A vector space semantics for reference frames in Yucatec

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Overview

- intro: the argument
- the lexical analysis of FoRs
- the indexical analysis of FoRs
- Vector Space Semantics
- FoRs in VSS
- FoRs in Yucatec
- extensions
- summary

Intro: the argument

- two kinds of *place functions* (Jackendoff 1983)
  - i.e., functions from reference entities into regions
    - *topological* (Piaget & Inhelder) – perspective=frame-free
      - means in practice independent of the orientation of the ground, the observer, and the figure-ground array (the configuration)

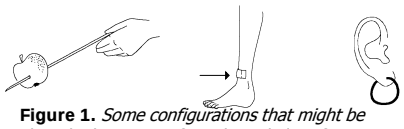

Figure 1. *Some configurations that might be described in terms of topological place functions*

(1.1) *The apple is on the skewer*
(1.2) *The band aid is on the shin*
(1.3) *The earring is in the ear (lobe)*

Intro: the argument (cont.)

- *projective* –framework-dependent
  - the place function returns a region defined in a coordinate system centered on the reference entity
  - the axes of the coordinate system are derived from an **anchor**
    - » in **intrinsic** frames, the anchor is the reference entity
    - » in **relative** frames, it is the body of an observer
    - » in **absolute** frames, it is some environmental entity/feature

Intrinsic — *The man is on the side of the tree.*

Relative — *The man is to the right of the tree.*

Absolute — *The man is east of the tree.*

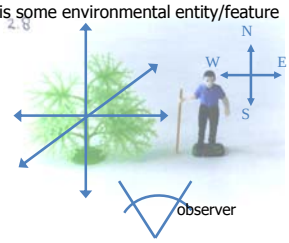

Figure 2. *The three types of spatial FoRs distinguished in Levinson 1996, 2003*

Intro: the argument (cont.)

- alternative classifications and subtypes

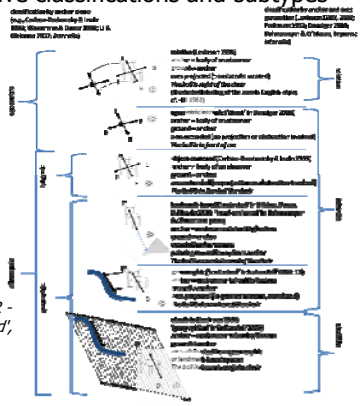

Figure 3. *Reference frame types and their classification (A - 'away from', B - 'back', D - 'downriver', F - 'front', L - 'left', R - 'right', T - 'toward', U - 'upriver'; Bohnemeyer & Levinson ms.)*

Intro: the argument (cont.)

- great amount of crosslinguistic variation
  - in terms of both availability and preferences

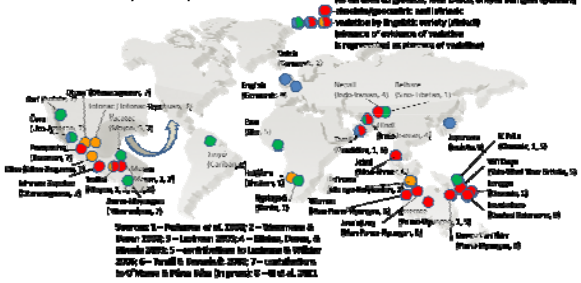

Figure 4. *Reference frame use in small-scale horizontal space across languages (Bohnemeyer & Levinson ms.)*

Intro: the argument (cont.)

- but what do semanticists have to say about FoRs?
  - Levinson (1996, 2003): lexical-semantic analysis
    - treats FoRs as part of the meanings of the relators
  - my objectives today
    - show that the lexical analysis is inadequate
    - argue that all projective relators are **indexicals**
      - correcting and generalizing the classic analysis by Bühler 1934
    - develop a model-theoretic treatment in the framework of Zwarts & Winter's (2000) **Vector Space Semantics**
    - apply this treatment to the analysis of FoRs in Yucatec
    - sketch extensions of the analysis to landmark-based FoRs and orientation descriptions in Yucatec
      - which have received little attention in the literature heretofore

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The lexical analysis of FoRs

- Levinson (1996, 2003)
  - frames are a lexical property of spatial relators
  - the anchor is a semantic argument of extrinsic relators, but not of intrinsic ones
    - intrinsic relators are binary, relative ones are ternary
  - Levinson's definitions
    - R – the meaning of the spatial relator
    - F – the **figure** – the entity to be located/oriented
    - G – a reference entity or **ground**
    - X – the origin of the coordinate system
    - A – an **anchor point**
    - V – the viewpoint of an observer
    - S – "'Slope' of a fixed bearing system, with infinite parallel lines across environment (Levinson 2003: 39)

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The lexical analysis of FoRs (cont.)

"An intrinsic spatial relator R is a binary spatial relation, with arguments F and G, where R typically names a part of G. The origin X of the coordinate system is always on the volumetric center of G. An intrinsic relation R(F, G) asserts that F lies in a search domain extending from G on the basis of an angle or line projected from the center of G, through an anchor point A (usually the named facet 'R'), outwards for a determined distance." (Levinson 2003: 42-43)

"A relative relator R expresses a ternary spatial relation, with arguments V, F and G, where F and G are unrestricted as to type, except that V must be centered on an observer and V and G must be distinct. The primary coordinate system always has its origin on V; there may be a secondary coordinate system with origin on G." (Levinson 2003: 47)

"An absolute relator R expresses a binary relation between F and G, asserting that F can be found in a search domain at the fixed bearing R from G. The origin X of the coordinate system is nearly always centered on G, and the system of terms anchored by reference to a conceptual 'Slope' S." (Levinson 2003: 50)

- absolute relators are treated as binary b/c the environmental "slope" argument S is assumed to be fixed
- S, V and A are all treated as properties of the anchor in the analysis developed below

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The lexical analysis of FoRs (cont.)

- problem I: ambiguity
  - intrinsic and relative descriptions are systematically ambiguous between the two interpretations
    - Bühler 1934 : 127-132; Fillmore 1997: 66-67; Miller & Johnson-Laird 1976: 394-405; Levelt 1984 *inter alia*

	true in which type of FoR?	
The ball is in front of the chair	relative	intrinsic
The ball is left of the chair	intrinsic	relative

Figure 5. *Truth conditions of intrinsic and relative descriptions of Ball & Chair 3.9 (left) and 3.12*

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The lexical analysis of FoRs (cont.)

- Levinson's account entails that this is polysemy
- this seems implausible *prima facie* in view of the fact that the pattern is apparently w/o exceptions
- moreover, it fails standard polysemy tests
  - (2.1) (uttered wrt Figure 6) does not seem *zeugmatic*

(2.1) *The ball is in front of both chairs. It is relatively in front of the first chair and intrinsically in front of the second*

Figure 6. *Ball & Chair 3.9 (left) and 3.12*

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The lexical analysis of FoRs (cont.)

- (2.2) and (2.3) seem to be contradictory

(2.2) # *The ball is not in front of the picture, it's between the observer and the picture*

(2.3) # *The ball is not in front of the picture, it's near the intrinsic front of the picture*

– for comparison, a bona-fide case of polysemy:

(2.4) *That's not a cow, that's a bull*

– the same argument can be advanced for the geocentric family of frames
  - where similar ambiguities arise b/w geomorphic or landmark-based and abstract absolute interpretations

Figure 6. *Ball & Chair 3.9 (top) and 3.12*

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The lexical analysis of FoRs (cont.)

- problem II: logic
  - if relative relators are ternary, so are intrinsic ones
    - both designate regions defined wrt. grounds in a reference frame derived from an anchor
    - the anchor is the observer's body in the case of relative interpretations and the ground itself in intrinsic ones
    - but logically, anchor and ground are distinct semantic argument positions even in intrinsic descriptions
      - they just happen to be filled by descriptors of the same entity
  - the same goes for absolute relators
    - just because the anchor is in this case invariant does not mean its role in the semantics of the relator is different

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The lexical analysis of FoRs (cont.)

- problem III: compositionality
  - functors of different arity fulfilling the same semantic function creates a headache
    - for compositional treatments
    - requiring fixes via type raising operations
  - all spatial relators are standardly assumed to be binary regardless of reference frame
    - in both mentalist (Jackendoff 1983) and model-theoretic treatments
      - e.g., Kracht 2002, Zwarts 2005, Zwarts & Winter 2000
  - this suggests that reference frames are not a part of the meaning of spatial relators
    - calling for a compositional and/or pragmatic analysis of the interaction b/w relators and frames

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The indexical analysis of FoRs

- that *relative* relators are indexicals has been known since at least Bühler 1934

Figure 7. *Karl Bühler (1879 – 1963)* http://www.dasrotewien.at

"Und wenn eines von den derart orientierten Lebewesen, nämlich der Mensch, den Mund auftut und deiktisch zu sprechen anfängt, so sagt er z.B. dort! muß der Bahnhof sein, *und nimmt dabei vorübergehend die Haltung eines Wegweisers an. Das Lexikon von Wörtern, die aus demselben Orientiertsein ihre Feldwerte erhalten, ist mit dem dort noch keineswegs erschöpft.* ***Wenn derselbe Mensch Wörter wie* vorn-hinten, rechts-links, oben-unten *verwendet, so wird eine neue Tatsache offenbar, die Tatsache nämlich, daß er in Relation zu seiner optischen Orientierung auch seinen Körper verspührt und zeigend einsetzt.****"*

'And when one of the creatures so oriented, man, opens his mouth and begins to speak deictically, he says, e.g., *there! must be the train station*, and temporarily assumes the bearing of a signpost. The lexicon of words that derive their field values from the same sense of orientation is by no means exhausted with *there*. **When the same person uses words such as *front-back*, *right-left*, *above-below*, a new fact is revealed, namely the fact that he senses his body in relation to his optical orientation as well and uses it for pointing.**' (Bühler 1934: 129; emphasis and translation *JB*)

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The indexical analysis of FoRs (cont.)

- the false equation of deixis with egocentricity
  - Bühler's notion of indexicality – **deixis** – is inherently egocentric

"Zwei Striche auf dem Papier, die sich senkrecht schneiden, sollen uns ein Koordinatensystem andeuten, O die Origo, den Koordinatenausgangs-punkt [cf. Figure 8; *JB*]. *Ich behaupte, daß drei Zeigwörter an die Stelle von O gesetzt werden müssen, wenn dies Schema das Zeigfeld der menschlichen Sprache repräsentieren soll, nämlich die Zeigwörter* **hier, jetzt, *und* ich***."*

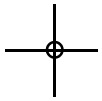

Figure 8.

'Two lines on the paper, intersecting at right angles, shall stand for a coordinate system and O for the origin, the coordinates of the starting point [cf. Figure 8; *JB*]. I argue that three deictic words must take the place of O if this scheme is to represent the deictic field of human language, namely the deictic words ***here*, *now*, and *I***.' (Bühler 1934: 102; emphasis and translation *JB*)

  - this may have prevented him from realizing that allocentric relators are just as indexical
  - the literature building on Bühler subsequently codified the false equation deictic/indexical = egocentric
    - cf. Fillmore [1971/1975] 1997: 66-67; Miller & Johnson-Laird 1976: 394-405; Levelt 1984 *inter alia*

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- Bühler meets Kaplan: the indexicality of projective relators
  - Kaplan (1989) defines indexicality in terms of two properties: context-dependence and **character**

"What is common to the words or usages in which I am interested is that **the referent is dependent on the context of use** and that **the meaning of the word provides a rule which determines the referent in terms of certain aspects of the context**. The term I now favor for these words is 'indexical'." (Kaplan 1989: 490; emphasis *JB*)

"The second kind of meaning, **most prominent in the case of indexicals, is that which determines the content in varying contexts**. The rule,

'I' refers to the speaker or writer

is a meaning rule of the second kind. ... **Let us call the second kind of meaning, *character*. The character of an expression is set by linguistic conventions and, in turn, determines the content of the expression in every context**." (Kaplan 1989: 505; emphasis *JB*)

"Just as it was convenient to represent contents by functions from possible circumstances to extensions (Carnap's intensions), so it is convenient to **represent characters by functions from possible contexts to contents**." (Kaplan 1989: 505; emphasis *JB*)

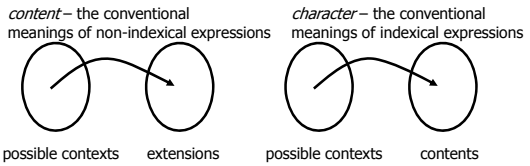


Figure 9. *Kaplan's theory schematically*

- the context-dependence of projective relators
  - every use of a projective relator requires the selection of an **anchor** from the context
- the character of projective relators
  - can be understood as a constraint the relator imposes on possible anchors

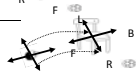
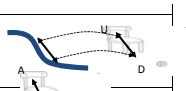
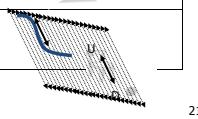
frame type	constraint on anchor	example	illustration
intrinsic	the ground	*The ball is in front of the chair*	
relative	the body of an observer (speaker, addressee, or generic)	*The ball is right of the chair*	
geomorphic	a salient environmental entity/feature	*The ball is downriver of the chair*	
landmark-based		*The ball is mountainward of the chair*	
absolute	(abstracted from) a salient environmental entity/feature	*The ball is downriver of the chair*	

Figure 10. *Frame type and anchor selection*

- the anchor and the speech situation
  - the role of the anchor in the semantics of projective relators corresponds to
    - the role of speaker and addressee in person deixis
    - the location of speaker and addressee in demonstratives
    - the time of utterance in temporal deixis
  - the anchor is part of the *deictic center*
  - possible objection: there is no *unique* anchor in any situation
  - response: "real-world" situations do not contain unique speakers and addressees either
    - but every *utterance* has a unique speaker and addressee
    - in the same vein, every projective spatial description has a unique anchor

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Vector Space Semantics

- the framework of choice for implementing the indexical analysis: **Vector Space Semantics**
  - **VSS**; Zwarts & Winter 2000
- the key advantage of VSS: vectors
  - VSS differs from other model-theoretic approaches to spatial semantics...
    - such as Kracht 2002 and Zwarts 2005
  - ... in that it treats the regions designated by place functions not as primitives
    - but as mappings from sets of vectors into sets of points

Vector Space Semantics (cont.)

- an example: the meaning of *above*
  - the region designated by *above* can be defined
    - as the endpoints of the set of vectors connected to the hull of the ground
      - that form an acute angle with the ground's vertical axis

(4.1) **above'** := $\lambda A.\lambda \mathbf{v}.\text{ext}(\mathbf{v}, A)$
$\& c(up, \mathbf{v}) > |\mathbf{v}_{\perp up}|$
(Zwarts & Winter 2000: 182)

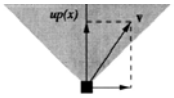

Figure 11. *The meaning of* above *(Zwarts & Winter 2000: 181)*

  - *A* ranges over sets of points, **v** over vectors
  - ext(**v**, *A*) requires **v** to be connected to *A*, the region occupied by the ground
  - *c*(*up*, **v**) is a scalar measuring the component of **v** along the vertical axis *up*
  - $\mathbf{v}_{\perp up}$ denotes the projection of **v** on a suitable axis $\perp up$ orthogonal to the axis picked out by *up*

Vector Space Semantics (cont.)

- the angle (☺) for modeling FoRs
  - the axis with respect to which the region is defined depends precisely on the frame of reference
  - this axis is derived from an axis of the anchor via translation ± rotation

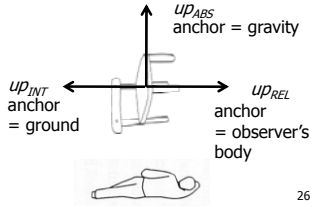

Figure 12. *Absolute* (up_{ABS})*, relative* (up_{REL})*, and intrinsic* (up_{INT}) *vertical axes of a chair in a given situation (based on Levelt 1996: 90)*

Vector Space Semantics (cont.)

- VSS: what's "under the hood"
  - an ontology defining a vector space *V* over the real numbers **R**
    - and the operations of vector addition and scalar multiplication over *V*
  - domains of points D_p and vectors D_v and the corresponding non-standard types *p*, *v*
- how it works – a Yucatec sample composition

(4.2) Ti' =yàan y=óok'ol le=mèesa le=lùuch=o'
PREP=EXIST(B3SG) A3=on/above DET=table DET=cup=D2
'The cup is on the table'

  - Yucatec is a VOS language, but the "subject" – the figure nominal in locative descriptions – is usually left-dislocated
    - in connected speech
    - this is ignored here, as is the incorporated preposition *ti'* and the role of pronominal arguments in semantic composition

Vector Space Semantics (cont.)

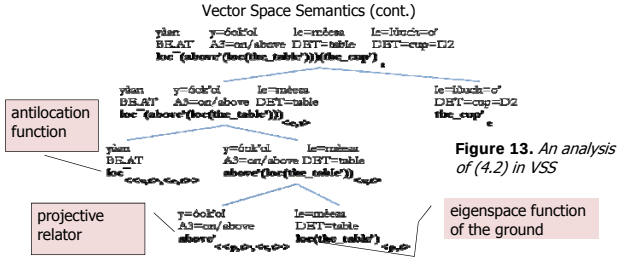

Figure 13. *An analysis of (4.2) in VSS*

  - the eigenspace function $loc_{<e,<p,t>>}$ maps entities into the regions they inhabit and is supplied by type raising
  - the 'antilocation' function loc^{-} maps sets of vectors to the set of entities "contained" in the set of their endpoints

(4.3) $loc^{-} := \lambda W_{<v,t>}.\ \lambda x_e.\ \forall \mathbf{p} \in loc(x)\ \exists \mathbf{v} \in W[\textit{e-point}(\mathbf{v}) = \mathbf{p}]$
(Zwarts & Winter 2000: 175)

Vector Space Semantics (cont.)

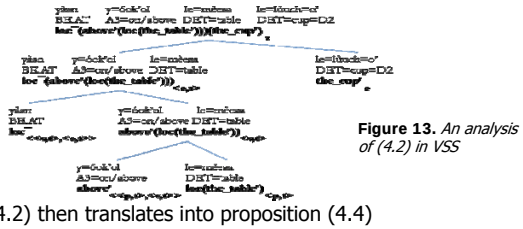

Figure 13. *An analysis of (4.2) in VSS*

  - (4.2) then translates into proposition (4.4)

(4.4) loc^{-}(**above'**(loc(**the_table'**)))(***the_cup'***)

  - given (4.2), (4.4) is equivalent to (4.5)

(4.5) $\forall \mathbf{p} \in loc$(**the_cup'**) $\exists \mathbf{v} \in$ **above'**(loc (**the_table'**))[*e-point*(**v**) = **p**]

  - i.e., for every point in the eigenspace of the cup
    - there is a vector in the denotation of the ground phrase [**above'**(loc (**the_table'**))] whose endpoint this point is

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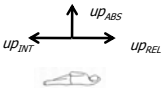
FoRs in VSS

- the proposal
  - all 'projective' (non-topological) functions of type <<p,t>, <v,t>> are indexicals
- implementation
  - the axis function
    - replace the axis constant in the denotation of the projective function...
      - *up* in the case of **above'**



(5.1) **above'** := $\lambda A.\lambda \mathbf{v}.\text{ext}(\mathbf{v}, A) \,\&\, c(up, \mathbf{v}) > |\mathbf{v}_{\perp up}|$

- ... with a function that maps the anchor into a unit vector of the relevant kind
- e.g., *up* maps the anchor into a vertical axis
  - where verticality is interpreted differently depending on the nature and identify of the anchor and thus the FoR

Figure 14. *FoR and axis assignment*

- the axis function is part of the meaning of the projective relator (see, e.g., (5.1))
- expand Zwarts & Winter's object-centric *up*, *front*, and *right* and their negative counterparts
  - with a set of geocentric axes selected by *upriver*, *uphill*, *north*, *east*, etc.
    - » and their negative and orthogonal partners
- each type of frame comes with its own unique set of axis functions

- the anchor constant
  - let a constant *anchor* pick out the anchor
    - the denotation of *anchor* is fixed by the interpretation function

- the assignment function
  - assume an "anchored" model M^a = <C, D_e, D_p, D_v, I, g> consisting of
    - a set of contexts C
    - the domains of individuals, points, and vectors
    - the interpretation function
    - and a variable assignment
- model theory
  - $[\![anchor]\!]^{M,a,g,c} = c_a$
  - $[\![up(anchor)]\!]^{M,a,g,c}$ denotes for each context
    - the ordered pair of the selected anchor and its vertical axis projected onto the origin of the reference frame

- a ground phrase headed by a projective relator
  - denotes the set of endpoints of vectors connected to the hull of the ground that form an acute angle...
  - ...with a vector based in the volumetric center of the ground and codirectional with the axis of the anchor
    - picked out by the axis function
    - see, however, below re. the codirectionality requirement
- a locative description is true iff
  - the eigenspace of the figure is included in the region designated by the ground phrase

- example

(5.2) $\forall \mathbf{p} \in loc(\textbf{the\_cup'}) \,\exists \mathbf{v} \in \textbf{above'}(loc(\textbf{the\_table'}))[e\text{-}point(\mathbf{v}) = \mathbf{p}]$

- $[\![(5.2)]\!]^{M,a,g,c} = 1$
  - if the table is in canonical vertical orientation
    - and the closest vectors pointing from the table to the cup form an acute angle with the gravity vector

Figure 15. *Scenarios that satisfy (5.2) in an absolute FoR (left) and a (dis-aligned) intrinsic one (right) (image from Bowerman & Pederson 1992)*

  - but also if the table is standing on one side
    - and the closest vectors pointing from the table to the cup form an acute angle with the table's intrinsic vertical axis

- 'disaligned' intrinsic interpretations (Carlson-Radvansky & Irwin 1993) of vertical relators are in fact common
  - in Yucatec discourse (cf. Bohnemeyer & Tucker 2010)

(5.3)

Le=bòola=o',	**y=àanal**	te'l	tu'x	k-u=kutal
DET=ball=D2	A3=under	DADV	where	IMPF-A3=sit:INCH.DIS
máak=o',	kóoh-ol		tu=chan	ba'l-il (...)
person=D2	hit\MIDDLE-INC		PREP:A3=DIM	thing-REL

'The ball, **under** there where a person sits, (it's) touching (the chair's) thing (...)'

Figure 16. *B&C 1.6*

FoRs in VSS (cont.)

- two important wrinkles
  - two subtypes of relative frames
    - the projection of the selected axis from the anchor onto the ground involves
      - translation + rotation in English-style relative frames
      - translation only in Hausa-style relative frames (Hill 1982)

English-style relative frames: the ground as a metaphorical mirror image of the observer

Hausa-style relative frames: the ground as a metaphorical avatar of the observer

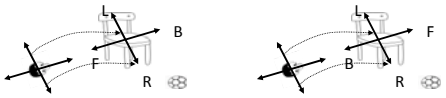


Figure 17. *English- and Hausa-type relative frames*

FoRs in VSS (cont.)

  - absolute frames
    - the axes of absolute frames are *abstracted* from concrete geomorphic and landmark-based systems
      - cf. Levinson 2003: 47-50
    - in this case, the anchor does not change with context
  - in absolute frames and English-type relative frames
    - the axis from which the designated region is projected is not simply codirectional with the selected axis of the anchor
  - these cases can be dealt with in terms of specialized axis functions

FoRs in VSS (cont.)

- a precursor
  - Maillat 2003 sketches a formalization of reference frames in DRT
  - his proposal shares with the present one the idea that reference frames are determined
    - by single (half)-axes represented by vectors
  - Maillat cites VSS to explain this idea
  - the present implementation has the advantage of preserving the compositionality of VSS

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FoRs in Yucatec

- ongoing research: **MesoSpace**
  NSF award #BCS-0723694 "Spatial language and cognition in Mesoamerica"
- 15 field workers
- 13 MA languages
  - Mayan
    - Chol (J.-J. Vázquez)
    - Q'anjob'al (E. Mateo Toledo)
    - Tseltal (G. Polian)
    - Yucatec (J. Bohnemeyer, PI)
  - Mixe-Zoquean
    - Ayutla Mixe (R. Romero Méndez)
    - Soteapanec (S. Gutierrez Morales)
    - Tecpatán Zoque (R. Zavala Maldonado)
  - Oto-Manguean
    - Otomí (E. Palancar; N. H. Green; S. Hernández-Gómez)
  - Juchitán Zapotec (G. Pérez Báez)
  - Tarascan
    - Purepecha (A. Capistrán)
  - Totonacan
    - Huehuetla Tepehua (S. Smythe Kung)
  - Uto-Aztecan
    - Cora (V. Vázquez)
    - Pajapan Nawat (V. Peralta)

Figure 18. *MesoSpace field sites*

Semantic typology (cont.)

- 3 non-MA "controls"
  - Seri (C. O'Meara)
  - Mayangna (E. Benedicto, A. Eggleston in collaboration with the Mayangna Yulbarangyang Balna)
  - Mexican Spanish (R. Romero Méndez)
- 2 (interrelated) domains
  - **frames of reference** and **meronyms** (labels for entity parts)

Figure 19. The *MesoSpace team (minus V. Peralta and R. Tucker)*

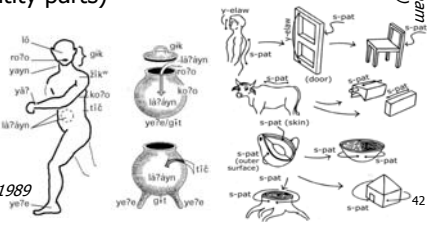

Figure 20. *Meronyms in Ayoquesco Zapotec (left) and Tenejapa Tseltal (adapted from MacLaury 1989 and Levinson 1994)*

- the MesoSpace tool for studying FoRs in discourse - **Ball & Chair (B&C)**
  - 4 x 12 photographs of configurations of a ball and chair
  - participants match corresponding pix in two identical sets through referential communication

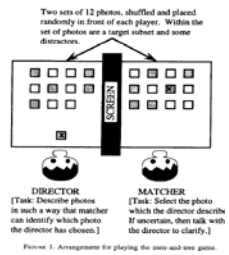

Figure 21. *Layout of Men and Tree task (Pederson et al. 1998: 562)*

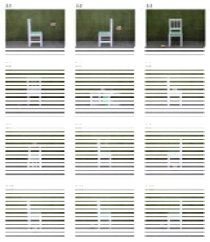

Figure 22. *Set 3 of Ball & Chair*

- B&C was conducted
  - with five pairs of Yucatec speakers
    - in the summer of 2008
- results
  - cf. Bohnemeyer in press

Figure 23. *A Yucatec B&C trial*

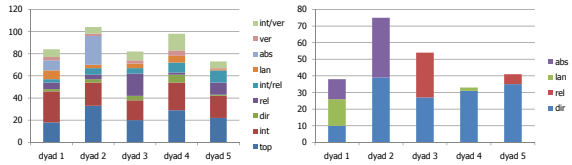

Figure 23. *Numbers of locative (left) and orientation descriptions by frame type*
top – topological; int – object centered; dir – direct (Danziger 2010); rel – relative; int/rel – object-centered/relative ambiguity; lan - landmark-based; abs – cardinal direction terms; ver - absolute vertical; int/ver – object-centered/absolute-vertical ambiguity

- examples: locative descriptions
  - topological

(6.1) (…) te'l **tu'x** **k-u=kutal** **máak=o', te=lu'm=o',**
DADV where IMPF-A3=sit-INCH.INC person=D2 PREP:DET=earth=D2
hun-p'éel bòola pek-ekbal **hachtu=tu'k'=o'.**
one-CL.IN ball lie.as.if.dropped-DIS(B3SG) really PREP:A3=corner=D2
'(…) there where one sits, **on (lit. with respect to) the ground**, a ball is lying, **right at its corner**.'

Figure 24. *Ball & Chair 2.6*

  - object-centered

(6.2) (…)tu=tséel=i', bwèeno, **tu=pàach**
PREP:A3=side=D4 well PREP:A3=back
te'l tu'x k-u=nak-tal máak=o'
DADV where IMPF-A3=lean-INCH.DIS person=D2
'(…) on its side, well, **behind where one sits**'

Figure 25. *Ball & Chair 2.11*

  - relative

(6.3) Ti'=pek-kun-a'n
PREP=lie.as.if.dropped-CAUS-RES(B3SG)
hun-p'éel chan=bòola=i' **tu=tséel**=e'
one-CL.IN DIM=ball=D4 PREP:A3=side=D3
'There lies a little ball, **on (the chair's) side**.'

Figure 25. *Ball & Chair 2.11*

  - absolute

(6.4) Te'l **chik'in**=o', náats' te=lu'm=o',
DADV west=D2 near(B3SG) PREP:DET=earth=D2
ti'=pek-ekbal hun-p'éel chan=bòola=i'.
PREP=lie.as.if.dropped-DIS(B3SG) one-CL.IN DIM=ball=D4
'There **in the west**, close by on the ground, there is lying a little ball.'

Figure 26. *Ball & Chair 3.12*

  - **landmark-based**

(6.5) Ba'l=e', **tu=tòoh-il** **le=kàancha=o',**
thing=TOP PREP:A3=straight-REL DET=court=D2
ti'=yàan le=bòola tu=pachk'ab-il=o'
PREP=EXIST(B3SG) DET=ball PREP:A3=back:hand-REL=D2
'But **toward the [volleyball] court**, there's the ball behind [the chair]'

Figure 27. *Ball & Chair 4.2*

  - **direct** (loosely based on Danziger 2010)

(6.6) YUC Te=pàarte **t-ak=tòoh-il-o'n**
PREP:DET=part PREP-A1PL=straight-REL-B1PL
bèey he'x kul-ik-o'n bèey=a'
thus how sit-EXFOC-B1PL thus=D1
ti'=pek-a'n te=lu'm=o' hun-p'éel bòola
PREP-lie.as.if.dropped-RES(B3SG) PREP=earth=D2 one-CL.IN ball
'In the part **in our direction** the way we are sitting like this, there a ball lying on the ground.'

Figure 28. *Ball & Chair 3.10*

- examples: orientation descriptions
  - relative

(6.7) (…)u=ho'l le=sìiya=o', estéen,
A3=head DET=chair=D2 HESIT
x-no'h **súut-ul**
F-right(B3SG) turn\MIDDLE-INC(B3SG)
'(…) the backrest (lit. head) of the chair, it's turned right'

Figure 29. *Ball & Chair 1.12*

  - absolute

(6.8) (…) le=pàarte tu'x k-u=kutal máak=o'
DET=part where IMPF-A3=sit:INCH.INC person=D2
chik'in **súut-ul** (…)
west turn\MIDDLE-INC(B3SG)
'(…) the part where one sits, it's **turned west** (…)'

Figure 30. *Ball & Chair 3.9*

– **landmark-based**

(6.9) (…)u=frèente tu'x k-u=kutal máak=o',
YUC A3=front where IMPF-A3=sit:INCH.INC person=D2
tu=tòoh-il **le=kàancha=o'**
PREP:A3=straight-REL DET=court=D2
'(…) its front where one sits, **it's in a straight line with respect to the volleyball court**.'

Figure 31. *Ball & Chair 4.12*

– **direct**

(6.10) Tu'x k-u=nak-tal máak=o',
YUC where(B3SG) IMPF-A3=lean.against-INCH.INC person=D2
estée **ta=frènte** **súut-ul**
HESIT PREP:A2=front turn\MIDDLE-INC(B3SG)
'The back (lit. where one leans against), uh, it's turned towards your front.'

Figure 32. *Ball & Chair 2.5*

- observations
  - orientation descriptions, like locative descriptions, may be interpreted with respect to FoRs
    - e.g., in Yucatec, they may employ cardinal direction terms and 'left'/'right' terms in relative interpretation
  - both locative and orientation descriptions may be landmark-based or direct
    - such descriptions are **head-anchored** (Bohnemeyer & O'Meara in press)
    - the truth conditions of **angular-anchored** descriptions…
      - » these are the traditionally recognized object-centered, relative, geomorphic, and absolute types
      - – … depend on the orientation of the anchor, but not on its location
    - the truth conditions of head-anchored descriptions in contrast depend on the anchor's location
      - – but not on its orientation

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Extensions

- the Yucatec data suggests two additional phenomena a semantics for FoRs should cover
  - orientation descriptions
  - head-anchored descriptions
- orientation descriptions are by necessity
  - projective - there are no topological orientation descriptions
  - extrinsic – there are no intrinsic/object-centered orientation descriptions

- making orientation descriptions work
  - the reference frame is centered on the figure
    - not on the ground as in locative descriptions
  - the axis function serves to align a suitable axis of the figure

(7.1) **Orientation:** any vector **v** defines the orientation of an object iff
(i) the base of **v** is the center of the object,
(ii) **a** is codirectional with one of the object's axes and pointing outward.
By default, **v** is codirectional with the object's front axis.

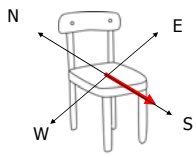

Figure 33. *Chair, facing south*

- making head-anchored descriptions work
  - the axis function in this case defines a set of vectors whose endpoints are on the anchor
    - rather than to select an axis of the anchor, as in angular-anchored frames

(7.2) *The chair is facing the door/us*
(7.3) *The ball is towards the door/us from the chair*

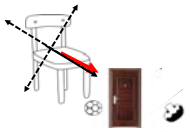

Figure 34. *Chair, facing door/observer*

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Summary

- proposals argued for
  - spatial frames of reference are not a part of the lexical meaning of spatial relators
  - projective spatial relators are indexicals
  - orientation descriptions are necessarily projective and extrinsic
  - two routes to constituting a reference frame
    - in angular-anchored descriptions, an axis of the frame is "copied" from one of the anchor
      - via translation ± rotation
    - in head-anchored descriptions, an axis of the frame is defined as a vector pointing toward the anchor

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