The Syntactic Organization of American Sign Language:

A Synopsis

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1 Overview of our Linguistic Research

Our research to date has focused on examination of the syntactic structure of American Sign Language (ASL). A skeletal view of ASL clause structure, as we understand it, is shown in Figure 1. Along with manual signing of lexical items, crucial information is expressed through specific facial expressions and movements of the upper body, collectively referred to as *non-manual markings*. These non-manual expressions extend over phrasal domains and play a critical role in the grammar of signed languages [1, 15, 16, 39, e.g.]. Our syntactic research [2, 11-13, 20, 33, 36, 38, 45, 47, 50, 51, 53-55, 58, 60-62] has included close attention to the linguistic roles of gestures such as raised or lowered eyebrows, eye gaze, nose wrinkles, as well as head nods, shakes, and tilts.

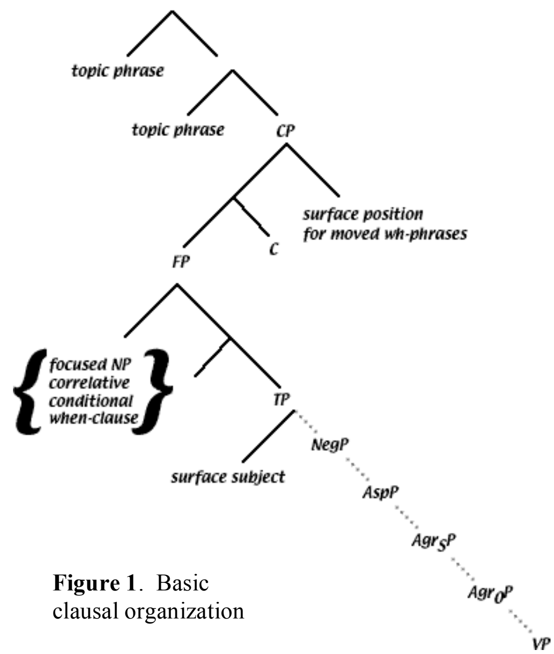

Figure 1. Basic clausal organization

1.1 Non-manual markings as expressions of syntactic features

We have argued that many non-manual behaviors express syntactic features (such as +wh, +neg, and agreement features) and that their distribution and intensity are predictable [60]. In general, the syntactic non-manual expression co-occurs with the manual sign in the node containing the relevant feature, and it optionally spreads over the c-command domain of that node, as illustrated for negative sentences and wh-questions (in which movement to a rightward Spec,CP position has occurred [58]) in (1)-(4) on the next page.[1] As with other non-manual markings, the marking for negation consists of a *cluster* of facial gestures. The negative marking includes, most prominently, a side-to-side headshake. The marking for wh-questions includes other behaviors, most notably lowered brows [14, 16, 39, 70]. The labeled lines in the examples below indicate the scope over which these markings occur.[2] For periodic motions of the head, such as nods and shakes, we have observed in our corpus that the head begins an anticipatory motion, either raising or moving sideward, so that the true starting position of the linguistic event allows for maximum thrust and path of movement (downward or to the side).[3] Thus, prior to the articulation of the sign meaning 'NOT', the head moves sideward. In tight alignment with the start of the manual sign, the head then begins a side-to-side shake that diminishes in intensity (in this case, amplitude) as the marking extends over the VP in a sentence like (3). The intensity of non-manual markings is greatest near the node of origin and decreases as distance from that node increases. So, in (3), where spread is left-to-right, intensity diminishes over time. However, in (4) the intensity of wh-marking, which spreads leftward from C over IP, increases progressively increases over time.

[1] For arguments against alternative claims about the data and an account in terms of leftward movement presented in [69], see [50, 53, 54]. See also [19] for speculation about why Spec,CP seems to be clause-final in signed languages generally.

[2] Details about the glossing conventions used here can be found in Section 5.

[3] Looking at this anticipatory movement (as opposed to the linguistically significant portion of the head shake) could have led to prior claims that the non-manual marking of negation necessarily occurs over the entire sentence [67-69] (although see [22]). The fact that the marking occurs over a phrase smaller than the entire sentence can be seen clearly in sentences with an adverb between the subject and verb:

$$\text{(a) JOHN MAYBE [} \overline{\text{NOT [BUY HOUSE]}_{VP}}^{\text{neg}} \text{]}_{NegP}$$

'John maybe didn't buy a house'

Negative sentences	*Wh-questions*
(1) JOHN [$\overline{\text{NOT}}^{\text{neg}}$ [BUY HOUSE]$_{VP}$]$_{NegP}$	(2) [[t_i LOVE JOHN]$_{IP}$ $\overline{\text{WHO}_i}^{\text{wh}}$]$_{CP}$
(3) JOHN [$\overline{\text{NOT [BUY HOUSE]}}^{\text{neg}}$$_{VP}$]$_{NegP}$	(4) [$\overline{\text{[} t_i \text{ LOVE JOHN]}_{IP} \text{ WHO}_i}^{\text{wh}}$]$_{CP}$
'John did not buy a house.'	'Who loves John?'

It would seem that the cases with and without spread in fact reflect differing prosodic structures.[4]

There is a strong preference to articulate such non-manual markers simultaneously with manual material. For example, the sign 'NOT' is not required (7) and the wh-phrase may remain *in situ*, which results in there being no manual material in head or Spec position to be associated with the +wh feature external to IP (8). In the absence of a manual item (either in Neg (7) or to the right of IP (8)), the spread of the non-manual marking over the c-command domain of the node with the corresponding syntactic feature is obligatory.

Negative sentences	*Wh-questions*
(5) * JOHN [$\overline{}^{\text{neg}}$ [BUY HOUSE]$_{VP}$]$_{NegP}$	(6) * [[WHO LOVE JOHN] $\overline{}^{\text{wh}}$]$_{CP}$
(7) JOHN [$\overline{\text{[BUY HOUSE]}}^{\text{neg}}$$_{VP}$]$_{NegP}$	(8) [$\overline{\text{[WHO LOVE JOHN]}}^{\text{wh}}$]$_{CP}$
'John did not buy a house.'	'Who loves John?'

The same patterns of intensity and spread of non-manual markings are found with yes-no questions. The non-manual marking for yes-no questions consists most notably of raised eye brows, widened eye aperture and a forward head movement. In addition, there is an optional question particle (glossed as QMwg) that, when used, occurs at the end of the sentence (in C). When this particle is present, the non-manual marking can either appear solely over the particle (9) or it can optionally spread over the entire sentence (11). When the particle is not present, the spread is obligatory (as shown by the contrast between (10) and (12)).[5]

Yes-No Questions	
(9) [JOHN BUY HOUSE]$_{IP}$ $\overline{\text{[QMwg]}}^{\text{y/n}}$$_C$]$_{CP}$	(10) $\overline{\text{[JOHN BUY HOUSE]}_{IP} \text{ [+y/n]}}^{\text{y/n}}$$_C$]$_{CP}$
(11) $\overline{\text{[JOHN BUY HOUSE]}_{IP} \text{ [QMwg]}}^{\text{y/n}}$$_C$]$_{CP}$	(12) * [JOHN BUY HOUSE]$_{IP}$ $\overline{\text{[+y/n]}}^{\text{y/n}}$$_C$]$_{CP}$
'Did John buy a house?'	'Did John buy a house?'

1.2 At the right periphery

Two other constructions also involve elements in the right periphery: right-dislocated pronouns and sentence-final tags. A "right-dislocated pronoun" is an unstressed pronoun coreferential with a previous NP in the sentence, as in (13) and (14).[6]

(13) JOHN$_i$ LEAVE, IX$_i$
'John left, him.'

(14) IX-1p$_i$ SEE$_j$ JOHN$_j$ YESTERDAY, IX$_j$
'I saw John yesterday, him.'

Such pronouns are part of the same prosodic unit as the preceding material, and there is not usually a pause before the pronoun. The same discourse factors that govern the use of right-dislocated pronouns in other languages (e.g., French and Norwegian) seem to apply to ASL as well [55].

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4 With negation, it appears that the pattern illustrated in (1) is the 'marked' case, and reflects a prosodic break (normally for purposes of emphasis) between the negative sign and the VP. The differences in usage between the patterns shown in (2) and (4) have proved more elusive and are still unclear.

5 In addition, so-called *rhetorical questions* (both wh- and yes-no varieties)—to which the speaker provides the answer, used productively in ASL for specific discourse purposes—pattern like information-seeking questions with respect to the distribution of non-manual markings. However, rhetorical questions uniformly include raised eyebrows (even for wh-questions). Although raised eyebrows are a part of both information-seeking and rhetorical yes-no questions, the former are distinguished by both a hold of the final sign and more direct eye gaze to the addressee (signaling that an answer is expected). For further details about the structure of relative clauses (and arguments against Wilbur's [86, 87] claim that the question and answer are contained within a single clause with the answer in a "focus" position), see [38].

6 Padden [64, 65] described such sentences as involving 'subject pronoun copy.' It should be noted that in ASL, a right-dislocated pronoun can be coreferential with the subject or the object.

While other languages allow full NP right-dislocation, such constructions are not found in ASL; thus a sentence like (15) is ungrammatical.[7] This fact is not particularly surprising since ASL makes use of specific points in space for pronominal reference; one cannot point (pronominally) to a location in space that has not yet been associated with a referent.

(15) * IX_i LEAVE, JOHN_i

In addition, to the extent that full NP right dislocation may function in other languages to disambiguate a referent, such disambiguation cannot be done this way in ASL, since referents referred to by pronouns are (already) unambiguously associated with specific locations in space.

Tags consist of a reduced clause that occurs at the end of the sentence for purposes of emphasis. Tags can contain modals, tense/aspect markers, and/or a pronoun coreferential with the matrix subject. There is an affirmative head nod, frequently associated with modals (and spreading over the VP), which is also frequently found [39] in many constructions that contain null verbal material (e.g., null copula and gapping constructions). Such a head nod distinguishes a sentence containing a right-dislocated pronoun (16) from a tag construction with a pronoun (17). It is also possible to have a right-dislocated pronoun at the end of a tag, as in (18).

(16) JOHN_i FUTURE_{tns} GO, IX_i
'John will go, him'

(17) JOHN_i FUTURE_{tns} GO, $\overline{\text{IX}_i}^{\text{hn}}$
'John will go, he (will).'

(18) JOHN_i FUTURE_{tns} GO, $\overline{\text{FUTURE}_{tns}\text{, IX}_i}^{\text{hn}}$
'John will go, (he) will, him.'

When a sentence contains an affirmative head nod both in the main clause and in a tag, it is often possible to distinguish two separate peaks of intensity; one in the main clause (which attenuates as the rest of the main clause is signed) and a second associated with the articulation of the tag. Such is the case in (19) and (20), with a schematic of the head movement in (19) shown in Figure 2. The same expression of two peaks of intensity of non-manual marking can be seen in a sentence with a negative tag as shown in (21).

(19) JOHN $\overline{\text{FUTURE}_{tns}\text{ GO PARTY}}^{\text{hn}}$, $\overline{\text{FUTURE}_{tns}}^{\text{hn}}$
'John will go to the party, (he) will.'

(20) JOHN $\overline{\text{CAN GO}}^{\text{hn}}$, $\overline{\text{CAN}}^{\text{hn}}$
'John can go, (he) can.'

(21) JOHN $\overline{\text{CAN'T GO}}^{\text{neg}}$, $\overline{\text{CAN'T}}^{\text{neg}}$
'John can't go, (he) can't.'

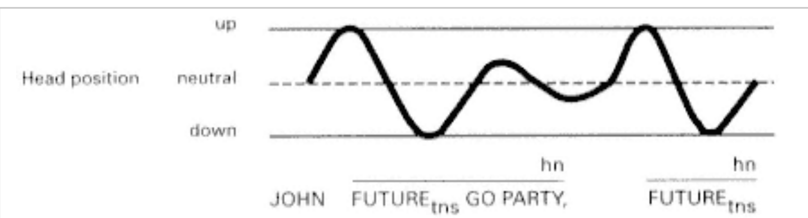

Figure 2. Head nod associated with both main clause and tag.

1.3 Agreement

Syntactic agreement in ASL is particularly interesting. Use of space enables expression of referential information along with person information.[8] Determiners, pronouns, possessives, emphatic reflexives, and morphological markers of subject/object verb agreement all involve the hands pointing (with varying handshapes) to the location associated with a given referent (which we have called the 'phi-location' [62]). In 1996, Bahan [12] discovered the existence of non-manual correlates of syntactic agreement, consisting of head tilt and/or eye gaze toward these phi-locations. In transitive clauses, head tilt and eye gaze mark subject and object agreement, respectively, as shown in (27)-(28). In intransitive clauses, agreement with the unique argument may be marked by either or both of these non-manual markings. Spread over the c-command domain of the agreement projections (which we posit) is obligatory, as there is no manual material in the nodes associated with the agreement features. These non-manual expressions of agreement, like overt manual expressions of agreement, license null arguments [13]. (A different account of agreement and the licensing of null subjects is presented in [41, 42].)

[7] This restriction leads Wilbur [87] to deny that right dislocation exists at all in ASL.

[8] See Liddell [40, e.g.], who uses the modality-specific expression of referential information (in part) to argue that agreement in ASL is not strictly grammatical; but see also the response in [62].

*Intransitive sentences**	*Transitive sentences*	
(22) IX$_i$ MAN [ARRIVE]$_{VP}$ headtilt$_i$	(23) JOHN$_i$ [LOVE MARY$_j$]$_{VP}$	(24) JOHN$_i$ [$_i$BLAME$_j$ MARY$_j$]$_{VP}$
(25) IX$_i$ MAN [ARRIVE]$_{VP}$ eyegaze$_i$	headtilt$_i$ eyegaze$_j$	headtilt$_i$ eyegaze$_j$
(26) IX$_i$ MAN [ARRIVE]$_{VP}$ headtilt$_i$ eyegaze$_i$	(27) JOHN$_i$ [LOVE MARY$_j$]$_{VP}$	(28) JOHN$_i$ [$_i$BLAME$_j$ MARY$_j$]$_{VP}$
(29) IX$_i$ MAN [ARRIVE]$_{VP}$	[*note:* LOVE is a verb that is articulated on the body; it does not overtly manifest subject and object agreement. Non-manual expression of agreement is still allowed.]	[*note:* BLAME is an 'agreeing verb': subject and object agreement is marked manually by the start and end points of the sign. See [64].]
'The man arrived.'	'John loves Mary'	'John blames Mary'
*"IX$_i$" represents the index finger pointing to the phi-location associated with the referent of 'the man.' We have analyzed this as a definite determiner in ASL, which takes the same form as the pronominal [11].		

Licensing of null subjects by overt expression of subject agreement	(30) * pro$_i$ [LOVE MARY$_j$]$_{VP}$ headtilt$_i$ eyegaze$_j$	(31) pro$_i$ [$_i$BLAME$_j$ MARY$_j$]$_{VP}$ headtilt$_i$ eyegaze$_j$
'(He) loves Mary.'	(32) pro$_i$ [LOVE MARY$_j$]$_{VP}$	(33) pro$_i$ [$_i$BLAME$_j$ MARY$_j$]$_{VP}$

In 1997, MacLaughlin [45] discovered these same patterns of non-manual agreement marking within Determiner Phrases, with possessive DP's patterning with transitive clauses and intransitive DP's patterning with intransitive clauses, as illustrated below. Note: there is one correctly predicted difference in the pattern of spread of the non-manual markings in the two domains. Since in ASL DP, unlike IP, can host manual material in the head of the agreement projection, the spread of non-manual subject/possessor agreement is obligatory in IP, but optional in DP: [9]

Non-possessive DP's		*Possessive DP's*	
without spread	*with spread*	*without spread*	*with spread*
(34) [IX$_i$ MAN]		(35) [JOHN$_i$ POSS$_i$ FRIEND$_j$]	
headtilt$_i$	headtilt$_i$	tilt$_i$ eyegaze$_j$	headtilt$_i$ eyegaze$_j$
(36) [IX$_i$ MAN] eyegaze$_i$	(37) [IX$_i$ MAN] eyegaze$_i$	(40) [JOHN$_i$ POSS$_i$ FRIEND$_j$]	(41) [JOHN$_i$ POSS$_i$ FRIEND$_j$]
(38) [IX$_i$ MAN] headtilt$_i$ eyegaze$_i$	(39) [IX$_i$ MAN] headtilt$_i$ eyegaze$_i$	[*note:* POSS is a manual sign marking possession, articulated with an open palm pointing to the phi-location of the possessor.]	
(42) [IX$_i$ MAN]	(43) [IX$_i$ MAN]		
'The man'		'John's friend'	

One puzzling observation about these markings of agreement is that they are very frequent in ASL but are not required (see (34)-(35)). Very recently, we have discovered subtle semantic differences between the cases in which overt expression of non-manual subject agreement is present and those in which it is not; and we have reanalyzed these expressions not as pure (and optional) markings of subject agreement, but rather as focus markers whose articulation includes an expression of subject (and, in the case of transitive verbs, object) agreement [62]. Thus, the difference in usage of sentences (22) and (25) is related to the fact that in (25), but not (22), there is focus on the VP (as discussed further on page 6).

Similarly, some light has been shed on the mystery of the apparent optionality of wh-movement through an understanding of the semantic differences between questions involving *in situ* vs. moved wh–phrases [58]. Here again, focus provides the key (as is further shown in [20]). The wh-phrase only moves when it has narrow focus. Thus the difference in meaning between a sentence like (8), with the wh-phrase *in situ*, and (2) or (4), with the wh-phrase moved to a clause-final Spec,CP position, is comparable to the difference in English between the neutral "Who came?" and the sentence with different prosody, "*Who* came?" where the latter (discussed, e.g., by [31, 32]) presupposes that someone did

[9] This kind of parallel—between transitive/intransitive clauses and possessive/non-possessive DP's—is also found in other languages. In Aleut, the number agreement marking on nouns with possessors is identical to the object agreement marking on verbs [17]. On possessor-less nouns, the marking is the same as subject agreement marking on verbs. Abney [4] notes a similar fact about agreement morphology in Yupik: possessive noun phrases pattern like transitive clauses and non-possessives with intransitives. Bittner and Hale [18] also report similar parallels of DP and IP with respect to case marking, for many languages.

come and therefore the answer "Nobody" would be unexpected. This is essentially the same prosodic difference found between the neutral "John came" and the English sentence with focus on 'John': "*John* came."

The basic idea is that because of Relativized Minimality [71, 72], a focused wh-phrase moves into a leftward focus position that plays a central role in ASL grammar, from which it then moves on to the higher Spec,CP position at the right edge of the clause. However, a wh-phrase that is *not* in focus is blocked from moving to the higher position by the intermediate FP in ASL.

1.4 Focus

ASL has a variety of mechanisms for marking focus. The "focused" phrase can remain *in situ* as in (44) with a characteristic non-manual marking, including raised eyebrows, which is here labeled 'foc'. However, it is quite common for a focused NP argument to move to a position at the left periphery, as in (45). The same characteristic non-manual marking, including most notably raised eyebrows, is found on the NP in this position. This is distinct from the position in which topics occur [1, 55]. Topics bear a similar, but distinguishable, non-manual marking, as described by Aarons [1, 3]; cf. (46).

It is argued in [58] that this same position is also used for several other types of syntactic constructions in ASL, including relative clauses (really correlatives) such as (47) and conditional clauses as in (48). Both of these types of clauses have a typical non-manual marking that includes raised eyebrows [21].

foc
(44) JOHN LIKE $\overline{\text{NOT BAGEL}}$ DONUT
'John likes *not bagels*, but donuts.'

foc
(45) $\overline{\text{BAGEL}_i}$ JOHN LIKE t_i
'*Bagels* John likes.'

top foc
(46) $\overline{\text{JOHN}_i}$ $\overline{\text{BAGEL}}$ IX_i LIKE BUT IX_i HATE LOX
'As for John, *bagels* he likes but he hates lox.'

foc/rc
(47) $\overline{\text{MOUSE CHASE CAT}}$ DIE
'The mouse that chased the cat died.'

foc/cond
(48) $\overline{\text{RAIN}}$ JOHN FUTURE_{tns} CANCEL PARTY
'If it rains, John will cancel the party.'

One argument supporting the claim that "focused" NP's, correlatives, and conditional clauses occur in the same position is that they occur in complementary distribution. This position plays an important role in the grammar of ASL; as just discussed, we have argued that it is also involved in the movement of (narrowly focused) wh-phrases.

Indefinite focus particle. Further evidence for the proposed account of wh-movement and non-manual expression of agreement in relation to focus comes from interaction between these two constructions and the distribution of a particle associated with focused indefinite constituents. This particle, first identified and described in [20], serves to express "uncertainty" in various ways, which can be formalized semantically in terms of a domain-widening effect of the same sort as that proposed for English 'any' by Kadmon and Landman [34]. Its function is to widen the domain of possibilities under consideration from the typical to include the non-typical as well, along a dimension appropriate in the context.

Indefinite constituents (including the ASL sign corresponding to the English 'someone/something/anyone/anything', as illustrated in (50)-(51) and wh-phrases, as in (55)-(56)) can be used with this particle *only* when they are in focus (compare with (52)-(53)). Moved wh-phrases are frequently followed by this particle, but non-focused, *in situ* wh-phrases are incompatible with this particle, as shown in (57)-(58).

y/n
(49) $\overline{\text{SOMETHING/ONE SEE JOAN}}$
'Did anyone see Joan?' [neutral with respect to focus]

y/n
(50) $\overline{\text{!SOMETHING/ONE!\^{}part:indef SEE JOAN}}$

y/n
(51) $\overline{\text{!SOMETHING/ONE! SEE JOAN}}$
part:indef--
'Did *anyone* see Joan?'

[Note that the particle can be articulated with either the dominant hand, as in (50) and (55), or with the non-dominant hand, simultaneously with the manual articulation of the indefinite constituent, as in (51) and (56)), or with both hands.]

y/n
(52) * $\overline{\text{SOMETHING/ONE\^{}part:indef SEE !JOAN!}}$

y/n
(53) * $\overline{\text{SOMETHING/ONE SEE !JOAN!}}$
part:indef–
'Did anyone see *Joan*?'

[The above examples are ungrammatical on the reading where *Joan* is focused.]

(54)
```
_________y/n
WHO SEE  JOAN
```
'Who saw Joan?' [neutral with respect to focus]

(55)
```
______________________________y/n
t_i SEE JOAN   WHO_i^part:indef
```

(56)
```
______________________y/n
t_i SEE JOAN  WHO_i-------
              part:indef
```

'*Who* saw Joan?'

(57) *
```
_____________________y/n
WHO^part:indef SEE !JOAN!
```

(58) *
```
_______________y/n
WHO------- SEE !JOAN!
 part:indef
```

'Who saw *Joan*?'

[The above examples are ungrammatical on the reading where *Joan* is focused.]

Focus marking realized by non-manual expression of syntactic agreement. As mentioned in section 1.3, the presence of non-manual subject and object agreement with the Verb Phrase correlates with a reading of predicate focus. (In fact, the use of non-manual expressions of syntactic agreement to mark focus within the clause and the DP is more general.)

Consider, for example, the following chart, which illustrates the range of situations in which it is—and is not—felicitous to find a verb co-occurring with a head tilt marking subject agreement.

Felicitous with head tilt to the subject's phi-location	***Not felicitous with head tilt to the subject's phi-location***
The verb BATHE in the following contexts: (59) John is *bathing*; Mary is taking a shower. (60) On Monday, John *bathes*; on Tuesday, he showers. (61) Everyone we know takes a shower, but John *bathes*. (62) Mary meditates to relax; John *bathes*. (63) What does John do in the morning? He *bathes*, he gets dressed, … (64) How does John get clean? He *bathes*.	The verb BATHE in these contexts: (65) A. Who bathes? John *bathes*. B. Is Peter bathing? No, John is *bathing*. The verb (BATHE, DIE) following any of the set of items we have postulated to occur in Spec,FP (i.e., a focused NP, a correlative, or a conditional or 'when' clause), e.g.: (66) `__foc   headtilt_i` * `JOHN_i   BATHE` '*John* is *bathing*.' (67) `__________foc/rc   headtilt_i` * `MOUSE_i CHASE CAT   DIE` 'The mouse that chased the cat *died*.'
The verb following a Topic: (68) `__top   headtilt_i` `JOHN_i   BATHE` 'As for John, he is *bathing*.'	With narrow focus on an indefinite within the VP (as marked by the focus particle) (69) `JOHN   VISIT   SOMETHING/ONE  part:indef` 'John is visiting *someone (or other)*.' (70) `____________headtilt_i` `JOHN_i   VISIT   SOMETHING/ONE` 'John is *visiting someone*.' (71) `__________________________headtilt_i` * `JOHN_i   VISIT   SOMETHING/ONE  part:indef`
	With narrow focus on a (right-peripheral) wh-phrase, with or without the focus marker (72) `_____headtilt_i------` * `JOHN_i   SEE YESTERDAY   WHO` '*Who* did John see yesterday?' (73) `_____headtilt_i---------------` * `JOHN_i   SEE YESTERDAY   WHO^part:indef` '*Who* did John see yesterday?'

Thus, several different strategies are available for marking focus in ASL, among them: non-manual marking (generally including raised brows), a left-peripheral focus position (in the case of wh-phrases, movement to this position renders the focused wh-phrase eligible to undergo rightward wh-movement to Spec,CP), and non-manual realizations of syntactic agreement co-occurring with the focused constituent within the VP (or DP, although we have not discussed that here).

The above is a very brief summary of some of the recent research of the American Sign Language Linguistic Research Project. See references for further details. This research has been carried out with assistance from SignStream, an application described in the next section, for annotation and analysis of data collected as described in section 3.

2 Development of SignStream Software

Examination of parallel activities of significance to signed languages has been greatly enhanced by SignStream [46, 48, 52, 56, 57, 59, 63], a tool for linguistic annotation of visual language data that we have developed and used extensively to analyze data from native ASL signers collected in the video collection facility described below. See the screen shot in Figure 3. A Java reimplementation is now in progress. The new cross-platform version will include new functionalities, including tools for displaying duration of events and for efficient data-entry of fine-grained phonological information (such as hand shape, orientation, location, and movement characteristics) in parallel fields.

3 Collection, Annotation & Distribution of High-quality Data from Deaf Native Signers

The National Center for Sign Language and Gesture Resources (NCSLGR)

We established a dedicated digital video image collection facility with multiple synchronized digital cameras to capture different views of the subject. The ASL data collected from native signers are carefully annotated, with identification of the start and end frames of each sign and of non-manual behaviors occurring in parallel with manual signing; part of speech tagging and English translations are also provided. The annotations and video data (available in a variety of formats) are made publicly available on the WWW and on CD-ROM. The data collected to date include more than 1,000 isolated sentences, 15 short stories (each several minutes long), and 2 25-minute dialogues. The resulting corpus, with over 11,000 sign tokens (signed in context, rather than in isolation), is the only sign language corpus of this kind.

The video data have also been analyzed by computer algorithms. The linguistic annotations make it possible to evaluate such algorithms, by providing a “ground truth” against which quantitative evaluation measures can be computed. For example, computer scientists have been developing algorithms for face tracking and detection of head movements and facial expressions. Our annotated corpus has been of critical importance in our own research on ASL linguistics and sign language recognition. It has also been used by others, including linguists, computer scientists, and sign language teachers and students.

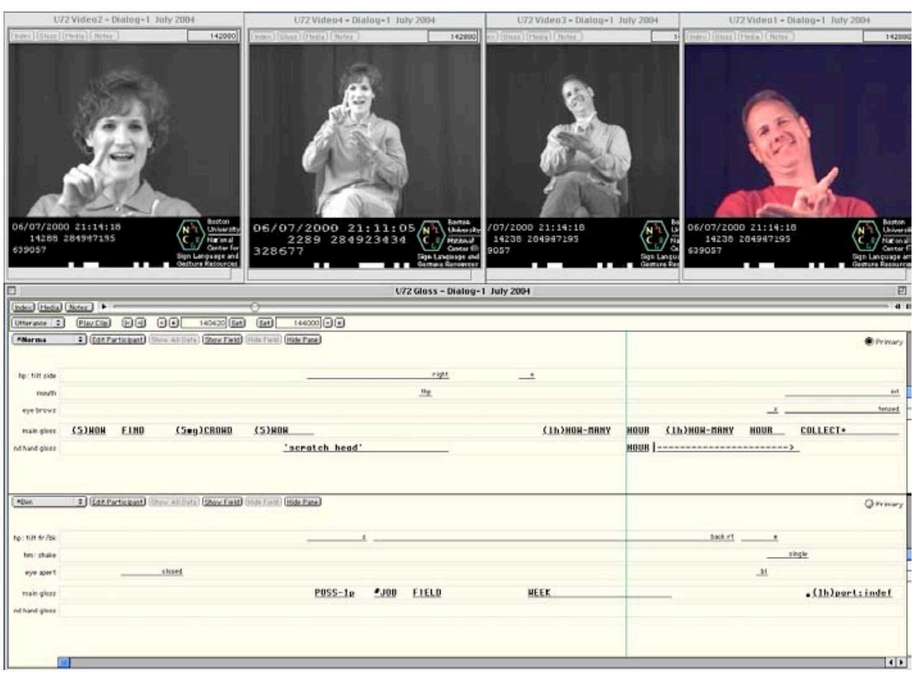

Figure 3. SignStream video and gloss windows. Fields are provided for encoding non-manual gestures, such as eyebrow raises and head tilts. This is in addition to gloss fields for both the dominant and non-dominant hands.

Items occurring in these fields are vertically aligned to represent their temporal relations and co-occurrence, as shown by the video alignment indicator marking the current frame.

Shown here is a dialog between two signers; separate participant panes display the (overlapping) signing of both.

4 Computer Science Research

Computer science research at BU by Stan Sclaroff and his colleagues and students has included hand pose estimation and detection of relevant head gestures and facial expressions [5-10, 29, 37, 43, 56, 73-80, 88]. UPENN and Rutgers publications that have resulted from these projects include [23-28, 30, 35, 44, 49, 66, 81-85]. Christian Vogler (now at Gallaudet University) and Dimitris Metaxas developed a framework for continuous sign language recognition, with a particular emphasis on phonetic and phonemic modeling. In addition, they developed methods to recognize and integrate the parallel tiers of sign language, and demonstrated the feasibility of the method by integrating the parallel information from the dominant and non-dominant hands, as well as the dominant handshape. The output of the recognition algorithm is information on what—and by extension, what phoneme—occurred when and for how long. Concurrently, Siome Goldenstein, in collaboration with Drs. Vogler and Metaxas, developed methods for robust 3D tracking of the human face from monocular video images. These methods recover the 3D pose of the head, along with some nonrigid deformations of the face, in particular the eyebrow movements and a coarse estimate of the mouth movements.

5 Glossing Conventions

Below are listed the conventions used in glossing the example sentences. A much more detailed exposition of the glossing conventions we have used for our annotations is available in [57].

In the interest of space (and ease of exposition), only the relevant non-manual markings under discussion are displayed for each example. Digital video examples are available in association with most of the publications in which these results are discussed at greater length; see http://www.bu.edu/asllrp/publications.html.

Glosses Standard glossing conventions are used here; signs are glossed in capital letters using the closest English approximation. Signs are not overtly marked as either one- or two-handed unless there is some variation from the unmarked form (e.g., a two handed sign articulated with only one hand or two hands articulating two different signs at the same time). When there are notable activities on both the dominant and non-dominant hands, these are listed on two separate lines, with the dominant hand listed first (as in (51)). Additional specifics about individual glosses items are noted below.

IX– a sign articulated with a pointing index finger toward a phi-location. This sign can function as a pronoun/definite determiner or locative adverb. When glossed simply as IX, it is assumed to be third person; first or second person is overtly marked with a –1p or -2p suffix. A subscript indicates the phi-location to which the sign is pointing, as well as marking coreference relations.
GLOSS^GLOSS – a contraction of two signs.
!GLOSS! – indicates a stressed, emphatic articulation.
$_{\mathbf{i}}$**VERB**$_{\mathbf{j}}$ – prefixes and suffixes on a verb gloss indicate (manual) subject and object agreement respectively. The indices indicate both coreference relations as well as the phi-locations associated with the subject and/or object. For ease of presentation, however, this agreement has not always been explicitly marked here, e.g. on the verb SEE in example (49).
POSS$_{\mathbf{i}}$ – a possessive sign articulated with an open palm toward the phi-location of the possessor (indicated by the subscript).
SOMETHING/ONE – a sign meaning ‘something’ or ‘someone’. In addition, this sign functions as an indefinite determiner. There is a co-occurring non-manual marking involving, most notably, an unfocused gaze and rapid headshake.
FUTURE$_{\mathbf{tns}}$ – a future tense marker (glossed in this manner to distinguish it from a similar sign (FUTURE$_{adv}$) that functions adverbially and does not occur in the tense position).
part:indef – an indefinite particle articulated with either one or both open hands, palms up, in a single outward movement. (It is distinct from a similar looking sign, glossed as “WHAT” , which involves a repeated side-to-side movement.)
QMwg – a question particle used optionally in yes-no questions consisting of a repeatedly bent and flexed index finger that is articulated toward the addressee. (The ‘wg’ refers to the wiggling movement of the finger.)

Non-manual markings Non-manual markings are clusters of movements of the face and upper body that are involved in wide range of constructions in ASL. The function as well as the salient characteristics of each of the markings used in examples are described below. In example sentences, the extent of non-manual markings is indicated with a labeled line over the signs with which the non-manual is coarticulated.. In addition, only the peaks of the relevant non-manual markings are labeled; onsets and offsets are not.

LABEL	FUNCTION OF MARKING	SALIENT ELEMENTS
neg	Negative	lowered eyebrows, side-to-side headshake
wh	Wh-question	lowered eyebrows, rapid side-to-side headshake
y/n	Yes-No Question	raised eyebrows, forward body lean
hn	Indicates null verbal material, effects compensatory lengthening, among other functions	head nod
(head)tilt	subject agreement (and DP internal possessor agreement)	head tilt to the relevant referent's phi-location (indicated by a subscript)
eyegaze	object agreement (transitive verbs) subject agreement (intransitive verbs) DP-internal agreement	eye gaze to the relevant referent's phi-location (indicated by a subscript)
top	Topic	raised eyebrows, single head nod
foc	Focus	raised eyebrows, backward head tilt
foc/cond	Conditional	raised eyebrows, squinted eyes
foc/rc	Relative Clause (correlative)	raised eyebrows, tensed cheeks

6 Further Resources

NCSLGR — collaborative project: Boston and Rutgers Universities. For information about our data collection facility, see `http://www.bu.edu/asllrp/cslgr/` and [56]. Video files, usually including a close-up of the face, a side view, and 2 stereoscopic front views, are available in a variety of formats (30/60 frames per second; compressed or uncompressed).

SignStream version 2.2.2 – distributed on a non-profit basis (Mac OS only)

Available for download from `http://www.bu.edu/asllrp/SignStream/`; or it can be ordered on CD-ROM along with the SignStream databases. Documentation is available from the Web site, including the User Guide [48] and detailed information about annotation conventions [57].

Java reimplementation

A Java version of SignStream, with many new features, is currently under development.

Computer vision research

`http://www.cs.bu.edu/groups/ivc/db/html/paper_list.php`

Data available on the WWW

A new Web-based search facility (being implemented by Benjamin N. Waber) to facilitate viewing and downloading subsets of our existing annotated data will be online by the end of summer 2005.

Available CD-ROM's distributed by the ASLLRP - See `http://www.bu.edu/asllrp/cd/` .

- *SignStream version 2.2.2* (2003).
- *NCSLGR SignStream Databases, Vol. 1* (2003). [includes 8 database files: **ncslgr10a,b,c,d,e,f,g,p,q**, containing a total of 310 utterances from three different native signers of ASL; with front and side views, close-up of the face]
- *ASLLRP SignStream Databases, Vol. 1,* version 2 [updated] (2003). [includes 4 excerpts of stories distributed by DawnSignPress, with annotations]
- ASLLRP Electronic Publications (June 2003).

Additional movie files–currently in the final stages of verification: about 700 additional utterances, 15 short stories, and 2 dialogues. Data will be released as verifications are complete.

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