question eyebrow marking is not syntactic because it varies by speaker intent, data for an ancillary comparison of the same sentence in Sandler and Lillo-Martin 2006 were collected.

4.6.1 Eyebrow Height for "Why Did He Leave Like That!"

The signers were given the scenario where a friend left and the party host commented to the others in amazement "Why did he leave like that!", and the signers were instructed to translate and sign their own version of the English sentence. Signers only saw the English sentence, as no scripted sentence was given. The results show the wh-word still retains a lexical lowering despite the speaker intent.

While the eyebrows are relatively raised by the emotion, the consistent attachment of lexical lowering to these wh-words remain in this example. Speaker intent perhaps impacts on the emotional level, but this does not remove the wh-question eyebrow lowering.

It is important to mention that Sandler and Lillo-Martin were considering the eyebrows to remove the brow furrowing. I suggest that this is the difference. In the data of emotional questions, there were many sentences without any brow furrowing. For example, brow furrowing regularly occurred over angry wh-questions and statements, often in sad, and often in wh-questions. In contrast, brow furrowing did not occur with regularity in surprise and happy regardless of question type.

Conversely, brow furrowing did occur with raised eyebrows in happy when the signer appeared to desire a further raise in eyebrow height but had already reached the physical maximum height for their face. In this instance, brow furrowing appeared to be added as a further distinction. The impression

was of a “higher” brow level, but the only distinction was the addition of this furrowing, along with wide eye aperture. These examples demonstrate that impressions based on brow furrowing will see intermittent patterns based on emotional states, but analyses of brow lowering with objective measures shows obligatory linguistic patterns that are consistent across signers.

Brow furrowing may or may not be removed during an expression, therefore, but brow height as seen in the data, remains attached to the wh-word.

4.6.2 Eyebrow Height in “Why Did You Leave Without Paying!”

A final test is seen in figure 4.18.

4.18 Eyebrow height for “Why Did You Leave Without Paying!” in sentence-final position

Figure 4.18 shows another secondary comparison that was made based again on discussion in Sandler and Lillo-Martin 2006. This is also to test their contention that the intent of the speaker will remove the obligatory wh-question lowering. The example is of a store keeper saying “Why did you just walk out of my store with that shirt without paying!” They suggest only an emotional expression will occur over this sentence. The image in 4.18 shows the sentence-final particle of indefiniteness remaining on the left hand while the right hand adds the second person pronoun “you”. The lexical lowering occurs over this frame with the lowest level at both the sentence initial WHY and the sentence final non-wh-word. Consultants signed this sentence with the same method as in the last sample comparison. The results again show that the lexical attachment remains over the wh-words, despite emotional states. The overall broad spread, however, could be varied by emotion and speaker intent, an area for future research.

4.7 Summary of Findings

As an overview, figure 4.19a-b shows some additional sample expressions from consultants in this study.

(a) (b)

(c) (d)

Figure 4.19a-d (a) surprise wh-question, (b) neutral state, (c) surprise statement, (d) sad yes/no question

Figure 4.19a is a WH-question with lowered eyebrows but a surprise emotion. This shows lowered and furrowed eyebrows with simultaneous wide eye aperture. Figure 4.19b shows eyebrows at neutral as the signer begins to sign NOW. Figure 4.19c shows a surprise statement with no eyebrow furrowing but wide eye aperture with raised eyebrows. Figure 4.19d shows a sad yes/no question with lowered eyebrows up, eyebrow furrowed, and cheek muscles tensed. Also, while the data were not coded for muscle movement, the Facial Action Coding System AU 1 (inner brow raise) appears to occur in 4.19d, but not AU2 (outer brow raise). This is a pattern observed in the yes/no questions in the data, where AU1 occurs despite emotional state, but AU 2 could be omitted by emotion.

Eyebrow heights vary within the co-occurrence of several other nonmanuals. The timing of eyebrow height changes, however, such as coinciding with a wh-word or occurring at the end of the sentence, reveals more than just static images, showing important dynamic clues to determining the question type through patterns regardless of the emotional state of the signer.

4.7.1 Summary of Wh-Questions: Three Spreads of Eyebrow Lowering

This work has introduced the idea of three different types of spread for eyebrow height in ASL questions: lexical, narrow, and broad. The following is a summary of the findings on this eyebrow movement.

1. Lexical. Wh-words show a consistent lexical lowering of at least 1 pixel over the word. If a sentence does not have an initial wh-word, this

lowering is not seen in initial position. In contrast, sentence-final position consistently produces a lexical lowering, whether over a wh-word or a wh-word substitute when a wh-word is not present. Also, eyebrow height changes at lexical boundaries and within lexical movements with regularity in all sentence types.

2. Narrow. While a lexical wh-lowering occurs regardless of the position of wh-words in the sentence, wh-questions that are braced with both initial and final wh-words show an additional lower level of height with the entire braced constituent than wh-questions without an initial wh-word. This difference in intensity or degree of lowering (number of pixels lowered) could be the reason qualitative impressions in ASL literature observe an obligatory wh-spread with a sentence-initial wh-word, and an optional spread with a sentence-final wh-word. Now with this new type of detail in eyebrow analysis, we see this narrow spread does indeed occur, but we also see that the wh-lowering over the wh-word still remains in any wh-question, situated within and relative to the additional lowering of the constituent.

One visible example of this narrow spread is in wh-question topics. When a sentence-initial topic is added to a wh-question, the eyebrows are raised for the topic, but to a lowered degree. This lowering is not as low as that of a non-topic wh-question, but is still lower than topics without wh-questions. Also, when a sentence-initial topic is preceded by a wh-word, a greater degree of lowering occurs over the entire constituent, similar to the wh-lowering that

occurs without an initial topic. The pattern within the sentence contour, however, shows a rise after the initial wh-word for the topic portion, and then a sharp fall to the typical wh-question height range for that expression. The data also show a second type of topic with much lowered levels, which is possibly a representation of topic marking 3 (Aarons 1994) that interprets the sentence as shared knowledge.

3. Broad. Wh-questions have an overall lowered level compared to statements and yes/no questions, but this overall pattern is variable within the categorical ranges of emotion and based on signer or situation. Sometimes questions and statements have an overall similar height range, while other times there are greater differences in the overall eyebrow height levels. This overall range, however, still patterns relative to the question type, such that yes/no questions are not lower than wh-questions, and wh-questions are not higher than yes/no questions relative to emotional state. This distinction, in fact, was observed in the statistical data for maximum and minimum values that gave a hint at this broad spread of eyebrow height.

4.7.2 Yes/No Questions

There are three observations about yes/no questions and eyebrow height that can be correlated to the three types of spread in wh-questions.

1. Broad. Yes/no questions are signed with an overall higher eyebrow level than statements and wh-questions, but as the statistical data show, are only consistently higher than wh-questions. This variable overall raising is

similar to the overall broad spread of lowering in wh-questions. The yes/no question overall broad spread of higher eyebrows raise topics to a degree such that they are slightly altered from levels without yes/no question overlap.

2. Narrow. In every yes/no question in the data, there is a lexical raise of at least 1 pixel that remains until the end of the yes/no question, what is termed here a narrow spread. This raise exists regardless of the emotion, and is an obligatory way ASL signals yes/no questions.

Also, when a sentence-initial topic is added to a yes/no question, the eyebrows are raised for the topic to an elevated degree. This raising is often a subtle difference from that of the already raised non-yes/no question topics, but shows a spread for raised eyebrows does exist. Whether this is only over certain types of topics, or whether this spread has other constraints is an area out of the purview of this research, and future study may determine whether this extra spread is part of the narrow or broad spread as discussed in this investigation (obligatory or optional, respectively).

The data also show a second type of topic with much lowered levels in yes/no questions just as in wh-questions, which is also possibly a representation of topic marking 3 (Aarons 1994) that interprets the sentence as shared knowledge.

3. **Lexical. –An echo or an effect?** For yes/no questions, current thinking is that no lexical word generates the spread of overall raised eyebrows. The contour data, however, show an attachment of lexical lowering to a sign in

yes/no sentences that needs further investigation. The sentence-medial rise that frequently occurs in statements does not generally occur in yes/no questions. Instead, yes/no questions show a lowering in the sentence. This lexical lowering is often over the verb, but is not over the same sign for every consultant. For example, it may occur over the pronoun in one sentence, and over the verb in another.

Sometimes the sentence begins at the lower level over a lexical element and then raises. It is possible then that this lowering effect is a byproduct of the sentence-final raising, but other times when this lexical lowering occurs, and when the eyebrow height returns to the previous height for a new sign, if the lowered sign is then again repeated, the lowering re-occurs. Whether this repeated lexical lowering is some type of an echo of a dip before the sentence-final rise, or is an actual lexical lowering effect as a trigger for the yes/no spread, is a matter for further investigation. Regardless of its purpose or function, it distinguishes questions from statements that do not show this lowering and final raising contour.

4.7.3 Lexical Height Changes

Eyebrow height changes either at lexical boundaries, or coordinated with specific movements in signs in the data. In addition, certain lexical items have a recurring but not obligatory height change over a part of the sign. The sign NOW was give as an example, where lexical eyebrow shifts occur coordinated with specific movements within the sign, depending on speaker intention of

stress or focus. This eyebrow change can be a lowering in height used to draw focus or attention to the moment, but it can also be a rise, such as when it is signed at the end of the sentence to ask a yes/no question. Also, obligatory lexical attachment of eyebrow height was observed over the fingerspelled loan sign #WHEN. This final lowering of at least 1 pixel over N occurs over every sample in the data.

4.7.4 Categorical Emotions in Questions

For emotions, all sentence types show a categorical distinction between the negative emotions sad and angry, and (most) all positive emotions. This categorical distinction for emotion not only exists in Deaf signers, but also in hearing non-signers speaking the same sentences. In contrast, Deaf signers show the categorical distinctions between question types, whereas hearing non-signers do not show any distinction between question types for maximum values in sentences.

The next chapter will discuss the significance and interpretation of these results, their theoretical implications, and specific suggestions for improvements in the ASL classroom based on the data.

CHAPTER 5

CONCLUSIONS AND IMPLICATIONS

5.1 Introduction

This chapter presents the conclusions of the study and their application to the theoretical discussion on nonmanuals in American Sign Language. The discussion also includes pedagogical implications for improved teaching on ASL questions. Section 5.2, “Summary of the Study”, presents a brief overview of the investigation focus and procedures, and findings of the statistical tests on individual data points in each sentence, and patterns of eyebrow height changes in questions and statements through contour charts of eyebrow measurements every three frames (0.1 second per three frames). Section 5.3, “Conclusions”, relates the findings to the literature in Chapter 2 by comparing the behavior of eyebrow height in ASL questions and statements to syntax, grammatical intonation, and prosody including emotional intonation. It is shown that these different functions co-occur through changes in eyebrow height.

Section 5.4, “Implications” considers the significance of these simultaneous functions towards a new approach to the nonmanual debate, and offers specific suggestions for curricula improvements for ASL and interpreting programs. Section 5.5, “Future Research” suggests further areas for objective

nonmanual analysis and comparing languages, and Section 5.6, “Summary” presents a few final words on the work.

5.2 Summary of the Study

This study examined raised and lowered eyebrows in American Sign Language questions and statements when signed in neutral and four emotions, happy, sad, angry, and surprise. Current literature debates the nature of eyebrow movements including their scope and function in ASL. I suggest ASL eyebrow research has been limited to qualitative methods until now primarily because of technology limiting the capture of consistent measures. This is the first study to examine ASL eyebrow behavior with such quantitative measurements, and demonstrates how the affordable digital tool used in this work makes quantified investigations of nonmanuals available to all researchers with computer access. Native Deaf consultants signed over 270 sentences, with over 3500 coded eyebrow measurements. A mixed model was performed on maximum, minimum, and onset values, and contour charts were presented for heights at every three frames (0.1 second per coded measure).

The goal was to contribute new detail on eyebrows to the debate, to discover if knowing more about eyebrow height patterns could improve the acquisition of ASL questions in the classroom, and to improve curricula to lessen misunderstandings.

The findings in this investigation show new detail of eyebrow height distinctions across sentence types and emotions. The data show that eyebrow height does play a significant role in misunderstandings. Learners of ASL might assume a linguistic nonmanual is instead an emotional expression, and the data confirm the likelihood of such an error by showing that eyebrow height is organized around emotional levels. Misunderstandings were discussed such as examples of questions that could be misinterpreted as statements, with potentially severe consequences.

Statistical data show that the maximum and minimum eyebrow heights in ASL sentences make significant distinctions between yes/no and wh-questions, but make no distinctions between questions and statements. The contour data, however, do show consistent distinctions made between not only question types but also questions and statements of all emotional states in the data.

Emotion alters eyebrow height by creating the ranges of height for expression. These levels are then exploited by ASL for linguistic purposes, not the reverse. There are consistent patterns for linguistic use of eyebrow height in ASL sentences. Statements show an overall declination for eyebrow height. Wh-questions show three types of wh-lowering: lexical, narrow spread, and broad spread. Yes/no questions also show both narrow and broad raised eyebrows, with a lexical lowering effect that merits future study.

5.3 Conclusions

In this section the findings on ASL eyebrow behavior are correlated to syntax and to intonation and prosody, showing that ASL alters eyebrow height to simultaneously function for multiple purposes.

5.3.1 Examine Brow Lowering rather than Brow Furrowing for Consistent Patterns across all Data

Sandler and Lillo-Martin (2006) previously reported the qualitative impressions that brow furrowing over wh-words can be omitted because of illocutionary force (also discussed in Meir and Sandler 2004). They use this contention as support that eyebrows represent intonation. While this current work shows evidence of such an intonational interpretation through broad spread of eyebrow height across constituents, this current work also suggests one reason the impressions of Sandler and Lillo-Martin excluded a syntactic account. Their conclusions are based on their focus of brow furrowing, but this current research has shown that brow furrowing does not accurately describe what regularly occurs over emotional wh-questions, since very often the furrow does not exist.

As discussed in Ekman (1992), eyebrows can lower, furrow, or lower and furrow. For ASL, eyebrow furrowing often occurs in wh-questions, but not consistently over emotional states. Brow furrowing can also occur in yes/no questions. A future examination into patterns of furrowing across emotional questions may reveal more detail on their linguistic patterns of occurrence in ASL questions, but to explain what distinguishes all wh-questions from yes/no

questions and to determine correlations of eyebrow behavior to spoken languages, brow furrowing is not sufficient. The research presented here shows that lowered eyebrows should instead be the focus when trying to explain general question behavior.

5.3.2 Conclusions on Wh-Questions

ASL eyebrow research discussed in Chapter 2 examines either lowered eyebrows that spread across a constituent, or lowered eyebrows over only the wh-word itself. The data and detailed measurements of this work now show that wh-questions simultaneously employ more than one type of lowering.

5.3.2.1 Lexical Lowering in Wh-Questions as Syntax

The data show the first glimpse at a lexical lowering that exists even when the spread of lowered eyebrows occurs across the constituent, not just over the wh-word. This lowering is present whether the wh-word is in sentence-initial, sentence-medial, or sentence-final position. The lexical lowering is of at least 1 pixel over wh-words, and is also present regardless of the emotional state in the data, and occurs even when the illocutionary force is not that of a content question. This lexical lowering, then, is attached to the word and is therefore a part of the syntax, supporting the traditional view that ASL question eyebrows are syntactic in nature (e.g. Aarons et a. 1992, Aarons 1994, Bahan 1996, Neidle et al. 2000).

Also, the control comparisons as discussed below for illocutionary force both show a lexical lowering over the wh-word and an overall lowering of the

sentence, showing it is not just a product of speaker intent but is driven by the syntax of the language.

5.3.2.2 Narrow Spread of Wh-Lowering as Syntax

The data show an additional spread exists across constituents that is triggered and constrained by the lexical lowering. This narrow spread is triggered by the wh-word in a sentence, whether overt or non-overt. In bracing wh-questions, the constituent is only raised within a tight distribution of usually only one pixel from the wh-word level. This narrow spread is obligatory and syntactic. When no sentence-initial wh-word exists, a greater range of height is observed. This narrow spread occurs in sentences with sentence-initial topics, too. Over topics without an initial wh-word, for example, the topic eyebrows are much higher than with an initial wh-word, but are still lower than topics without a wh-construction.

These objective measurements show that instead of emotions replacing the wh-question marker, when examining eyebrow height, the consistent brow lowering remains. I therefore argue this provides further evidence that the spread of wh-question eyebrow lowering is indeed a representation of syntax, in support of prior syntactic analyses for wh-spreading (e.g. Aarons et a. 1992, Aarons 1994, Bahan 1996, Neidle et al. 2000).

5.3.2.3 Broad Spread of Lowering in Wh-Questions as Intonation

The overall lowering of the sentence contour, relative to the overall range for statements in similar emotions, is often lower relative to the current

emotional state of the conversation, and relative to the statement and yes/no question levels. This broad spread of overall lowering, however, does not pattern consistently from emotion to emotion, where sometimes, for example, an angry wh-question can be as high as an angry statement for the overall range of eyebrow height across the sentence. This overall lowering can therefore be varied by speaker, and best correlates to the overall interrogative intonation and other prosodic intonation in spoken languages.

5.3.3 Conclusions on Yes/No Questions

Yes/no questions also show correlations to intonation and syntax through eyebrow height in ASL.

5.3.3.1 Broad Spread of Raised Eyebrows in Yes/No Questions as Intonation

The broad spread of overall raised eyebrows in yes/no questions occur in a similar pattern as the overall lowering in wh-questions. The eyebrows are generally raised above statements and wh-questions, but can show slight variability across signers and sentences in similar fashion as the wh-question broad spread. This overall raised level that can change for prosodic purposes correlates to the interrogative intonation in spoken languages.

5.3.3.2 Narrow Spread of Raised Eyebrows in Yes/No Questions as Syntax

I argue that the consistent pattern of rising by the end of the constituent for yes/no questions is a representation of syntax. This sentence-final raising of

eyebrows occurs in every sample in the data, and is therefore an obligatory feature to produce a yes/no question.

Also, when a topic is added to the beginning of yes/no questions, the overall height is raised higher, and for the second type of topic observed, the strikingly lower height occurs over the topic, but is still elevated at a yes/no level. I suggest this extra raising across topics could also represent an effect of this syntactic spread, but a closer analysis is outside the scope of this research. Future studies might also show correlation of the spread into topics as part of the overall broad spread that is intonational instead.

5.3.3.3 Lexical Lowering Patterns in the Middle of Yes/No Questions

The lexical lowering in the yes/no questions, if its appearance and omission can be explained as a pattern in future studies, could be a further representation of syntax, and a syntactic trigger for the overall yes/no eyebrow level. This could also be simply an effect of the sentence-final raised eyebrows, and its repeated appearance could be an echo, but still a syntactic feature. Future studies may argue the pattern is rather a representation of an intonation effect of the contour, while others may also consider it syntactic. This is an area for future investigation, and my data can be seen as opening up the forum for examination into this aspect of yes/no questions.

5.3.4 Overall Declination in All Sentence Types as Intonation

As discussed in the findings, statements show a clear declination in eyebrow height across the sentence, and this declination is also seen to a

lesser degree before sentence-final position in questions. This decline in height makes it clear that eyebrows, while simultaneously making syntactic distinctions in questions, also act as intonation similar to what is seen in languages such as English.

5.3.5 Eyebrow Height Showing Lexical Stress or Focus as Intonation

The data also show a lexical stress over a part of sign movement, such as the eyebrow lowering (or raising) over the sign NOW as the hand shapes lower to waist position. These eyebrow height changes are not required over the sign, but instead appear to function as stress or a type of focus. This behavior, therefore, is one example of how eyebrow height correlates to grammatical intonation in spoken languages. This lexical height change can simultaneously occur within the overall raised or lowered syntactic eyebrows, and also can occur within the prosodic declination of a sentence.

5.3.6 Eyebrow Height Showing Lexical Attachment as Syntax

One further example of syntax in the data is the obligatory lexical attachment of lowering in the fingerspelled sign #WHEN over the N, which shows that eyebrow height can attach to a lexical item as part of the sign itself. This lexical attachment is also a representation of syntax, occurring in every example of the sign in the data.

5.3.7 Categorical Emotions by Eyebrow Height as Paralinguistic Intonation

The categorical distinction between sad and angry and the other emotions for the maximum heights in sentences show how eyebrow height

creates emotional intonation. The strength of this prosodic influence is seen in the fact that overall sentence levels depend on the emotional state of the signer, and then the syntactic or other intonational changes occur within this emotional eyebrow height range.

5.4 Implications

This section discusses the applications from the conclusions to the theoretical debate, and then discusses the significance for the classroom.

5.4.1 A Focus on Eyebrow Height

The conclusions show eyebrow height and not furrowing alone should be the focus when determining what occurs over all questions. This changes the focus of many investigations that may now want to re-examine their data for brow lowering rather than brow furrowing.

5.4.2 ASL Eyebrows and the Upper Face Function Similar to Pitch in Tone Languages

I argue that ASL eyebrows are not best compared to English, but instead make linguistic changes despite emotional states similar to how tone languages allow emotion to modulate within a tone contour. As discussed in Chapter 2, tone languages may have a syntactic tone at one level, but also can allow grammatical and emotional intonation to vary the tone within a range such that the syntactic tone level still remains distinct, cf. the waves and ripples model of Y.R. Chao (1968). I contend this is similar to how ASL eyebrow height functions. ASL eyebrow height does allow the universal emotional eyebrow

levels to appear for ASL questions, but unlike many contentions of prior research, the objective data show the linguistic distinctions still remain regardless of the addition of emotion.

For topics, the eyebrow are only subtly altered by emotion in the data, while topics make a near consistent height level in emotional questions. ASL question grammar does not overwhelm the overall broad spread like topics, but allows emotion to alter the questions in greater ways. Still, within these emotional ranges, ASL questions make firm distinctions based on timing, lexical height changes, and scope of height changes across constituents. ASL makes these distinctions through overall raised or lowered eyebrows in yes/no and wh-questions respectively, lexical lowering over wh-words, and sentence-final raised eyebrows in yes/no questions.

5.4.3 The Debate: A Broadened Perspective that is Not Mutually Exclusive

On the debate, I agree with Wilbur (2000, 2003) that different upper face nonmanuals can each function differently, for example one as syntax and another as intonation. I also argue for a further expansion of this layering, where one nonmanual, the eyebrow channel, can itself function as both syntax and intonation.

The data in this study present evidence that, for eyebrow height, one nonmanual can function as both syntax and intonation at one moment. In a wh-question, for example, there can be a lexical lowering over a wh-word that occurs within an additional lowering across the braced sentence, that also

occurs within an overall broad spread of lowering to distinguish the question from a yes/no question or statement. This shows all three functions, the lexical and narrow spread (syntactic) and overall broad spread (intonational) co-occurring with one eyebrow movement. Additionally, there is further layering if there is also declination simultaneously occurring, a lexical stress or obligatory lexical eyebrow height change, and an emotional prosodic height change. This shows that several functions can occur simultaneously within one channel, the eyebrows.

This adds to the debate that until now has focused on a mutually exclusive analysis where eyebrows must be either syntax or intonation. Instead of two divergent paths for analyses, the conclusions presented in this work support the expanded theory that both analyses can be correct, and that through one eyebrow movement, the height can function as syntax, grammatical intonation, and emotional intonation similar to spoken languages. While disagreement over various nonmanuals may continue, this new finding and new methodology can broaden and enhance future research and the approaches to nonmanuals across signed languages.

5.4.4 Suggestions for Improved Curricula on ASL Questions

The data show eyebrow height does play a significant role in misunderstandings in questions, but explicit teaching and practice of the patterns in questions can remove many of the difficulties in acquiring and recognizing questions in ASL. First, emotions are understood naturally, but

ASL learners can mistakenly assume a linguistic eyebrow raising or lowering is emotional. It is therefore crucial for interpreting programs to show emotional question-and-answer pair examples as well as forms in the traditionally taught neutral discourse.

Also, curricula need to expand the discussion of nonmanuals in general and specifically in relation to eyebrows in ASL questions. Eyebrows do indeed go “up” in yes/no questions and “down” in wh-questions, but video tape examples frequently give the impression that extreme raised or lowered eyebrows are always seen when in reality there are degrees of raising and lowering in ASL questions.

I suggest that teaching specifics for nonmanual sign production will improve fluency and acquisition in the same way that teaching specifics for speech production improves fluency (e.g. Derwing and Rossiter 2003 for spoken languages). While living in Mexico, I experienced this benefit, as an instructor taught my Spanish class specific details that he assured us would drastically improve our fluency in the language, such as producing the intervocalic /d/ as [ɵ]. These and other suggestions that are not typically taught in school textbooks in the United States greatly improved my ability to communicate in everyday conversation. While I was only beginning to understand the prosody of the language, and I was still learning much of the vocabulary, I was better able to use what I did know, all because of very targeted instruction.

The ASL classroom can benefit from specific details on nonmanuals, and students will not only better understand conversations, they will be more willing to engage in signing experiences. For future interpreters, this is crucial to obtaining fluency.

The data from this investigation allow for several specific suggestions to broaden the depth of teaching given in the classroom on ASL questions (an instructional chart summarizing ASL questions suitable for students is included in Appendix B). First, eyebrow furrowing does not occur in all the data, so it is important to distinguish between furrowing and lowering when referring to wh-questions. ASL questions should be taught as distinguished by eyebrow height. The difference between the center of the eye and the center of the eyebrow will vary in height during a conversation. Regardless of the emotional state, signers can look for this raising and lowering for clues to whether the sentence is a question or a statement.

Next, wh-words may not be present in all wh-questions, but the end of every wh-question will have at least a slight lowering relative to the signs immediately before the end of the sentence. Students should look for this extra lowering at the end of every wh-construction.

For yes/no questions, the ending should also be the focus, as there will be at least a subtle raise in eyebrows by the end of the construction. I also suggest instructing students to look for an inner brow raise (similar to AU1) by the end of the yes/no questions, as that was regularly observed in the data

(even when emotion omitted AU 2 outer brow raise). The inner brow raise appeared at least in sentence-final position in the data, therefore it is also a good marker for students searching for clues to the yes/no construction.

Also, students need to know that eye aperture changes such as wide eyes and squints may occur in various emotions (such as wide eyes for surprise and squints for angry). Unlike the traditional teaching based on neutral, however, when emotional states are expressed in questions, eye squints or wide aperture do not pattern consistently with ASL questions across emotions. Squints are not present in all wh-questions nor are wide eyes in all yes/no questions, now made apparent through emotion added to questions in the data.

An angry or sad yes/no question may include brow furrowing and squinted eyes, but the eyebrow height will still raise compared to the surrounding conversational level, so students can look for this subtle shift in height. Also, a happy wh-question can omit brow furrowing and will still appear to show happy emotion on the face, but the eyebrow height will still lower relative to the surrounding conversation.

Finally, during the questions and statements there will be eyebrow height changes at lexical boundaries throughout the sentences for both syntactic and prosodic purposes. Students do not have to let this distract them from recognizing the overall lowering or raising of the eyebrow height. In addition to an overall change in eyebrow height, students can compare a raising or lowering at the end of the sentence relative to the rest of the sentence to see if

there is a lowering (wh-question over the last sign) or raising (yes/no questions).

For topics, eyebrows generally raise to more extreme values than questions alone (with the exception of the topic with lower levels), but this initial raised brow level does not prevent the rest of the non-topic constituent from creating a wh-question or yes/no question. Students can still look at the end of the sentence for clues to raised or lowered values for question types.

Also, other nonmanuals can provide clues, such as body leans and head tilts, but these are not as determinative across all question types, so until further research clarifies specific patterns that help distinguish ASL questions uniformly, the first focus should remain on eyebrows in ASL, targeted now at eyebrow height.

With practice in conversation students will begin to recognize these subtle shifts, and such practice should begin in the classroom setting. These suggestions on eyebrows in ASL questions are only the beginning of what I hope will be a continued effort among researchers to contribute meaningful improvements to curricula on nonmanuals in signed languages.

5.5 Future Research

Eyebrows play an important part in several other constituents in ASL, so future work can examine conditionals, relative clauses, and other constructions. Also, the combination of nonmanuals could provide clues to behavior of

individual nonmanuals, so it would be productive to expand this investigation to include measurements of multiple simultaneous nonmanuals. The combination of eye aperture changes, head tilts, and body leans should be added to investigations of eyebrows in ASL questions to see their interactions across emotions.

The Screen Calipers tool could be applied to analyze these other nonmanuals by hand. Other tools may also be developed for hand coded and computerized capture of reliable objective measurements on the face. Furthermore, a comparison of objective measurements across signed languages can provide greater understanding on differences in the organization of nonmanuals and their importance to signed languages as a whole.

5.6 Summary

This research introduces a novel approach to eyebrow analysis, and provides new details of eyebrow behavior in questions of different emotions based on the first quantitative measurements of eyebrow height in ASL. The findings show that eyebrow height in terms of raised or lowered eyebrows distinguishes questions uniformly, and not the presence or absence of brow furrowing. Also, eyebrow height maintains its linguistic distinctions in questions despite emotion similar to the way tone languages can maintain their lexical distinctions despite emotional or grammatical intonation.

The conclusions suggest a new focus in the debate on eyebrows in ASL, as the data show consistent patterns and ranges of raising or lowering that can simultaneously function as syntax, grammatical intonation, and emotional intonation similar to the intonation of spoken languages. The new findings also allow for suggestions to improve ASL curricula and lessen life-threatening misunderstandings of ASL questions.

I argue that as more ASL research is conducted on subtle layering of nonmanuals within a single channel, and as more fine details of not only ASL but other signed language nonmanuals are discovered and examined, we can better understand how signed languages and spoken languages share general patterns. The research shows that ASL nonmanuals, rather than comparing to English, are better compared to tone languages that allow pitch to not only create intonation contours but also to create minimal pairs. The complex simultaneous layering in ASL nonmanuals is analogized to the complex simultaneous layering in some spoken languages, such as voice quality, vowel quality, and changes in pitch.

The data show more new clues to the intricate nature of nonmanuals in ASL. As known signed languages show some similarities and some differences in nonmanual use and functions, one might wonder if all signed languages layer in a manner as complex as ASL, or if some languages will show less complexity on the face, and even other signed languages will show even greater layering.

I suggest that comparisons of how a channel functions can help us make comparisons across languages in either modality, whether visual or spoken. This research on nonmanuals and the works of many prior studies show that this area of ASL research is a wide open field rich with linguistic treasures waiting to be uncovered. This research has now provided an additional craft for future voyages, and contributed additional detail to the map for the road ahead.

APPENDIX A

TYPE-BY-EMOTION STATISTICS

Difference of Least Squares Means for Maximum Pixel

Effect	Sentence	Type	Emotion	Sentence	Type	Emotion	Std. Error	Adj. P
Sentence	1			2			.2364	.6454
Sentence	1			3			.2364	.2107
Sentence	2			3			.2364	.0280
Type		Y/N			WH		.7613	.0071
Type		Y/N			DECL		.7613	.4173
Type		WH			DECL		.7613	.0880
Emotion			HAPPY			SURP	.3052	.0632
Emotion			HAPPY			NEUT	.3052	<.0001
Emotion			HAPPY			ANGRY	.3052	<.0001
Emotion			HAPPY			SAD	.3052	<.0001
Emotion			SURP			NEUT	.3052	<.0001
Emotion			SURP			ANGRY	.3052	<.0001
Emotion			SURP			SAD	.3052	<.0001
Emotion			NEUT			ANGRY	.3052	<.0001
Emotion			NEUT			SAD	.3052	<.0001
Emotion			ANGRY			SAD	.3052	0.0010
Type*Em		Y/N	HAPPY		Y/N	ANGRY	.5287	<.0001
Type*Em		Y/N	HAPPY		Y/N	SAD	.5287	<.0001
Type*Em		Y/N	HAPPY		WH	SURP	.8962	<.0020
Type*Em		Y/N	HAPPY		WH	NEUT	.8962	<.0001
Type*Em		Y/N	HAPPY		WH	ANGRY	.8962	<.0001
Type*Em		Y/N	HAPPY		WH	SAD	.8962	<.0001
Type*Em		Y/N	HAPPY		DECL	ANGRY	.8962	<.0001
Type*Em		Y/N	HAPPY		DECL	SAD	.8962	<.0001
Type*Em		Y/N	SURP		Y/N	ANGRY	.5287	<.0001
Type*Em		Y/N	SURP		Y/N	SAD	.5287	<.0001
Type*Em		Y/N	SURP		WH	SURP	.8962	<.0001
Type*Em		Y/N	SURP		WH	DECL	.8962	<.0001
Type*Em		Y/N	SURP		WH	ANGRY	.8962	<.0001
Type*Em		Y/N	SURP		WH	SAD	.8962	<.0001
Type*Em		Y/N	SURP		DECL	NEUT	.8962	0.0200
Type*Em		Y/N	SURP		DECL	ANGRY	.8962	<.0001
Type*Em		Y/N	SURP		DECL	SAD	.8962	<.0001
Type*Em		Y/N	NEUT		Y/N	ANGRY	.5287	<.0001
Type*Em		Y/N	NEUT		Y/N	SAD	.5287	<.0001
Type*Em		Y/N	NEUT		WH	SURP	.8962	0.0366
Type*Em		Y/N	NEUT		WH	NEUT	.8962	<.0001
Type*Em		Y/N	NEUT		WH	ANGRY	.8962	<.0001
Type*Em		Y/N	NEUT		WH	SAD	.8962	<.0001
Type*Em		Y/N	NEUT		DECL	ANGRY	.8962	<.0001
Type*Em		Y/N	NEUT		DECL	SAD	.8962	<.0001
Type*Em		Y/N	ANGRY		WH	HAPPY	.8962	<.0001
Type*Em		Y/N	ANGRY		DECL	HAPPY	.8962	<.0001
Type*Em		Y/N	ANGRY		DECL	SURP	.8962	<.0001
Type*Em		Y/N	ANGRY		DECL	NEUT	.8962	0.0042

Type*Em		Y/N	SAD		WH	HAPPY	.8962	0.0246
Type*Em		Y/N	SAD		DECL	HAPPY	.8962	0.0105
Type*Em		Y/N	SAD		DECL	SURP	.8962	<.0001
Type*Em		WH	HAPPY		WH	SURP	.5287	0.0076
Type*Em		WH	HAPPY		WH	NEUT	.5287	<.0001
Type*Em		WH	HAPPY		WH	ANGRY	.5287	<.0001
Type*Em		WH	HAPPY		WH	SAD	.5287	<.0001
Type*Em		WH	HAPPY		DECL	ANGRY	.8962	<.0001
Type*Em		WH	HAPPY		DECL	SAD	.8962	0.0012
Type*Em		WH	SURP		WH	ANGRY	.5287	<.0001
Type*Em		WH	SURP		WH	SAD	.5287	0.0002
Type*Em		WH	SURP		DECL	SURP	.8962	0.0002
Type*Em		WH	NEUT		WH	ANGRY	.8962	0.0035
Type*Em		WH	NEUT		DECL	HAPPY	.8962	0.0026
Type*Em		WH	NEUT		DECL	SURP	.8962	<.0001
Type*Em		WH	ANGRY		DECL	HAPPY	.8962	<.0001
Type*Em		WH	ANGRY		DECL	SURP	.8962	<.0001
Type*Em		WH	ANGRY		DECL	NEUT	.8962	<.0001
Type*Em		WH	SAD		DECL	HAPPY	.8962	<.0001
Type*Em		WH	SAD		DECL	SURP	.8962	<.0001
Type*Em		WH	SAD		DECL	NEUT	.8962	0.0026
Type*Em		DEC	HAPPY		DECL	SURP	.5287	0.0112
Type*Em		DEC	HAPPY		DECL	ANGRY	.5287	<.0001
Type*Em		DEC	HAPPY		DECL	SAD	.5287	<.0001
Type*Em		DEC	SURP		DECL	NEUT	.5287	<.0001
Type*Em		DEC	SURP		DECL	ANGRY	.5287	<.0001
Type*Em		DEC	SURP		DECL	SAD	.5287	<.0001
Type*Em		DEC	NEUT		DECL	ANGRY	.5287	<.0001
Type*Em		DEC	NEUT		DECL	SAD	.5287	<.0001

APPENDIX B

ASL EYEBROW BEHAVIOR INSTRUCTIONAL GUIDE

ASL Eyebrow Behavior In Questions and Topics

- WH-Questions:
  May see overall lowered eyebrows
  Will see subtle lowering over wh-words
  Will see subtle lowering at the end of sentences (on a wh-word or a substitute)

- Yes/No Questions:
  May see overall raised eyebrows
  Will see subtle raising at some point to the end of the sentence
  Look for inner brow raise by the end of the sentence

- Topics:
  Often very high raising, beginning of the sentence

****

» Look for Eyebrow Height: the center of the eye to the middle of the eyebrow

» Emotions are recognized naturally, but do not assume what you see is purely emotional

» Eyebrows raise and lower in subtle ways over signs and groups of signs. Do not let this distract you from observing the eyebrow height for questions at the end of the sentences.

» Eyes often squint with wh-questions, but can squint with yes/no questions. Conversely, wide eyes often follow yes/no questions, but can occur in wh-questions.

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BIOGRAPHICAL INFORMATION

Traci Weast began signing at age 5. She worked for six years as an interpreter, was NAD certified, and is a Texas certified teacher with both Spanish and American Sign Language subject endorsements. Her ten years of teaching experience include instruction in an interpreter training program. In her undergraduate work, she majored in Linguistics with a Spanish minor, receiving a Certificate to Teach English as a Second Language. She focused on ASL child language acquisition with a broader emphasis on theories of language learning. She also worked at the San Diego State University Foundation under Judy Reilly, transcribing child ASL data.

In graduate school, she focused on phonetic analysis and the interface between tone and affect. Although her emphasis was on American Sign Language, she also worked with advanced computer software to examine languages such as Korean, Kabiye, and Somali. She presented her Korean findings at a Harvard University conference, later published in their proceedings. In 2008, she presented her dissertation findings at the Chicago Linguistics Society to be published in the 44th proceedings. She will also present her work in the June 2008 SignTyp conference on American Sign Language Phonology. She intends to continue in academia, and to continue research on nonmanuals in American Sign Language.