ASL Loci: Variables or Features?

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1 Overview

- In American Sign Language, both referential and quantificational NPs can be placed at locations ('loci') in the signing space; pronouns later retrieve these by pointing.
- At a first pass, these loci seem to behave strikingly like **variables** in formal logic.
- However, the variable-based theory undergenerates:
  - Counterexample: two different variables may be spatially indexed at a single locus.
  - ASL loci can *prevent* pronoun binding; however, syntactically independent choices can't *force* two pronouns to corefer.
- In contrast, ASL loci share certain properties with morphosyntactic **features**:
  (a) they may remain uninterpreted in certain environments (specifically, in ellipsis and under focus sensitive operators),
  (b) they induce verbal agreement, and
  (c) they are used optionally in some cases, mirroring patterns of featural underspecification in spoken language.

2 Background

- In American Sign Language, NPs may be associated with locations ('loci'). Pronouns refer back to these NPs by literally pointing at the relevant locus.

(1) [7] IX-a JOHN TELL IX-b BILL {IX-a/IX-b} WILL WIN.
'John$_i$ told Bill$_j$ that he$_{\{i/j\}}$ would win.'
Video.

  - Note: ASL gloss conventions. Methodology. Dialect 1: native signer (parents also Deaf).

- These loci can be placed at arbitrary locations in the horizontal plane in front of the signer (modulo some pragmatic restrictions), and there can be arbitrarily many loci (modulo psychological constraints).

- Pronouns show quantificational binding: bound pronouns co-vary with the quantifier.

(2) ^{7} [ALL BOY]$_a$ WANT [ALL GIRL]$_b$ THINK {IX-a/IX-b} LIKE {IX-b/IX-a}.
'Every boy wants every girl to think that {he/she} likes {her/him}.'

(3) ^{7} [NO BOY]$_a$ WANT [ANY GIRL]$_b$ THINK {IX-a/IX-b} LIKE {IX-b/IX-a}.
'No boy wants any girl to think that {he/she} likes {her/him}.'
Video.

- Further, generalized quantifiers at two different loci may range over the same set of individuals.

(4) ^{7} WHEN SOMEONE$_a$ HELP SOMEONE$_b$, IX-b HAPPY.
'When someone helps someone, the latter is happy.'

- A striking parallel between loci and formal variables: sometimes even my English glosses are forced to use variables as subscripts!

- It is this observation that motivates Lillo-Martin and Klima (1990) and others to propose that, in fact, **loci are the overt phonological manifestation of variable names.**

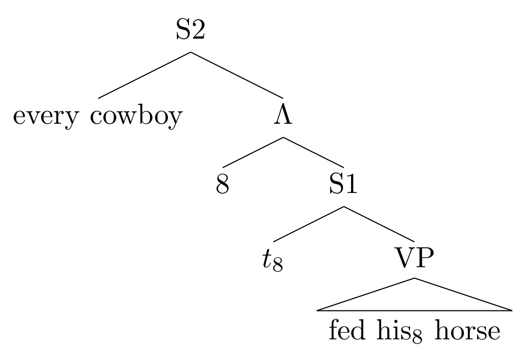
3 Variables

- The hypothesis:

(5) **The (strong) loci-as-variables hypothesis.**
There is a one-to-one correspondence between ASL loci and formal variables.

- Binding with variables. Standard Heim and Kratzer:

(6)



(7) a. $[\![S1]\!] = \lambda g[g(8) \text{ fed } g(8)\text{'s horse}]$
b. $[\![8\ S1]\!] = \lambda g \lambda x [\![S1]\!]^{8 \rightarrow x}$

- **Variable capture:** A variable is bound by the lowest operator which scopes over it and quantifies over that variable.

(8) $\exists x[\forall x.R(x,x)]$
$= \exists x[\forall y.R(y,y)]$
$\neq \exists x[\forall y.R(y,x)]$

- Critically, assignment functions are **functions**: each variable is mapped to a unique individual.
- Therefore, under the hypothesis that they are in a one-to-one correspondence with formal variables, we predict that every locus indexes a unique individual.

4 Counterexample 1: Loci indexing more than one individual

- This prediction is not borne out:

(9) [6] EVERY-DAY, JOHN$_{\mathrm{a}}$ TELL MARY$_{\mathrm{a}}$ IX-a LOVE IX-a. BILL$_{\mathrm{b}}$ NEVER TELL SUZY$_{\mathrm{b}}$ IX-b LOVE IX-b.
'Every day, John$_i$ tells Mary$_j$ that he$_i$ loves her$_j$. Bill$_k$ never tells Suzy$_l$ that he$_k$ loves her$_l$.'

- Both John and Mary are indexed at locus a! Both Bill and Sally at locus b!
- How do we know it's the same locus?
  - Production: Signer instructed to repeat loci.
  - Reception: Sentence judged as "technically ambiguous," but with one weird reading in which John is informing Mary of her own mental state.

4.1 The influence of pragmatics

- Why aren't such sentences more common?
- Pragmatic principle: "Avoid ambiguity."
  - In (9), of four logical readings, two are eliminated by Condition B and one due to implausibility.
- Prediction: If ambiguity is reintroduced, the rating will go down.

(10) * [4] EVERY-DAY, JOHN$_a$ TELL MARY$_a$ IX-a THINK IX-a SMART. BILL$_b$ NEVER TELL SUZY$_b$ IX-b THINK IX-b SMART.
'Every day, John tells Mary that he thinks {he/she} is smart. Bill never tells Susan that he thinks {he/she} is smart.'

- A small amount of literature has begun to investigate other pragmatic motivations for loci placement (Geraci 2013, Barberà 2012); nevertheless future work is needed.

5 Counterexample 2: Uninterpreted loci under *only*

- English: Pronouns under *only* may optionally co-vary in the focus alternatives.

(11) a. [Only Mary$_x$] $\lambda y.y$ did her$_x$ homework.
→ John didn't do Mary's homework.

b. [Only Mary$_x$] $\lambda y.y$ did her$_y$ homework.
→ John didn't do his own homework.

- In (a), the pronoun is free and co-referential with Mary; in (b), the pronoun is bound by the lambda operator.

- Further, Kratzer (2009) observes that when two pronouns appear under *only*, it is possible to get mixed readings, with one pronoun bound and one free.

(12) Only Billy told his mother his favorite color.

(13) **The two mixed readings:**

a. [Only Billy$_x$] $\lambda y.y$ told y's mother x's favorite color.
Context: In class on Friday, Sally learned that Billy's favorite color is pink, and, to his horror, soon told everybody else in the class. Later, Billy told his mother the situation, and said he was worried that the children would spread the gossip to their mothers. It turns out that Billy had nothing to worry about.

b. [Only Billy$_x$] $\lambda y.y$ told x's mother y's favorite color.
Context: Billy's mother can be very embarrassing sometimes. When she has his friends over to play, she asks them all sorts of personal questions, which they are usually reluctant to answer. Yesterday, she asked them what their favorite color is, but only Billy answered.

- If loci are variables, then spatial co-indexation should eliminate the mixed readings.
  - Both pronouns — denoting the same variable — must be captured by the same operator, so both must receive the same reading: bound or free.

- However, mixed readings *are* attested.

(14) ^{7} IX$_b$ BILLY ONLY-ONE FINISH-TELL POSS$_b$ MOTHER POSS$_b$ FAVORITE COLOR.
'Only Billy told his mother his favorite color.'

Can be read as: *bound-bound, bound-free, free-bound, or free-free.*

- The loci-as-variables hypothesis **undergenerates**.

5.1 Uninterpreted features

- An alternative way to think about loci: loci are morphosyntactic features, parallel to gender and person in English.
  - A pronoun may be bound by any NP that agrees with it the spatial feature.
  - Sentence (9) no longer a problem.
- What about (14)?
- Kratzer 2009 observes: under focus sensitive operators, features may be **uninterpreted**. E.g. (15a) entails that John didn't do his homework, even though he is not a female.

(15) a. Only Mary did her homework.
  b. Only I did my homework.
  → *Both sentences have bound and free readings for pronoun.*

- Sentence (14) is exactly parallel: the pronoun bears a spatial feature which is uninterpreted in the focus alternatives.

6 Parallels with Features

(A note on the logic of the argument.)

- We have already seen one: **uninterpreted loci**.
- Now, **agreement** and **underspecification**.

6.1 Agreement

- Features may induce changes on verbal and adjectival morphology in the form of agreement.

(16) a. A boy sleeps. *(Match)*
  b. * A boy sleep. *(Mismatch Subject)*

- In ASL, 'directional verbs' move from the locus of one argument to the locus of another.

(17) a. ^{7} BOOK, JOHN$_a$ $_a$GIVE$_b$ MARY$_b$. *(Match)*
  b. * $^{3.5}$ BOOK, JOHN$_c$ $_a$GIVE$_b$ MARY$_b$. *(Mismatch Subject)*
  c. * $^{3.5}$ BOOK, JOHN$_a$ $_a$GIVE$_b$ MARY$_c$. *(Mismatch Object)*
  'John gave the book to Mary.'

- Under a feature-based analysis, directional verbs fall out as a special case of feature agreement.
  - A variable-based account would need to posit a new mechanism (see, e.g. Aronoff et al. 2005 for an analysis of 'index copying'.)

6.2 Underspecification

- Verbs may be underspecified for agreement features, in ASL as in English.

(18) *Slept* takes a subject of any number (c.f. (16)).
  a. A boy slept.
  b. Boys slept.

(19) HAPPY takes a subject at any locus (c.f. (17)).
  a. [7] JOHN$_a$ HAPPY.
  b. [7] JOHN$_b$ HAPPY.

7 Interim summary

- The strong loci-as-variables hypothesis has been falsified.
- But:
  - Weaker forms of the hypothesis available. E.g. loci create *partitions* of variables; pointing to a locus retrieves one of a set of variables.
  - Or one could deny focus examples: LF is always bound; "free" readings come through some other mechanism. (Think Fox-style Binding Theory. Or certain dynamic theories.)
  - Even if a variable-based analysis of loci is falsified, it does *not* mean that variables don't exist in natural language, it just means that loci aren't them.
- Implications for Variable-Free Semantics.
  - Jacobson (1999) argues that the logic underlying natural language does not make use of formal variables.
  - One motivation: variables are never overt in natural language — in (spoken) language, there is never a phonological difference between 'he$_x$' and 'he$_y$'.
  - Loci in ASL provided a potential fatal counter-example; thus, by arguing the variable-based analysis, I rescue the Variable-Free Hypothesis.
  - Nevertheless, the situation is begging for a constructive proof: can we provide a variable-free fragment of loci?

8 Developing feature-based fragment

- Yes. Here I present a fragment which is both Variable-Free and Directly Compositional.
- I account for locus agreement purely through syntactic sub-categorization.
  - E.g. for English: we say *sleeps* subcategorizes for a singular noun and *sleep* for a plural.

Categorial Grammar:

- Subcategorization frames are listed in lexical entries.
  - Only NP and S (and a few other categories) are taken to be primitives.
  - **Composition rules:**

    1. $\mathsf{A/_R B} \quad \mathsf{B} \rightarrow \mathsf{A}$
    2. $\mathsf{B} \quad \mathsf{A/_L B} \rightarrow \mathsf{A}$

  - *Example:* VP = $\mathsf{S/_L NP}$ = "give me an NP on my left and I'll give you an S."

- Derivations indicate deduction rules for each step:
  - lex = lexical entry; $f.a.$ = function application.

$$\dfrac{\dfrac{\textsf{Edith}}{\textsf{NP}}\,lex \qquad \dfrac{\dfrac{\textsf{eats}}{(\mathsf{S/_L NP})/_\mathsf{R}\mathsf{NP}}\,lex \quad \dfrac{\textsf{cookies}}{\textsf{NP}}\,lex}{\mathsf{S/_L NP}}\,f.a.}{\mathsf{S}}\,f.a.$$

8.1 Spatial features and directional verbs

(20) *Composition rules (f.a.):*

a. $\langle \mathrm{A/_R B}, f\rangle \quad \langle \mathrm{B}, x\rangle \rightarrow \langle \mathrm{A}, f(x)\rangle$

b. $\langle \mathrm{B}, x\rangle \quad \langle \mathrm{A/_L B}, f\rangle \rightarrow \langle \mathrm{A}, f(x)\rangle$ *(Note that R and L are left out below.)*

- The spatial feature is represented with a subscript: an NP at locus i is of category NP_i.
  - *Example:* the lexical entry for JOHN_a is $\langle \mathrm{NP}_a \,,\, j \rangle$.
- Directional verbs specify a spatial feature on one or more of their NP arguments.
  - *Example:* the lexical entry for ${}_a\mathrm{HELP}_b$ is $\langle (\mathrm{S/NP}_a)/\mathrm{NP}_b \,,\, \lambda xy.\mathrm{help}'(x)(y) \rangle$.
- Ungrammaticality of agreement mismatch arises from subcategorization mismatch.

(21) ^{7} JOHN_a ${}_a\mathrm{HELP}_b$ BILL_b.

$$\dfrac{\dfrac{\mathrm{JOHN}_a}{\mathrm{NP}_a}\,lex \qquad \dfrac{\dfrac{{}_a\mathrm{HELP}_b}{(\mathrm{S/NP}_a)/\mathrm{NP}_b}\,lex \quad \dfrac{\mathrm{BILL}_b}{\mathrm{NP}_b}\,lex}{\mathrm{S/NP}_a}\,f.a.}{\mathrm{S}}\,f.a.$$

(22) * ^{3} JOHN_c ${}_a\mathrm{HELP}_b$ BILL_b.

$$\dfrac{\dfrac{\mathrm{JOHN}_c}{\mathrm{NP}_c}\,lex \qquad \dfrac{\dfrac{{}_a\mathrm{HELP}_b}{(\mathrm{S/NP}_a)/\mathrm{NP}_b}\,lex \quad \dfrac{\mathrm{BILL}_b}{\mathrm{NP}_b}\,lex}{\mathrm{S/NP}_a}\,f.a.}{\textbf{can't combine}}\,f.a.$$

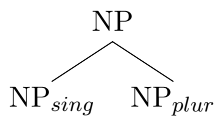
8.2 Underspecification

- Recall the parallels between English and ASL:

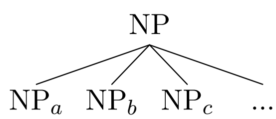
(23) a. A boy sleeps.
b. * Boys sleeps.
BUT
c. A boy slept.
d. Boys slept.

(24) a. [7] $\text{JOHN}_a\ {}_a\text{HELP}_b\ \text{BILL}_b$.
b. * [3] $\text{JOHN}_c\ {}_a\text{HELP}_b\ \text{BILL}_b$.
BUT
c. [7] JOHN_a HELP BILL_b.
d. [7] JOHN_c HELP BILL_b.

- Bernardi and Szabolcsi (2007): Syntactic categories are organized as partially ordered sets; being a satisfactory argument for a given function requires subsumption, not identity.
  - For (23), NP subsumes NP_{plural} and $\text{NP}_{singular}$. *Slept* asks for an argument of category NP, but will be satisfied by any subcategory.

(25)


- For ASL, underspecified predicates are similar.

(26)


  - *Example:* the lexical entry for HAPPY is $\langle\ \text{S/NP}\ ,\ \lambda x.\text{happy}'(x)\ \rangle$.

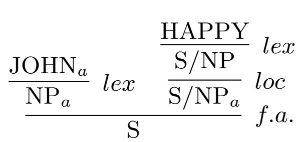
- This deduction pattern can be formalized as a combinator which fills in the spatial feature on an argument slot of an underspecified verb.

(27) $\text{loc} = \langle\ ((\text{A/NP}_i)/\text{B})/((\text{A/NP})/\text{B})\ ,\ \lambda X.X\ \rangle$

- **Examples:**

(28) a. $\text{HAPPY} = \text{S/NP} \xrightarrow{loc} \text{S/NP}_a$
b. $\text{LIKE} = (\text{S/NP})/\text{NP} \xrightarrow{loc} (\text{S/NP}_b)/\text{NP}$

(29) [7] JOHN_a HAPPY.



- Note: see Kuhn 2013 for a strategy for building this family of 'loc' combinators recursively from a few basic primitives.

8.3 Pronouns and Binding

- Using the plumbing that we have just built for verbal agreement and underspecification, pronominal agreement arises "for free" from a generalized definition of Jacobson's **z**-operator.

> **Variable Free Semantics:**
>
> - Pronouns denote the identity function.
>   - he $= \langle \ \text{NP}^{\text{NP}} \ , \ \lambda x.x \ \rangle$
> - The argument gap is passed along via function composition (specifically, via $\mathbf{g}$).
>   - *Example (free pronoun):* "He left" $= \langle \ \text{S}^{\text{NP}} \ , \ \lambda x.\text{left}'(x) \ \rangle$
> - Pronouns are bound by the **z**-combinator, which merges two argument slots of a verb.
>
>   (30) **z** $= \langle \ ((\text{B/C})/\text{A}^{\text{C}})/((\text{B/C})/\text{A}) \ , \ \lambda V_{\langle\alpha,\langle\gamma,\beta\rangle\rangle}\lambda f_{\langle\gamma,\alpha\rangle}\lambda x_{\gamma}[V(f(x))(x)] \ \rangle$
>
>   - *Example (binding):*
>   **z**-loves $= \langle \ (\text{S/NP})/\text{NP}^{\text{NP}} \ , \ \lambda fx.\text{loves}'(f(x))(x) \ \rangle$
>   **z**-loves(his mother) $= \langle \ (\text{S/NP}) \ , \ \lambda x.\text{loves}'(\text{mother-of}'(x))(x) \ \rangle$

- IX-a is defined as $\langle\ \text{NP}_a^{\text{NP}_a}\ ,\ \lambda x.x\rangle$
- For spatial features, the category C in the **z**-schema is NP_i. The definition of **z** ensures that the locus of the binder matches the locus of the bindee.

(31) [7] JOHN$_a$ LIKE SELF-a.

$$\dfrac{\dfrac{\text{JOHN}_a}{\text{NP}_a}\,lex \quad \dfrac{\dfrac{\dfrac{\dfrac{\dfrac{\text{LIKE}}{(\text{S/NP})/\text{NP}}\,lex}{(\text{S/NP}_a)/\text{NP}}\,loc}{(\text{S/NP}_a)/\text{NP}_a}\,loc}{(\text{S/NP}_a)/\text{NP}_a^{\text{NP}_a}}\,\mathbf{z} \quad \dfrac{\text{SELF-}a}{\text{NP}_a^{\text{NP}_a}}\,lex}{\text{S/NP}_a}\,f.a.}{\text{S}}\,f.a.$$

(32) * [2] JOHN$_b$ LIKE SELF-a.

$$\dfrac{\dfrac{\text{JOHN}_b}{\text{NP}_b}\,lex \quad \dfrac{\dfrac{\dfrac{\dfrac{\dfrac{\text{LIKE}}{(\text{S/NP})/\text{NP}}\,lex}{(\text{S/NP}_a)/\text{NP}}\,loc}{(\text{S/NP}_a)/\text{NP}_a}\,loc}{(\text{S/NP}_a)/\text{NP}_a^{\text{NP}_a}}\,\mathbf{z} \quad \dfrac{\text{SELF-}a}{\text{NP}_a^{\text{NP}_a}}\,lex}{\text{S/NP}_a}\,f.a.}{\textbf{can't combine}}\,f.a.$$

- Essentially, the z-rule turns a predicate into an agreeing predicate: [**z**-LIKE SELF-a] is of the same syntactic category as [$_a$HELP$_b$ JOHN$_b$]: both are of category S/NP$_a$.
  - The fragment thus reduces pronominal agreement to a special case of verbal agreement.

9 Summary

- At first pass, loci seem to pattern like formal variables.
- However, several examples show that ASL loci seem insensitive to variable capture, thus falsifying the strong loci-as-variables hypothesis.
- Moreover, we see close parallels between loci and features, including uninterpreted loci, verbal agreement, and underspecification.
- Finally, as proof of concept, I presented a variable-free fragment, in which the syntax ensures that a bound pronoun must share the same locus as its binder.

Appendix A: The full fragment

(33) *Composition rules (f.a.):*

a. $\langle \mathrm{A}/_{\mathrm{R}}\mathrm{B}, f\rangle \quad \langle \mathrm{B}, x\rangle \quad \rightarrow \quad \langle \mathrm{A}, f(x)\rangle$

b. $\langle \mathrm{B}, x\rangle \quad \langle \mathrm{A}/_{\mathrm{L}}\mathrm{B}, f\rangle \quad \rightarrow \quad \langle \mathrm{A}, f(x)\rangle$ *(Note that subscript R and L are left out below.)*

(34) *Definitions of lexical items (lex):*

a.	JOHN_a	=	$\langle$	NP_a	,	j	$\rangle$
b.	IX-a	=	$\langle$	$\mathrm{NP}_a^{\mathrm{NP}_a}$	,	$\lambda x.x$	$\rangle$
c.	SELF-a	=	$\langle$	$\mathrm{NP}_a^{\mathrm{NP}_a}$	,	$\lambda x.x$	$\rangle$
d.	LIKE	=	$\langle$	(S/NP)/NP	,	$\lambda xy.\mathrm{like}'(x)(y)$	$\rangle$
e.	THINK	=	$\langle$	(S/NP)/S	,	$\lambda py.\mathrm{think}'(p)(y)$	$\rangle$
f.	SEE_a	=	$\langle$	$(\mathrm{S/NP})/\mathrm{NP}_a$	,	$\lambda xy.\mathrm{see}'(x)(y)$	$\rangle$
g.	${}_a\mathrm{HELP}_b$	=	$\langle$	$(\mathrm{S/NP}_a)/\mathrm{NP}_b$	,	$\lambda xy.\mathrm{help}'(x)(y)$	$\rangle$

(35) *Locus underspecification deductions on verbs (loc):*

a. $\mathrm{loc} \quad = \quad \langle \quad ((\mathrm{A/NP}_i)/\mathrm{B})/((\mathrm{A/NP})/\mathrm{B}) \quad , \quad \lambda X.X \quad \rangle$

(36) *Syntactic and semantic definitions of function composition via Geach (* **g** *):*

a. $\mathbf{g} \quad = \quad \langle \quad (\mathrm{A}^{\mathrm{C}}/\mathrm{B}^{\mathrm{C}})/(\mathrm{A/B}) \quad , \quad \lambda f \lambda h \lambda y[f(h(y))] \quad \rangle$

(37) *Syntactic and semantic definitions of binding (* **z** *):*

a. $\mathbf{z} \quad = \quad \langle \quad ((\mathrm{B/C})/\mathrm{A}^{\mathrm{C}})/((\mathrm{B/C})/\mathrm{A}) \quad , \quad \lambda V_{\langle \alpha, \langle \gamma, \beta \rangle\rangle} \lambda f_{\langle \gamma, \alpha \rangle} \lambda x_{\gamma}[V(f(x))(x)] \quad \rangle$

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