Vertical representation of quantifier domains

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Abstract. We show via American Sign Language (ASL) productions of singular indefinites, plural pronouns, and negative quantifiers that ASL can use space to convey set size and quantifier domain restriction, and moreover, that sets are interpreted as increasingly larger as they are signed higher in space. Such overt markings of domain size are more than simply emphatic, participating in adverbial quantifier binding and exhibiting more systematicity than emphasis in English. We discuss our findings in light of previous research on the semantic use of sign height in ASL, and speculate on the origin of such a strategy in sign languages.

Keywords: Quantifiers, domain restriction, sign language, ASL, discourse referents, space.

1. Introduction

One well-known problem at the interface of semantics and pragmatics is the issue of quantifier domain restriction: how does the formal semantic component of grammar interact with contexts to sufficiently restrict the domain for the quantificational phrase "every student" in (1) such that it need not be the case that every single student in the world attended and enjoyed a lecture for (1) to be true (Barwise and Cooper 1981, von Fintel 1994; Szabo and Stanley 2000, a.o.)?
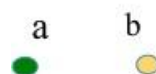
(1)   Every student enjoyed the lecture.

There is one (unlikely) interpretation of (1) in which every student in the entire world enjoyed the lecture. Another very plausible interpretation of (1) can be paraphrased as *Every student who went to the lecture enjoyed the lecture* or even *Every student that is relevant in our discourse now enjoyed the lecture*. Importantly, there is a strong intuition that there are indeed contexts in which (1) is true while there are simultaneously students who have no opinions on the lecture, as long as such students are not part of the (somehow restricted) domain for the universal quantifier *every*. In (1) in English, there is no explicit marking of the restriction of the domain of the quantifier *every*, while other languages may mark the domain more explicitly (Etxeberria and Giannakidou to appear, and earlier work). In this paper, we focus on domain restriction in American Sign Language (ASL), showing that the restriction of quantifier domains can be marked overtly by signing quantifiers in the location of their domain, and that intermediate levels of domain widening can be signaled by signing a quantifier increasingly higher in space.

In the remainder of section 1 we discuss some background on quantifiers and plurals in ASL, present new data, and sketch our proposal. Section 2 provides detailed examples using a variety of quantifiers and pronouns in ASL. Section 3 presents our proposal that height is linked to large set sizes that can be used as quantifier domains and presents further supporting arguments. Section 4 discusses other uses and possible origins of height in ASL, while section 5 concludes.

ASL is notable from the semantic/pragmatic point of view for using *spatial loci*, or locations in a horizontal signing plane perpendicular to the signers body, that unambiguously keep track of discourse referents. For example, in (2a) the sign for John (JOHN: capital letters of the rough English gloss will be used to transcribe a sign) is signed in location *a* (here, the signer's ipsilateral side), while BOB is signed in location *b* (the signer's contralateral side). An indexical point (IX) functions here as a pronoun, such that if the signer points to location *a* (IX_a) the sentence is interpreted as 'John is smart', while an indexical point to the other location (IX_b) would have been interpreted as 'Bob is smart'. Loci are not required in contexts without pronouns (2b), but are nevertheless frequently used in ASL, especially in multi-clause discourses.

(2)   a. $JOHN_a$ LIKE BOB_b. IX_a SMART.
              'John likes Bob. He (John) is smart.'
        b. JOHN LIKE BOB.
              'John likes Bob.'

Loci can be placed anywhere in the low horizontal plane, so there are theoretically an infinite number of loci, and therefore an infinite number of pronominal assignments, and so relatively stable assignments. This contrasts with English, which is limited to essentially "he," "she," and "it", so that each pronoun must frequently be re-assigned throughout a discourse.

A similar pattern is found for plural sets, which may also be assigned loci that are marked for plurality. In (3a), the bare noun STUDENT is followed by a plural pronoun (plural-marked because the indexical point makes an arc movement) around location *a*, while TEACHER is followed by the same indexical arc around location *b*, and both are interpreted as plurals. The plural-marked loci can participate in anaphoric relationships just like singulars, so that IX-arc_a in (3a) refers to the students, but if it had been traced near location *b* it would refer to the teachers. Like singulars, loci are also optional for plural marked entities, but without them the (grammatical) bare noun phrases are unmarked for definiteness or number (3b).

(3)   a. STUDENT IX-arc_a LIKE TEACHER IX-arc_b. IX-arc_a SMART.
              'The students like the teachers. They (the students) are smart.'
        b. STUDENT LIKE TEACHER.
              'Some/the student(s) like some/the
              teacher(s).'

Schlenker et al. (2013) describe how plural sets in sign languages retain information about the geometry of the sets that they refer to, so that if one arc is properly contained within another arc, then the sets referenced by the first set must be a proper subset of the latter (4)(Figure 1).

(4)   STUDENT IX-arc_{a+b} SMART. GIRL IX-arc_a HAPPY.
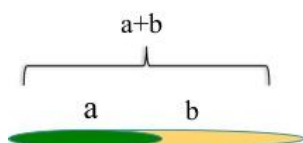   'The students are all smart. The girls (a subset of the students) are happy.'

Figure 1. The large locus (a+b) and loci inside it (a, b) reflect set/subset relationships

More intriguingly, they show that the complement of the subset can be referred to in ASL by pointing to the space contained by the larger arc but excluded by the smaller (5a); this kind of "complement anaphora" is not available in English (5b), but sign languages seem to take unique advantage of the iconic properties of these sets to refer to as-yet unmentioned discourse referents that become salient in the discourse due to the geometry of two mentioned referents.

(5)   a. STUDENT IX-arc$_{a+b}$ SMART. GIRL IX-arc$_a$ HAPPY. IX-arc$_b$ NOT HAPPY.
            'The students are all smart. The girls (a subset of the students) are happy, but the rest (the boys) are not happy.'
        b. #The students are smart. Of them, the girls are happy but they are not.
            (where "they" is interpreted as the students who are not girls)

Schlenker et al. restrict their discussion to subset/superset relationships where at least one subset and the superset are both *explicitly* located in space through IX-arcs (the green and yellow arcs in Figure 1). As a jumping-off point for our own discussion in this paper of domain marking in ASL, we note that the same subset-superset geometry can be extended to a single set and its complement even with *implicit* marking of the superset (blue arcs, Figure 2). Consider (6), where the set of students is associated with locus *a*. In (6a), if IX-arc traces a path over a larger area outside of this location in the same horizontal plane, it is interpreted as the complement set of that original set ("the rest"), as if the whole horizontal plane is understood to be the set containing everyone in the current context. Moreover, a similar IX-arc signed *above* the horizontal plane containing the original set, with IX-arc pointed upwards, is also interpreted as the complement of the original set, but as if the superset contained many more individuals under consideration, seemingly anyone (not just the individuals already relevant to this context). In other words, IX-arc$_{LOW-a}$ (the LOW plane minus what is in locus *a*) is interpreted as "not the students, but the other ones in our context/discussion", while IX-arc$_{HIGH}$ is interpreted as "not the students, but basically everyone else (irrespective of our context/discussion)."

(6)   a. STUDENT IX-arc$_a$ SMART. IX-arc$_{LOW-a}$ NOT.
            'The students, they are smart. The rest are not.'
        b. STUDENT IX-arc$_a$ SMART. IX-arc$_{HIGH}$ NOT.
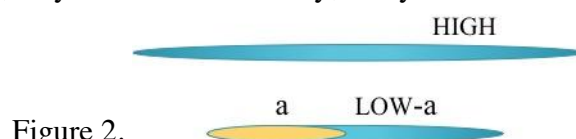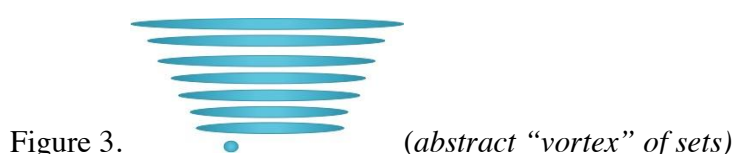   'The students, they are smart. Generally, everyone else is not.'

Figure 2.

In the remainder of this paper we will argue that this use of vertical (LOW/HIGH) space is a way to implicitly convey set size, and can be used to provide information about the restriction of quantifier domains. So, in (6a) the low, default, horizontal plane represents the current context, while the high plane widens the set of individuals under consideration. We show that this use is systematic across a variety of constructions (not just those indicated through the plural pronoun/demonstrative seen here, but also implicitly through the height of quantifiers), and is actually multi-leveled, so that signing at intermediate heights is interpreted as intermediate sized domains. Because it allows multiple levels, in which increasingly higher levels correspond to increasingly larger sets, we represent the organization of these sets with the abstract "vortex" in Figure 3, with the smallest possible a singleton set (see discussion in section 2.2 on specific indefinites).

Figure 3.   (*abstract "vortex" of sets*)

In what follows we use this vortex figure to illustrate the semantic effect of signing various quantifiers and a pronoun at different heights. In doing so, we urge the reader to keep in mind that this vortex is abstract and (at this point) seemingly only present in the mind: we are not necessarily claiming that one *signs* any *wider* when one signs high, only that when one signs higher, the *interpretation* is of a larger referenced set.

2. Quantification in ASL and Sign Height

2.1. Quantifier domains in ASL

Quantification has been surprisingly understudied in ASL, particularly the semantic aspects of quantification. Petronio (1995) and Boster (1996) present detailed descriptions at the syntactic/semantic interface of noun phrases in ASL, including quantifiers, but focus on possible word orders within quantified noun phrases. Quer (2012) shows that quantifiers in sign languages can be analyzed using a tri-partite structure, and Schlenker (2011) provides a detailed dynamic account of many binding properties of sign language quantifiers. At the pragmatic level, Davidson (2011) shows that at least one version of ALL and SOME in ASL form a scale for scalar implicatures. Barberà (2012) discusses how in Catalan Sign Language, the domain of a quantifier in ASL can be marked in the low horizontal plane by placing the quantifier in the location of a plural discourse referent that serves as its domain. We have found that a similar spatial modification occurs in ASL. Consider (7a), in which the set of students is associated with locus *a*. When a quantifier is signed in the same location later in the discourse, the interpretation is that the domain of the quantifier NONE, ONE/SOMEONE, or (fingerspelled) A-L-L is the set of students. Again, the use of loci is not *necessary* (7b), but like Barberà (2012) we modify our translation slightly to include a partitive construction in (7a) to indicate that the second sentence in (7a) contains information about the domain for the quantifiers, while (7b) does not (it is only available from the greater discourse context).
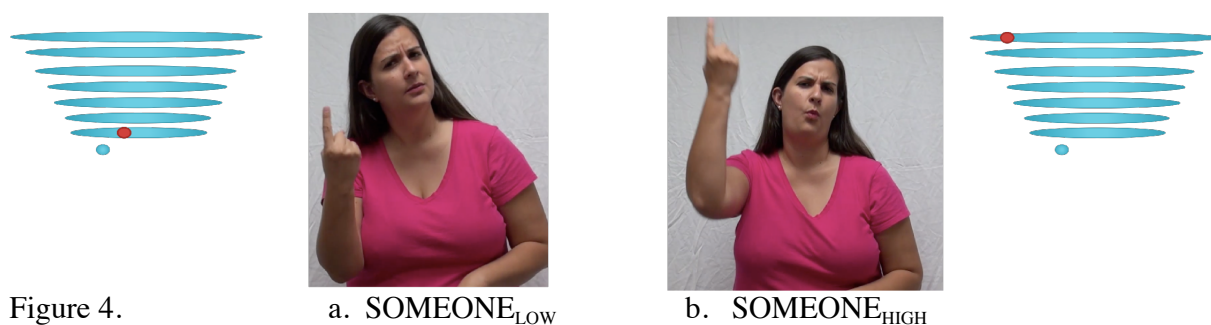
(7)   a. MY STUDENT IX-arc$_a$ SMART. NONE$_a$/ONE$_a$/A-L-L$_a$ SKIP CLASS.
            'My students, they are smart. None/one/all of them skip(s) class.'
        b. MY STUDENT SMART. NONE/ONE/A-L-L SKIP CLASS.
            'My students are smart. None/one/all skip(s) class.'

Schlenker (2011) analyzes quantifiers signed in locations (as in the second sentence of (7a)) as introducing a discourse referent in that locus; clearly more should be done to understand the relationship between domain restriction (involving plural sets) and the creation of discourse referents (which are often marked with singular number). In this paper we focus on domain restriction, especially the use of *height* to signal relative *set size* in a variety of constructions.

2.2. Height and Existential Quantifiers

We begin with the use of height to signal domain size for existential quantifiers. The sign we gloss as SOMEONE can be seen in Figure 4, which includes still frames from a video containing the sentences in (8). (Unlike the English word "someone", the sign we gloss here as SOMEONE is not just used for humans, but can range over inanimate objects just as easily as people.) In Fig. 4a, the quantifier SOMEONE is signed lower than in 4b, and the sentences they correspond to are interpreted with restricted (8a) and wide domains (8b), respectively.

(8)   *Context: Signer is discussing her friend getting a nanny for her children.*
        a. IX$_1$ WILL FIND **SOMEONE$_{LOW}$**.
            'I will find someone (among the usual group).'
        b. IX$_2$ MUST FIND **SOMEONE$_{HIGH}$**.
            'You need to find someone (anyone)!'

Figure 4.   a. SOMEONE$_{LOW}$ b. SOMEONE$_{HIGH}$
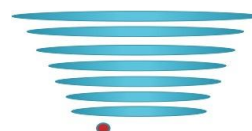
Previous analyses of the semantics of vertical sign height have focused (exclusively, it seems) on existential quantifiers of precisely this kind, and in particular the very high, circling SOMEONE in Figure 4b. MacLaughlin (1997) describes this sign as a non-specific SOMEONE used for less identifiable references, in contrast to specific indefinites and definites, which she argues must be signed in the low plane. According to Barberà (2012), in Catalan Sign Language high signing space is reserved for non-specific indefinites, while specific indefinites and some discourse-prominent non-specific indefinites are signed in the low plane. We fully agree with these

researchers that the more identifiable, definite, or specific noun phrases are, the more likely they are to be signed in the low plane. However, we suggest that underlying these tendencies in ASL is a general rule for using high space to represent wide set sizes.

Three points in particular lead us to adopt an analysis of set widening to correlate with height in ASL, and not definiteness or specificity. First, as we will see in the following two subsections, pronouns and quantifiers other than existentials can make use of this abstract height system, and we cannot account for their behavior using specificity or definiteness. Second, specificity can actually be modeled under some accounts (see Schwarzschild 2002) as domain narrowing to a singleton set, so having specific indefinites in the lower plane is predicted by our account under that view, where it would simply be a special case of extreme domain narrowing (Jeremy Kuhn, p.c.). Example (9) contains a specific indefinite, and is signed low in space, which can be modeled as a domain size of one. Third, when an existential has a clearly non-specific interpretation, but still a highly restricted domain, in ASL it is signed in a locus *a* in the low plane, not high (10).

(9)   *Context: Signer is discussing her friend getting a nanny for her children.*
        IX$_1$ FOUND **SOMEONE$_{a(LOW)}$**. IX$_a$ WONDERFUL.
        'I found someone, she is wonderful.'

(10)   TEAM$_a$, NEED VOLUNTEER **SOMEONE$_{a(LOW)}$**
        'We need a volunteer (anyone) from the team'.

There is much to say about domain widening and existentials, and we cannot address all of it here. However, we note a few important facts to situate the ASL case with respect to previous research on wide domain indefinites in spoken languages. First, (8b) tends toward an "aggressively indiscriminate" free choice interpretation (Horn 2000), most easily translated with English "someone, anyone!" Second, there does not seem to be any negative polarity behavior associated with SOMEONE signed in the high plane (see Chierchia 2013 for an account of why negative polarity and domain widening frequently occur together).

2.3. Height and Plurals

We next turn back to a somewhat more simple use of height for marking set size in ASL: plural pronouns (IX-arc), which we saw earlier in our introduction. The semantics of the indexical point is still not understood (it is seen sometimes as a definite article, deictic, or pronoun), but we will adopt a very conservative analysis in which IX-arc is simply a plural pronoun that delimits sets (as we saw above), but like quantifiers can make use of vertical height to implicitly signal the size of these sets.

Consider (11). The context for this dialogue is the following: the signer is traveling with his family, and it becomes a late night on the road so he hastily finds a place for them to spend the night. When they awake in the morning, they realize they are staying at a nudist colony, although

the signer and his family are not practicing nudists. As we saw earlier in (6), we see here in (11) that when the context supplies a natural domain (here, the people in a nudist colony), this context set is automatically established in the lower signing space (11a). When the same IX-arc is signed higher in the continued discourse in (11b) with *IX-arc* or a series of *IX-points* oriented upwards in high sign space, it applies to people including those outside of the context, seemingly the entire universe. Crucially, a property ascribed to this high set (such as wearing clothes) should apply to nearly everyone except the sets that have already been mentioned (the nudist colony), which is why nudity works well in the example.

(11)   *Context: At or discussing a nudist colony*
     a. **IX-arc$_{LOW/MID}$** NOT WEAR CLOTHES.
       'The people at this nudist colony don't wear clothes.'
     b. **IX-arc$_{HIGH}$** WEAR CLOTHES
       'They all/People generally wear clothes.'
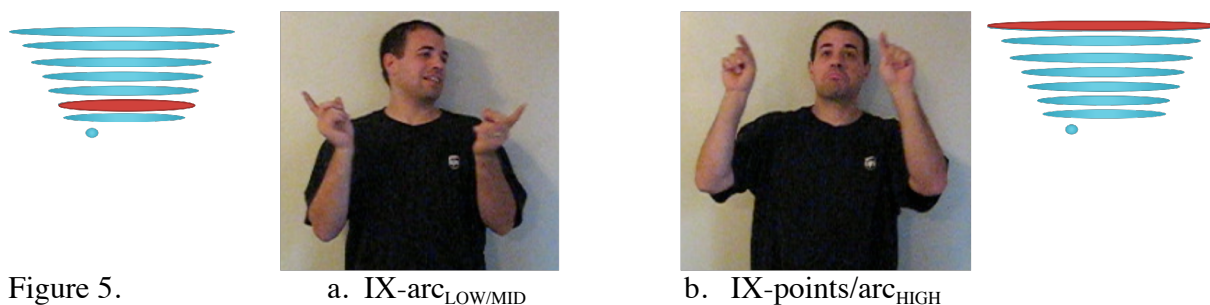

Figure 5.   a. IX-arc$_{LOW/MID}$ b. IX-points/arc$_{HIGH}$

There are variations on both signs. In Figure 5a, the signer chose a level somewhere above the very lowest plane, possibly to indicate that the nudist colony is somewhat large and seems like it's taking up much of the context. However, it clearly contrasts with the high level in 5b, which is interpreted as a much wider set (basically, everyone) compared to the sign in 5a. Other researchers report signers not varying in the level at which they sign IX-arc, but instead having eye gaze directed further upwards for a sentence like (11b) than for (11a). This suggests, first, that there may be variation among signers, but also that this grammatical use of height can perhaps be expressed through a variety of methods, beyond the manual sign for a pronoun or quantifier. Finally, in Fig. 5b this signer used a scattered series of high IX-points instead of an arc, and we leave it to future research to determine the nature (if any) of this difference.

It is also an open question how many exceptions a high plural permits. Clearly it does not seem to be interpreted as a universal, since the nudists are a clear counterexample to a universal in (11). In some cases it may be best to analyze IX-arc as a plural pronoun ("they"), while in others as a definite determiner forcing a "maximal" interpretation on the set ("the people"), and both would be consistent with previous analyses of IX in ASL. It's also possible that the most natural analysis of the highest signing is as a generic, but we will leave this and other detailed semantics of IX-arc for future research. In closing, however, we note that in all of the examples in section 2.3, IX-arc can be replaced by the fingerspelled sign A-L-L tracing the same arc, and the

interpretation is more strongly universal (e.g. (11b)*"everyone* wears clothes!") as we would expect if A-L-L is a universal quantifier like the English word it is clearly related to.

2.4. Height and Negative Quantifiers

The third use of vertical height indicating set size that we focus on in this paper involves the negative quantifier, NONE. Consider (12), where a signer is asked if anyone else in her family is deaf. The same string of manual signs NONE ONLY-ONE$_1$ can have two interpretations, depending on how high NONE is signed: in low space the signer conveys that no one in her family (e.g. mother, father, brother, sister, cousins) is deaf, while by signing it higher she conveys that not even her ancestors, distant relations, etc. are deaf.

(12)   *Context: Signer is asked if anyone in her family is deaf beside herself. She replies:*
         a. NONE$_{low}$ ONLY-ONE$_1$.
            'None, only me.'
         b. NONE$_{high}$ ONLY-ONE$_1$.
            'None at all, only me (not even, e.g. ancestors, distant relations).'
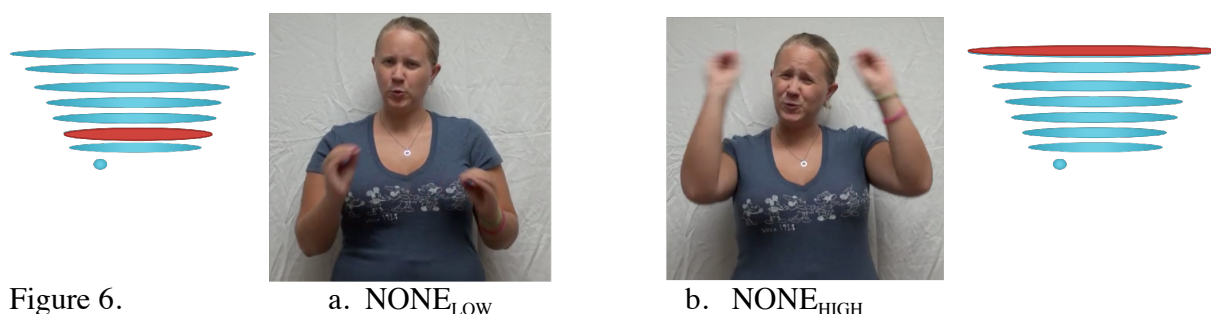

Figure 6.   a. NONE$_{LOW}$ b. NONE$_{HIGH}$

In section 3 will we present our proposal for the use of domain height as marking quantifier height, and indicate why we think it is more than just the emphasis that sometimes accompanies quantifiers in English (regular "No-one" vs. emphatic "NO-ONE!").

Before moving on, we note that the use of height to indicate domain size seems to be available to quantificational expressions (section 2.2 and 2.4) and can be referenced by pronouns/deictics (section 2.3), but it cannot be used in the same way with bare noun phrases, which are otherwise very common in ASL. For example, in (13a) the production of the sign DOG high in space might imply that a dog was in a high position (e.g. on a roof, under a purely iconic interpretation), but it will not select a dog from an especially wide set of dogs, or indicate willingness to accept a particularly unusual dog. For that, one must sign DOG followed by the sign SOMEONE seen in section 2.2 (here, glossed as SOMETHING)(13b).

(13)   *Context: Talking about adopting a pet.*
   a. IX$_1$ WANT **DOG**$_{\text{HIGH}}$.
       #'I want a dog (any kind of dog).'
   b. IX$_1$ WANT **DOG SOMETHING**$_{\text{HIGH}}$.
        'I want a dog (any kind of dog).'

3. Height as domain widening

Now that we have seen multiple ways that ASL can make use of sign height to signal set sizes, in this section we present our proposal for the meaning of sign height and for the structure of noun phrases that make use of this height, which we follow with further arguments supporting this proposal.

3.1. Proposal

Our proposal for the syntactic/semantic contribution of high and low loci in ASL is the following. First, we suggest that there exists an ordering of loci according to vertical height: Let H_n be loci in signing space, and $<_v$ a "vertical" ordering relation among loci: for any H_j and H_k, if H_k is physically higher in signing space in the vertical plane (toward to the signer's head) than H_j, then $H_j <_v H_k$. In our transcriptions in the examples in this paper, we have been using "HIGH", "MID" and LOW" to stand for three heights H where $H_{\text{LOW}} < H_{\text{MID}} < H_{\text{HIGH}}$. The ordering corresponds to the subset relation (14).
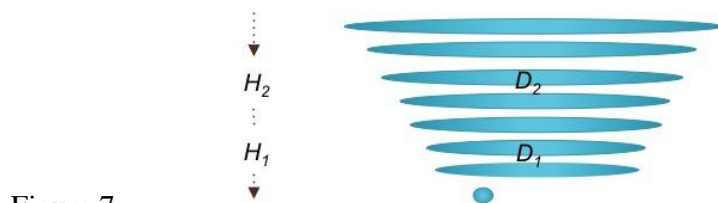

Figure 7.

(14)   Let $S \subset U$ be a set signed in locus H_j, and $S' \subset U$ be a set signed in locus H_k. If $H_j <_v H_k$, then $S \subset S'$.

How is this condition on loci heights and sets related to the compositional structure of the noun phrase? As we briefly mentioned in our introduction, the problem of how or whether to incorporate quantifier domains into the structure of a quantified noun phrase has been the focus of a large body of research in both linguistics and philosophy. In our limited space, we will present a few options for ASL. First, recall from section 2.1 that when a quantifier is signed in a locus that has been assigned to a plural, the interpretation is that the plural set serves as the domain for the quantifier (see (7), repeated below).

(7)   MY STUDENT **IX-arc**$_a$ SMART. **NONE**$_a$/**ONE**$_a$/**A-L-L**$_a$ SKIP CLASS.
        'My students, they are smart. None/one/all of them skip(s) class.'

We might be inclined to say that the quantifier and the domain combine analogously to the partitive construction that we use in the translation. Under this view, signing a quantifier (e.g. NONE) in a plural locus a is interpreted as "None of the set that is in a", or here, "None of my students". Within the generalized quantifier framework (Barwise & Cooper 1981), a quantifier like NONE is of type $<<e,t>,<e,t>,t>>$, and so should combine with a predicate of type $<e,t>$, to create a generalized quantifier of type $<<e,t.>,t>$. If the set associated with the locus is the predicate that combines with NONE to form a generalized quantifier, then we might expect that references back to a plural locus should be able to be interpreted as a predicate, which we consider in (15). First, we see in (15a) that signing a name BOB in a location a associated with the plural set "my students" is only marginally grammatical as a stand-alone sentence (without much context, signers feel that the sentence is incomplete). However, it improves if Bob is contrasted with another person, John (15b). The best way to signal that Bob is a member of the set is to sign his name and use the indexical point in the location of the plural locus (15c). In general, predicates can occur with bare nouns and no copulas to form clauses, so the marginality of (15a) is not due to a general problem of signing names in locations or a lack of copula (15d).

(15)   *Context : Signer and interlocutor are discussing Bob's intelligence. The interlocutor doesn't realized that Bob is actually a student in the signer's class.*
        a. ??MY STUDENT IX-arc$_a$ SMART. BOB$_a$.
            'My students, they are smart. Bob is one of them.'
        b. MY STUDENT IX-arc$_a$ SMART. BOB$_a$ JOHN$_b.$
            'My students, they are smart. Bob is one of them. John is not'
        c. MY STUDENT IX-arc$_a$ SMART. BOB IX$_a$.
            'My students, they are smart. Bob is one of them.'
        d. MY STUDENT IX-arc$_a$ SMART. BOB$_b$ FINE.
            'My students, they are smart. Bob (who is not one of them) is just alright/fine.'

As we mentioned earlier, there is debate about the function of IX as a definite determiner or as a deictic (see MacLaughlin 1997 for arguments that (only) a pre-nominal IX conveys definiteness). While a complete discussion of definiteness in ASL is outside of the scope of this paper, we note that IX clearly also has some deictic properties, since it is in fact a point of the index finger to a location in space! As such, we note a similarity with quantified noun phrases in St'a´t'imcets, for which Matthewson (2001) argues that every quantifier must take as its first argument a noun phrase that has combined with a deictic determiner, allowing the (gloss-only) schema in (16a) but not the English-type structure in (16b).

(16)   *Schema of structures in St'a´t'imcets:*
        a. [DP [Q every][D [the/that][N girl]]] [VP laughs]
        b. *[DP [D every][N girl]] [VP laughs]

There has been debate about whether the surface structure in St'a´t'imcets reflects the underlying structure, or whether it should be better analyzed as having an intermediate type-shifting operation in which the DP ("the girl") is turned into a predicate before combining with the

quantifier (Etxeberria and Giannakidou to appear), and more work will need to be done on ASL to determine how the ASL noun phrase contributes to this debate. We anticipate that this may be complicated: sets associated with loci were only marginal when used as predicates (15), but it's possible that the quantifier must be present to trigger the type shifting operation. Importantly, there is one major difference between ASL and St'a´t'imcets when it comes to quantified noun phrases: in ASL, the quantifier can easily combine with a bare noun when loci are not involved, as in (17).

(17)   ALL/ONE/NONE GIRL LIKE MATH.
        'All/one/no girl(s) like(s) math.'

We take from this discussion the possibility that in ASL, a set established in a plural locus can (and maybe must) be interpreted as a complete determiner phrase, and that quantifiers can be co-located with these loci. When the quantifier is located at a plural locus, it is interpreted as if the referent of the DP serves as the domain for the quantifier. How this should best be modeled at LF, and how closely it follows other languages, is a topic for future investigation.

As a very first pass at a proposed structure, let us consider the IX-arc plural pronoun in section 2.3 and example (11), repeated below. These may act as simple pronouns (Figure 8a-b).

(11)   *Context: At or discussing a nudist colony*
        a. **IX-arc$_{LOW/MID}$** NOT WEAR CLOTHES.
           'The people at this nudist colony don't wear clothes.'
        b. **IX-arc$_{HIGH}$** WEAR CLOTHES
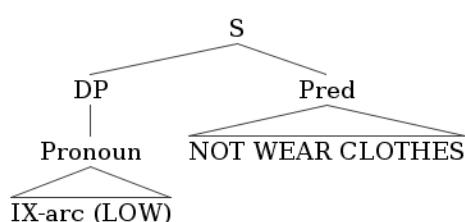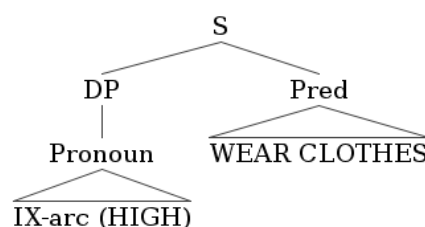   'They all/People generally wear clothes.'

Figure 8. a. Proposed structure(s) for (11a)   b. Proposed structure(s) for (11b)

Since IX-arc in (11a) is produced low, it simply refers to the maximal plural individual in the set made salient by the default context. Whenever IX-arc is produced higher, however, it refers to the maximal plural individual of a set that must be a superset of the default context. In (11b), it is produced quite a bit higher, and so the set that the plural is created from should be a superset that in (11a) with also many intervening levels, pragmatically providing a very wide set.

Let's also consider a quantificational noun phrase. For (12), repeated from earlier, we propose the structure(s) in Figure 9.

(12)   *Context: Signer is asked if anyone in her family is deaf beside herself. She replies:*
       a. NONE$_{low}$ [DEAF]. ONLY-ONE$_1$.
          'None [are deaf], only me.'
       b. NONE$_{high}$ [DEAF]. ONLY-ONE$_1$.
          'None at all [are deaf], only me (not even, e.g. ancestors, distant relations).'
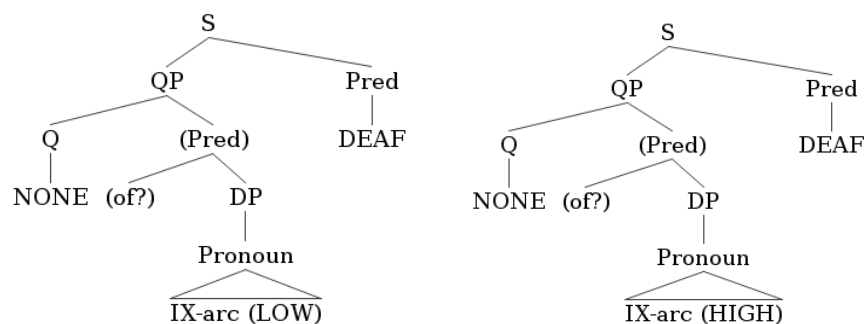
Figure 9.   a. Proposed structure(s) for (12a)   b. Proposed structure(s) for (12b)

In parentheses we provide optional structure, which we hope to investigate further. Without this structure, we could use a compositional semantics involving choice functions along the lines suggested by Matthewson (2001). If there is an intervening type shift, then the usual semantics for generalized quantifiers can be used, but of course the domain is still provided through the locus in the DP complement. In Fig. 9, the high locus must be a superset of any other set (including the default context set, which is signed in low space), which results in a widened domain for NONE. Our indefinite example (8) and other quantifiers (including the universal we briefly mentioned in section 2.3) can all participate in the implicit marking of domain sizes in the same way as NONE. Of course, this kind of analysis assumes that the spell-out process involves spatial combination (e.g. of NONE with the locus), in addition to linearizing all of the elements, an assumption that probably deserves much more discussion than we can provide here.

3.2. Multi-leveled domain restriction

We have stressed the way that high quantifiers in ASL can use height to overtly convey information about their domains, but there are also some lexical items in spoken languages, like English "any", that appear to overtly signal information about domain size as well (especially a wide domain)(Kadmon and Landman 1993). What we find especially interesting about ASL, that does not seem to be true for English "any," is that the vertical use of space can express intermediate domain sizes by intermediate placement of the quantifier between low and high planes. Such intermediate levels motivated our multi-level vortex structure presented in Figure 7. Example (18) illustrates this phenomenon using the same family-visits-nudist colony setup that we saw in (11), but now with three hierarchically related sets.

(18)   *Context*: *Signer is discussing a family visit to a nudist colony.*
        [Her family is a subset of people at the nudist colony, who are in turn a subset of people
        in the world.] She remarks:
        a. POSS-1 FAMILY **IX-ARC_{LOW}** WEAR CLOTHES.
           'My family, they all wear clothes.'
        b. **IX-ARC_{MID}** NOT WEAR CLOTHES.
           'They all (at the nudist colony) don't wear clothes.'
        c. **IX-ARC_{HIGH}** WEAR CLOTHES.
            'They all (people generally) wear clothes.'

Figure 10.   a. IX-arc_{LOW}   b. IX-arc_{MID}   c. IX-arc_{HIGH}

The number of levels that can be expressed seems to be limited only by the perceptual system; it's possible to sign a very restricted set ("our class") in the lowest space, with successive heights used for the department, the university, the state, the country, and the world. Eye gaze and manual signs usually track together, but given our earlier discussion about the possible ways that the heights can be expressed (potentially only with eye gaze), we expect the same to hold true at multiple levels.

3.3. More than emphasis

While lexical items like *any* in English are seemingly limited to a binary distinction when it comes to signally domain widening (wide v. default), intonational contours in spoken languages could potentially provide the multi-leveled distinction that height does in ASL. Consider the "high" examples from section 2, but now in English with emphasis (19) (note that here the capitalized words are emphatic English words, not ASL signs).

(19)   a.   *Context: discussing a possible nanny.*
                You need to find SOMEONE, (ANYONE)!
        b.   *Context: contrasting with a nudist colony*
                EVERYONE/*THEY wear(s) clothes!
        c.   *Context: Is anyone in your family deaf?*
                No, NO-ONE is!

The response in (19a) with emphasis (where here we take emphasis to perhaps be focus, and to have increased volume and an exaggerated intonational contour) is felicitous, especially with the indiscriminate "someone, anyone" phrase. However, it's not clear that this can be signaled at intermediate levels: in (20), the context is a mother talking to a friend and mentions she is looking for a babysitter, but has been having difficulty finding one. The friend can use intonation to express (20a) and (20c), but it's not clear that (20b) can be distinguished from these using merely different intonation, although it *can* be expressed with different heights in ASL.

(20) *Capitalization is emphasis, and bold capitalization is extremely emphatic:*
        a. There has to be someone available. (The mother hasn't quite exhausted her list yet)
        b. *There has to be SOMEOME available. (There are some other qualified people)
        c. There has to be **SOMEONE** available. (Regardless of qualification)

Proceeding to (19b), it's interesting that the translation of the IX-arc here doesn't work as a stressed 3rd person plural pronoun, which we might expect based on the morphology of IX-arc in ASL. Nevertheless, we can express a widened domain by emphasizing the quantifier EVERYONE, and it might even be possible to contrast two levels of widened domains (21).

(21)   a. EVERYONE wears clothes, and **EVERYONE** has DNA.

If we try the same for the negative quantifier, we can also use emphasis felicitiously, and we might even be able to emphasize it more and more as the possibilities mentioned become increasingly unlikely. For example, in (22) perhaps no one in the speaker's family is deaf (NO-ONE is Deaf), and even if maybe there is one possible person who is slightly hard-of-hearing they certainly don't know ASL (**NO-ONE** knows ASL), and even if possibly, *maybe*, somebody knew a sign or two they certainly couldn't interpret (**NO-ONE** can interpret).

(22)   a. NO-ONE is Deaf, and **NO-ONE** knows ASL, and **NO-ONE** can interpret.

At this basic level we agree that emphasis can serve to widen domains in English: Rohrbaugh (1997) even suggests that focus is a more reliable marker of domain widening than a lexical item like "any." We also think that signing large sets higher in space in ASL is emphatic. The signer is going outside of the default sign space, which conveys some sort of markedness in ASL. However, we do *not* conclude from the use of emphasis for domain widening in English, and the emphatic nature of high signs in ASL, that signing quantifiers higher in space is *just emphasis*. One reason is that the use of vertical space in this way is *systematic* in ASL –a sign produced higher in space *always* selects from a larger set, and a sign produced lower in space *always* makes reference to a smaller set – potentially even a singleton set. In contrast, intonational contours in English do not have this systematicity. For example:

(23)   a. *Context: A friend advising a mother on babysitting:*
            SOMEONE must be available!
        b. *Context: A mother looking at her child suspiciously:*
            SOMEONE stole the cookie!

In the English sentences in (23a) and (23b), SOMEONE is emphasized in both, but the domain for (23a) is especially wide, while the domain for (23b) is especially narrow: the mother clearly knows that it is the child. The intonational contour may or may not be different, and if it is different, it's possible that there is an intonational contour in English that does correspond to the use of height in ASL for domain widening. However, it can't be just focus/emphasis, since (23b) is clearly marked and emphatic, and does not express a wide domain for the existential quantifier.

3.4. Binding

There is a further piece of data concerning the linguistic status of the use of height in ASL, and its conventionalized use beyond simply "emphasis" as part of an overtly marked set size. Consider the case where a quantifier is embedded under an adverb of quantification as in (24). In a context in which an interlocutor is wondering whether someone at his next party will want mustard, the host can discuss his prediction based on previous parties using the adverb TYPICALLY (signed with an "open 8" handshape moving from the signer's heart outwards). If he signs SOMEONE$_{LOW}$, the interpretation is that for most typical parties, there exists someone at that party who likes mustard, although it doesn't have to be the same person from party to party (24a). If, on the other hand, the host signs SOMEONE$_{HIGH}$, the interpretation of the sentence is that for most typical parties, there exists someone out there in the world who likes mustard (24b). This data suggests to us that, first, the use of height to signal domains is not merely deictic, since the restricted domain in (24a) varies with the values of contexts that the adverb ranges over, and second, it seems to be different than intonation in English, where it is difficult, if not impossible, to get the reading in (24b) just by emphasizing "someone".

(24)   *Context*: *A host throws many parties. In preparing for the upcoming party, a helper asks for advice on what condiments to put out on the table. The host replies:*
    a. TYPICALLY SOMEONE$_{LOW}$ LIKE MUSTARD.
      'Usually at the parties, someone likes mustard.' (maybe a different person each party)
    b. TYPICALLY SOMEONE$_{HIGH}$ LIKE MUSTARD.
      'Usually someone in the world likes mustard.' (obviously true)

We note that another possible interpretation of (24b) is that the host is very unsure who it is at each party who likes mustard. This interpretation is something like: "Typically, there is someone, I have no idea who, that likes the mustard." Perhaps not surprisingly given cross-linguistic similarities between unknown indefinites and free choice, the large set size in high space in ASL seems to be able to convey something about the epistemic status of the indefinite, in addition to the size of the domain for various quantifiers.

3.5. Multiple vortices

Finally, in addition to multiple sets stacked upon each other in a single vortex, we have also found that ASL signers can access two different sets of sets. In (25), the signer divides the signing space into a left and right side to correspond to two opposing sides in a war, and accesses

a separate vortex on each side to represents set sizes. A specific general is located on the left side that corresponds to his "side" (allies, etc.) in the war, while his assassin is located on the right side that is associated with the forces opposing the general.

(25)   WAR$_{\text{LEFT-RIGHT}}$, GENERAL **IX-left$_{\text{LOW}}$**, **SOMEONE-right$_{\text{HIGH}}$** SHOT$_{\text{HIGH RIGHT TO LEFT LOW}}$
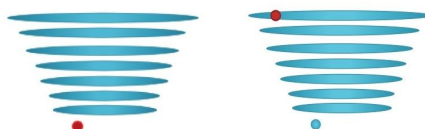   `During the war a general on one side was shot by an undetermined person from the other army.'

Figure 11. Two opposing sides in a war: IX-left$_{\text{LOW,}}$ SOMEONE-right$_{\text{HIGH}}$

Example (25) is also an example of using the large set size in high space to signal the epistemic status of the indefinite: while the assassin may be specific, he's very clearly unknown.

4. Other uses of height in ASL and the metaphor of height and set size

So far, we have focused on the specific use of vertical sign height to signal set size in ASL, but we do not want to give the impression that this is the only use of height in ASL. As a natural sign language, ASL uses space in several ways, some more "iconically" than others (where here, we take "iconic" to be either transparent in meaning or motivated in form). Schlenker et al. (2013) discuss two other uses of vertical height in ASL (and French Sign Language, or LSF), both iconic but to different degrees: a signer can direct the indexical point IX towards the upper sign space if the referent is physically high by virtue of being tall; he can also use high sign space if the referent holds a higher social status than the signer or has a place of relative importance to the signer, such as a mother for a child, a doctor for a patient, or a judge for a defendant. Both literal height (how tall one is) and relative social stature (a more abstract, but still motivated use of height) appear to have some of the same presuppositional properties as gender features (Schlenker et al. 2013). Note that (25) cannot be an example of this use of height, as the general has a position of high social status, but is place low in signing space.

Of course, vertical height can come into play in a purely iconic sense as well: IX may be directed upwards if the referent is in a high location, such as at the top of a stairwell or the attic of a house, and high space can be use to locate north when discussing a map, or ancestors when discussing a family tree. We raise this last example of the family tree because it is the only example we have come across in which a smaller set is placed high (the matriarch and patriarch of many generations of a larger family, for example), and a larger set lower (all of the great-great-great-grandchildren), with middle-sized sets at intermediate levels (great-grandchildren, etc.). Of course, the use of height in such an example is clearly motivated by our usual illustrations of these kind of familial relations in family trees, and is distinct from the more abstract use of height to mark set size.

In this paper, we have emphasized the abstract and grammatical nature of the use of sign height to convey set size in ASL, but this is quite consistent with it having a gestural origin that may have motivated the current form. One indication that this might be the case is that English makes ample use of height as a metaphor for set size, even in the case of "upward" and "downward" entailments (Larry Horn, p.c.), which is just one particular case of describing sets as going "up in size" when they gain members and "down in size" when they lose members, which in turn links (at least finite) cardinalities with a vertically oriented number line ("high" numbers are used for greater numerosities).

5. Conclusions

In this paper we have discussed a previously undescribed phenomenon of using vertical sign height in ASL to convey something about the size of a set. We have argued that ASL can make use of an overt signal of signing a quantifier increasingly higher to indicate increasingly larger domains, and that this can be signaled at not just binary, but intermediate levels that seem to be limited only by the number of different heights that we can perceptually distinguish. Our account has advantages over previous accounts of the semantics of sign height for ASL (MacLaughlin 1997) by modeling the use of height for multiple quantifiers (although it appears that Catalan SL differs from ASL in this regard for strong quantifiers, see Barberà 2012), and in accounting for the use of non-specific indefinites that are signed low when their domains are restricted.

We have also argued that while this use of sign height may be emphatic, it is not reducible to focus or "emphasis." We expect that the abstract and grammaticalized use of this kind of set size marking is made easier by the visual language mode, although we left open that there may be a use of intonational contours in spoken languages that can do the same. Finally, we situated this use of sign height among other uses of height in ASL and speculated on its origins and the similar metaphor we find in English. We hope that our account has contributed toward a better understanding of quantification in ASL, an area clearly ripe for further investigation.

Finally, as noticed by Partee (1989) and subsequently discussed by many other researchers, the problem of domain restriction extends beyond quantification over individuals to implicit domain restriction of times, situations, etc. Here we have focused on quantification over individuals, but leave open the possibility that this use of height may be used for other types of quantification.

Acknowledgments

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