

A vector space semantics for reference frames in Yucatec*

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1. Introduction: the argument

This paper pursues three goals: (i) extend Vector Space Semantics (VSS; Zwarts and Winter 2000) to develop a model-theoretic treatment of spatial reference frames which treats frame-dependent expressions as indexicals; (ii) explore frame dependence beyond locative and motion descriptions, in orientation descriptions; (iii) introduce a previously unrecognized dichotomy between two types of frames, angular-anchored vs. head-anchored frames, which affect the truth conditions of utterances interpreted in them in characteristically different ways. The empirical basis of the paper is an experimental investigation of the use of reference frames in Yucatec Maya.

The remainder of this section provides some background information on reference frames. Reference frames have been studied by linguists and cognitive scientists mostly for their role in the semantics of **place functions** (Jackendoff 1983) or ‘localizers’ (Kracht 2002), mappings from individuals into regions of space defined with respect to them. Following Piaget and Inhelder 1956, two types of place functions may be distinguished: **topological** place functions, whose interpretation does not depend on reference frames, and **projective** place functions, whose interpretation does. The truth conditions of topological place functions are independent of the orientation of the reference entity or **ground**, but also of the orientation of the observer and the figure-ground configuration (where the **figure** is the individual whose location is at issue (see Talmy 2000 for the terms ‘figure’ and ‘ground’). The examples (1)–(3) illustrate topological descriptions.

(1) *The apple is on the skewer*

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(2) *The band aid is on the shin*

(3) *The earring is in the ear (lobe)*

In contrast, projective place functions are frame-dependent. They return regions defined in a coordinate system centered on the reference entity. Speakers and hearers normally compute these coordinate systems on the spot when processing spatial descriptions, although they may to some extent also retrieve them from long term memory (there is surprisingly little discussion of this issue in the literature). The axes of the coordinate system are generally derived from an object (e.g., an observer, the ground, or some landmark), a topographic feature (e.g., a mountain slope or river), or an event (e.g., the sunrise, a prevailing wind, a sea current). This model of the frame is its **anchor**. For example, in terms of the classification of reference frames proposed by Levinson 1996, 2003:

- 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.

The kind of anchor involved is one of two properties that play a role in the classification of frames. Figure 1 introduces the types of frames distinguished in this paper. This classification is elaborated on in sections 3 and 5 below.

Reference frames have received little attention by semanticists, and especially by formal semanticists. Levinson (1996, 2003) has proposed a lexical-semantic analysis which treats reference frames as part of the meanings of the place functions interpreted with respect to them. The first objective of the present paper is to make the case that this lexical analysis is inadequate. I argue that all projective place functions are indexicals, in the process correcting and generalizing the classic analysis by Bühler (1934). On the basis of the indexical analysis, I develop a model-theoretic treatment in the framework of Zwarts and Winter's (2000) Vector Space Semantics. I then extend this analysis to 'head-anchored' frames as instantiated in descriptions such as (4)-(5):

(4) *The ball is toward the volleyball court from the chair*

(5) *The ball is on the volleyball court's side of the chair*

Data from Yucatec Maya show that such descriptions at least in that language have the formal properties of projective spatial descriptions. Levinson (2003) treats such descriptions as a subtype of intrinsic representations, which he terms 'landmark-based'. However, as shown in Bohnemeyer and O'Meara (in press), the role of the frame in the truth conditions of the representation is different from other projective representations. I also look at the use of reference frames in Yucatec orientation descriptions. The function of frames in representations of the orientation of objects has received very little attention in the literature so far.

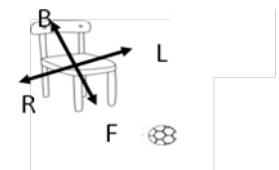
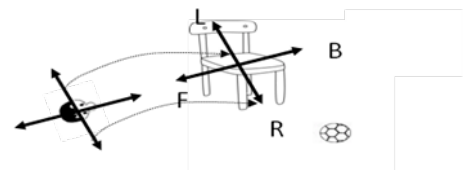
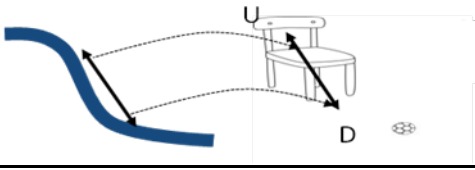
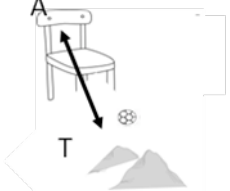
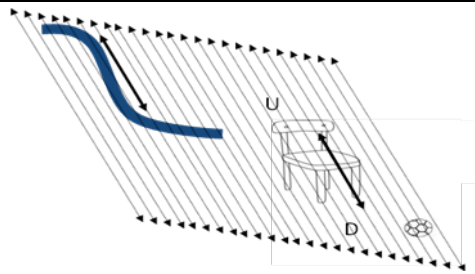
frame type	constraint on anchor	example	illustration
intrinsic	the ground	<i>The ball is in front of the chair</i>	
relative	the body of an observer (speaker, addressee, or generic)	<i>The ball is right of the chair</i>	
geomorphic	a salient environmental entity/feature	<i>The ball is downriver of the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

Figure 1. *Frame type and anchor selection*

2. The lexical analysis of reference frames

Levinson (1996, 2003) has proposed an analysis according to which reference frames are a lexical property of the place functions interpreted in them. He treats the anchor as a semantic argument of extrinsic place functions, but not of intrinsic ones. Accordingly, he classifies intrinsic place functions as binary, but relative place functions as ternary. Absolute place functions are treated as binary because their logical/conceptual anchor argument is fixed; see below. The definitions cited below make use of the following symbols (cf. Levinson 2003: 39):

- R – the meaning of the place function

- F – the **figure** – the entity to be located/oriented (Talmy 2000: 25)
- G – a reference entity or **ground** (Talmy *ibid.*)
- X – the origin of the coordinate system
- A – an **anchor point** – the anchor or a part of it
- V – the viewpoint of an observer
- S – the ‘slope’ of a fixed bearing system, with infinite parallel lines across the environment (Levinson 2003: 39)¹

Levinson then defines the three classes of place functions as follows:

“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)

As mentioned, absolute place functions are treated as binary because the environmental slope argument S is assumed to be fixed. In the alternative analysis developed below, S, V and A are all treated as properties of the anchor, and the anchor in turn is treated as a contextual index.

I see four problems or weaknesses in this analysis. The first is the systematic ambiguity (or, to use a term that avoids biasing the analysis, multiplicity of senses) in the interpretation of place functions that occur in multiple frame types. If the frame is a lexical semantic property of the place function, then all of these apparent ambiguities are instances of polysemy. The best-known instance of this kind of multiplicity of senses is that between intrinsic and relative interpretations (Bühler 1934 : 127-132; Fillmore 1997: 66-67; Miller and Johnson-Laird 1976: 394-405; Levelt 1984 *inter alia*). Figure 2 illustrates this.

¹ The term ‘slope’ appears to be based on a somewhat idiosyncratic metaphor that may appear a lot more plausible when one is working on a type of absolute system that happens to be anchored to a mountain slope, such as that described in Brown & Levinson (1993) and Levinson (1996, 2003).

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For non-geocentric projective place functions and languages in which the relative frame type is available, this ambiguity appears to be without exceptions. A similar systematic apparent ambiguity applies to absolute representations. It appears that absolute frames are always abstracted from concrete ‘geomorphic’ (see below) or landmark-based frames. Descriptions that can be interpreted in absolute frames systematically also permit interpretations in the non-abstracted source frames. Figure 1 cites the example of a



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

Figure 2. *Truth conditions of intrinsic and relative descriptions*

concrete, geomorphic ‘upriver’/‘downriver’-system and an abstract absolute frame type derived from it. I use the term ‘geomorphic’ for reference frames whose anchor is some environmental gradient – the direction of a stream or current, the slope of a mountainside, a prevailing wind direction, etc. Levinsonian absolute frames can be abstracted from such geomorphic frames by letting the terms that denote the directions ‘upriver’ and ‘downriver’ in reference to the actual course of the stream – the axis of the anchor – denote the entire set of vectors pointing in the direction in which the river flows and in the opposite direction, respectively, regardless of their beginning points. It is this field of vectors that Levinson calls the ‘slope’. Suppose the concrete geomorphic system is used in village A by a major river that has a saliently constant direction in the vicinity of that village, but does meander and eventually courses in the opposite direction near village B. Suppose furthermore that there is an absolute system in use in both villages that is abstracted from the geomorphic use in village A, due to the greater cultural significance of that village. Then in village A, geomorphic and absolute interpretations of ‘upriver’ and ‘downriver’ align, whereas in village B, they not only diverge, but the terms in fact denote inverse directions under the two interpretations (much like ‘left’ and ‘right’ do in reference to the sides of a person or a chair facing the observer depending on whether the intrinsic or the relative interpretation is selected). For actual examples of such co-occurrence of geomorphic and absolute interpretations with the same place functions, see Brown and Levinson 1993, de León 1994, Wassmann and Dasen 1998, and Polian and Bohmeyer 2011.

The lexical-semantic treatment of such apparent ambiguities in terms of polysemy fails to account for their systematicity and apparent unavoidability. On the analysis advanced below, they are the result of the systematic underspecification and context-dependence of projective place functions vis-à-vis the selection of the anchor. The anchor is not a semantic argument of the place function, but rather a contextual index. Additional

evidence supporting the analysis in terms of underspecification rather than polysemy comes from the standard polysemy test in (6)-(7):

- (6) Uttered as a description of the first picture in Figure 2:
#*The ball is not in front of the chair, it's between the viewer and the chair*
- (7) Uttered as a description of the second picture in Figure 2:
#*The ball is not in front of the chair, it's near the front of the chair*

If the complex preposition *in front of* had discrete senses with distinct truth conditions associated with the intrinsic and relative interpretations, it should be possible to deny the applicability of the place function under one interpretation while at the same time asserting without contradiction that the other applies, as illustrated by textbook examples such as (8)-(9):²

- (8) *That's not a cow; that's a bull*
- (9) *Floyd isn't a doctor; he has a PhD in linguistics*

That such selective deniability of senses is impossible with projective place functions suggests that they are vague, rather than ambiguous, in terms of the identity of the anchor – in other words, that the anchor is not a semantic argument of the place function.

Another weakness of the lexical analysis is the implausibility of the binary-ternary distinction. If relative place functions are ternary, intrinsic place functions ought to be ternary, too. Both designate regions defined with respect to 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 the roles of anchor and ground in the truth conditions of spatial representations are distinct, and if these roles are represented by distinct semantic argument positions in relative descriptions, then they should be represented by such positions in intrinsic descriptions as well, even in case they happen to be filled by descriptors of the same entity. The same goes for absolute place functions: just because the anchor is in this case invariant does not mean its role in the semantics of the place function is different.

A final argument against the lexical analysis is the problem that the binary-ternary contrast creates for compositionality. Since Levinson's binary and ternary place functions fulfill the same role in the composition of spatial representations, one would have to assume a type-raising operation to make at least one of the two types of place functions satisfy the type restrictions imposed by the other. An alternative analysis that makes do without necessitating type raising would be favored by Occam's Razor. In fact, all spatial place functions are standardly assumed to be binary regardless of reference frame in both mentalist (Jackendoff 1983) and model-theoretic treatments (e.g., Kracht 2002, Zwarts

² See Cruse (1986: 58-74) for more discussion of this and other polysemy tests.

2005, Zwarts and Winter 2000). This suggests that reference frames are not a part of the meaning of place functions.

Conceivable alternatives to the lexical-semantic treatment are compositional and/or pragmatic analyses of the interaction between place functions and frames. The proposal sketched below combines elements of both types of approaches.

3. The indexical analysis of reference frames

On the account proposed here, all projective place functions are indexicals. That place functions – or at least one type of place functions, namely those interpreted in *relative* frames – are indexicals is by no means a new suggestion. In fact, it has been known since at least Bühler (1934: 129). However, Bühler did not apparently consider allocentric descriptions indexical. The reason might be that Bühler’s notion of indexicality – *deixis* – is inherently egocentric. Consider, for instance, his famous characterization of the deictic center in terms of the “origo of ‘now’, ‘here’, ‘I’” (Bühler 1934: 102). This equation of indexicality with egocentricity may have prevented Bühler from realizing that allocentric place functions are just as indexical as egocentric ones. The literature building on Bühler then subsequently codified the false equation deictic/indexical = egocentric (Fillmore [1971/1975] 1997: 66-67; Miller and Johnson-Laird 1976: 394-405; Levelt 1984 *inter alia*). Kaplan (1989) defines indexicality in terms of two properties: context-dependence and *character*, understood as a mapping from contexts to intensions (or ‘contents’). I argue that the context-dependence of projective place functions manifests itself in the requirement to select an anchor from the context. This requirement accompanies every use of a projective place function. The character of projective place functions can be understood as a constraint the place function imposes on possible anchors, as illustrated in the second column of Figure 1 above. If the speaker/observer chooses an intrinsic frame, they commit themselves to the ground or reference entity as anchor. Relative frames require an observer as anchor. In discourse, this can be the speaker, the addressee, or a generic observer, as in examples such as (10):

(10) *When one enters the institute, the reception desk is immediately on the left*

Geomorphic and landmark-based frames require the selection of a suitable anchor from the environment. The same holds for absolute frames, which differ from geomorphic and landmark-based frames merely in that they involve abstraction of the frames’ axes from the anchor, in a sense to be spelled out in section 5.

The role of the anchor in the semantics of projective place functions corresponds to the role of speaker and addressee in person deixis, the role of the location of speaker and addressee in demonstratives, and the role of the time of utterance in temporal deixis. The anchor is part of the deictic center on the account proposed here. One might object that the speech situation does not generally include a *unique* anchor. However, the speech situation of an utterance is not simply any situation that includes it. Rather, the speech situation is selected from the set of situations that include the utterance according to a template that requires speakers and hearers to make certain choices. Without these

selections, the situations containing the utterance do not involve unique speakers and addressees either. But every *utterance* has a unique speaker and addressee, and the speech situation is chosen in accordance with their identities. In the same vein, every projective spatial description has a unique anchor, and the speech situation is chosen from the set of situations containing the utterance so that the anchor is a part of it.

The analysis just sketched is formalized in section 5. First, however, section 4 introduces the Vector Space Semantics framework.

4. Vector Space Semantics

The theory of choice for the formalization of the indexical analysis of projective descriptions is **Vector Space Semantics** (VSS), proposed by Zwarts and Winter 2000. 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. For example, the region designated by the English preposition *above* can be defined as the set of vectors connected to the hull of the ground and forming an acute angle with the ground's vertical axis, as captured by (11). The endpoints of these vectors then characterize a spatial region in the conventional sense – a set of points.

$$(11) \quad \mathbf{above}' := \lambda A. \lambda \mathbf{v}. \text{ext}(\mathbf{v}, A) \ \& \ c(\mathbf{up}, \mathbf{v}) > 0$$

In (11), A ranges over sets of points and \mathbf{v} over vectors. The predicate $\text{ext}(\mathbf{v}, A)$ requires \mathbf{v} to be connected to A , the region occupied by the ground. The scalar $c(\mathbf{up}, \mathbf{v})$ measures the component of \mathbf{v} along the vertical axis \mathbf{up} .³ This facilitates the modeling of frame dependence, since 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, reflection, or scaling. Figure 3 illustrates this for absolute (anchored to the Earth's field of gravity), relative (anchored to a reclined observer), and intrinsic interpretations of *above the chair*, uttered in reference to a chair lying on one side.

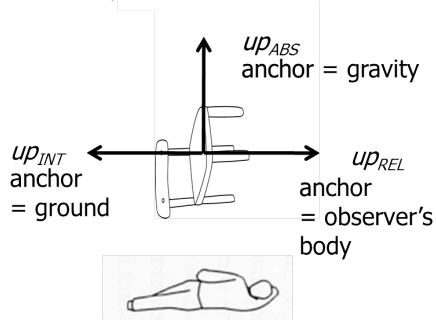


Figure 3. Absolute (up_{ABS}), relative (up_{REL}), and intrinsic (up_{INT}) vertical axes of a chair in a given situation (based on Levelt, Willem J. M., *Perspective taking and ellipsis in spatial descriptions*, in P. Bloom, M.A. Peterson, M.F. Garrett, & L. Nadels (eds.),

³ This is slightly different from the solution in Zwarts & Winter (2000: 182), which the authors claim to yield the set of vectors that form an acute angle with the ground's vertical, but which actually appears to single out only those vectors that form an angle smaller than 45° with it.

Language and space, Figure on p. 90, © 1996 Massachusetts Institute of Technology, by permission of The MIT Press)

To simplify matters, I do not follow Zwarts and Winter (2000: 173-174) in deriving points from vectors. Instead, I opt for a richer ontology that treats both vectors and points as primitives, ignoring the question of the relation between the two. I do, however, agree with Zwarts and Winter's intuition that regions of space can be characterized alternatively by sets of points or by sets of vectors. I assume, then, beside the standard domains D_e and D_t for individuals and truth values, a domain of points D_p and a domain of vectors D_v with the standard functions of vector addition $+ : (D_v \times D_v) \rightarrow D_v$ and scalar multiplication $\cdot : (\mathbf{R} \times D_v) \rightarrow D_v$ defined over D_v and the real numbers \mathbf{R} . The function $c(\mathbf{u}, \mathbf{v}) : (D_v \times D_v) \rightarrow \mathbf{R}$ returns \mathbf{v} 's component along \mathbf{u} , a scalar (see (11) above). I use $\mathbf{p}, \mathbf{q} \in D_p$ for point variables and $\mathbf{u}, \mathbf{v}, \mathbf{w} \in D_v$ for vector variables. The functions *s-point* and *e-point* from D_v into D_p return the starting and end point of vectors, respectively. Interpretations are mediated by translation into a typed lambda calculus whose type system distinguishes, in addition to the standard atomic types for individuals and formulae, the types p and v for points and vectors. For English, Zwarts and Winter assume that *e-type* NPs are type-raised to $\langle p, t \rangle$ (sets of points) by the *eigenspace* function *loc* from D_e into $D_{\langle p, t \rangle}$, which maps objects into the spaces they occupy. Prepositions ($\langle \langle p, t \rangle, \langle v, t \rangle \rangle$) map sets of points into sets of vectors and prepositional phrases type-shift these back to sets of individuals ($\langle e, t \rangle$) via an *antilocution* function loc^- from $D_{\langle v, t \rangle}$ into D_e , which maps sets of vectors to the set of entities contained in the set of their endpoints:

$$(12) \quad loc^- := \lambda W_{\langle v, t \rangle}. \lambda x_e. \forall \mathbf{p} \in loc(x) \exists \mathbf{v} \in W[e\text{-point}(\mathbf{v}) = \mathbf{p}]$$

Let us call the sister of the head of a locative or motion predicate the **ground phrase**. In English, the ground phrase is most commonly a PP. Yucatec has two prepositions which can head the ground phrase, but also a set of relational nouns – **meronyms** or object part descriptors – which appear in the same position. An example is *óok'ol* 'top surface', 'on', 'above' in (13):

$$(13) \quad Ti'=yàan \quad y=óok'ol \quad le=mèesa \quad le=lùuch=o'$$

there=EXIST(B3SG) A3=on/above DET=table DET=cup=D2

'The cup is on the table'

The 'A3' (ergative/possessor) clitic $y=$ is a bound pronominal marker indexing the possessor of the meronym – in (13), the ground, the table. The meronyms that head projective ground phrases always describe surfaces of the referential ground in Yucatec. How one gets from these surfaces to the projected spatial regions is not in all instances a trivial matter. In the case of *óok'ol*, the projected region is determined the same way as that of *above* according to (11), except that the top surface of the ground is included in the designated region, which one might crudely represent as in (14):

$$(14) \quad \text{óok'ol}' := \lambda A. \lambda \mathbf{v}. \text{ext}(\mathbf{v}, A) \ \& \ c(\text{up}, \mathbf{v}) \geq 0$$

As in (11), the region designated by *óok'ol* is understood in terms of the endpoints of a set of vectors. The function expressed by *óok'ol* maps the eigenspace *A* of the ground into the set of vectors connected to the hull of the ground that form an acute angle or a right angle with the ground's vertical axis. The desired 'on top of' interpretation results when the angle with the vertical axis becomes 90°. This of course captures exclusively the ideal case of a perfectly level surface.

In the following, I assume that the precise semantics of the meronyms is irrelevant for present purposes and ignore it. I furthermore treat the semantic type of the meronyms as $\langle\langle p,t \rangle, \langle v,t \rangle\rangle$ on a par with that of spatial adpositions, reducing the surfaces they describe to regions (sets of points) and ignoring the question of their mereological interpretation as object parts.

Figure 4 shows a sample composition for the locative description in (13).⁴ I assume that the antilocation function loc^- is expressed by the head of the locative predicate in Yucatec, rather than to be triggered by the preposition or meronym via a type shifting rule, as Zwarts and Winter argue for English. The different analysis is motivated by the fact that Yucatec ground phrases uniformly denote regions of space. Crucially, the form of the ground phrase does not distinguish between locative and motion descriptions. See Bohnemeyer (2007, 2010), Bohnemeyer and Stolz (2006), Bohnemeyer et al (2009), and Pérez Báez and Bohnemeyer 2008 for detailed analysis and evidence.

Yucatec is a VOS language, and this is reflected in both (13) and Figure 4. However, the (notional) subject⁵ – the figure nominal in locative descriptions – is usually left-dislocated in connected speech. This is ignored here, as is the role of pronominal arguments in semantic composition. As shown in Figure 4, (13) translates into (15) in VSS:

$$(15) \quad loc^-(\acute{o}ok'ol'(loc(\mathbf{the_table'})))(\mathbf{the_cup'})$$

Given (12), (15) is equivalent to (16):

$$(16) \quad \forall \mathbf{p} \in loc(\mathbf{the_cup'}) \exists \mathbf{v} \in \acute{o}ok'ol'(loc(\mathbf{the_table'}))[e\text{-point}(\mathbf{v}) = \mathbf{p}]$$

That is, for every point in the eigenspace of the cup, there is a vector in the denotation of the ground phrase [*óok'ol'(loc (the_table'))*] whose endpoint this point is. And the ground phrase yields, via (14), the set of vectors connected to the hull of the table that form an acute or right angle with the table's vertical axis.

⁴ An element omitted in Figure 4 is the incorporated place adverb *ti* 'there' on the left periphery of the verbal complex in (10). *Ti*' tends to precede the locative predicate unless the ground phrase is focalized.

⁵ It is not obvious that the subject function plays the consistent and pervasive role in the grammar of Yucatec that it plays in English; cf. Bohnemeyer 2009.

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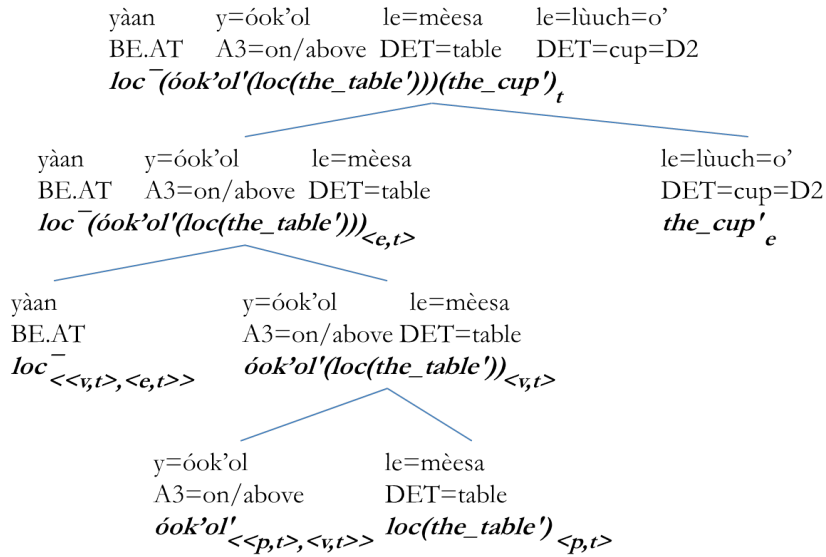


Figure 4. An analysis of (13) in VSS

5. Reference frames in VSS

In a nutshell, the proposal I wish to advance is that all projective (i.e., non-‘topological’) place functions of type $\langle \langle p,t \rangle, \langle v,t \rangle \rangle$ are indexicals. To formalize this proposal, I introduce the axis function and the anchor constant. The **axis function** replaces the axis constant in the semantics of projective place functions such as *up* in the cases of **above’** and **óok’ol’** discussed in the previous section. The axis function maps the anchor into a unit vector of the relevant kind. For instance, *up* maps the anchor into a vertical axis, where verticality is interpreted differently depending on the nature and identity of the anchor and thus the frame, as illustrated in Figure 3 above. As illustrated in (11) and (14), the axis function is part of the semantics of projective place functions. Zwarts and Winter (p181) distinguish the object-centric axis constants *up*, *front*, and *right* and their negative counterparts. I postulate the corresponding functions and in addition functions for the geocentric axes selected by *upriver*, *uphill*, *north*, *east*, etc., and for their negative and orthogonal partners. Each type of frame comes with its own unique set of axis functions.

The denotation of the anchor constant is fixed by the interpretation function. I assume an “anchored” model $M^a = \langle C, D_e, D_p, D_v, I, g \rangle$ consisting of a set of contexts C , the domains of individuals, points, and vectors, the interpretation function, and a variable assignment. Then the constant *anchor* picks out the anchor in every context: $[\text{anchor}]^{M^a, g, c} = c_a$. The denotation of the axis function *up* applied to the anchor constant $[\text{up}(\text{anchor})]^{M^a, g, c}$ is in 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 (or, in cases such as that of Yucatec *óok’ol* discussed in the previous section, a right 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 concerning the codirectionality requirement in absolute and relative frames). A locative description is true iff the eigenspace of the figure is included in the region designated by the ground phrase.

The model theory sketched here predicts that (13) above, via (11) and (13), is true when the table is in canonical vertical orientation and the closest vectors pointing from the table to the cup form an acute or right angle with the gravity vector, but also when the table is standing on one side and the closest vectors pointing from the table to the cup form an acute or right angle with the table's intrinsic vertical axis, as illustrated in Figure 5.

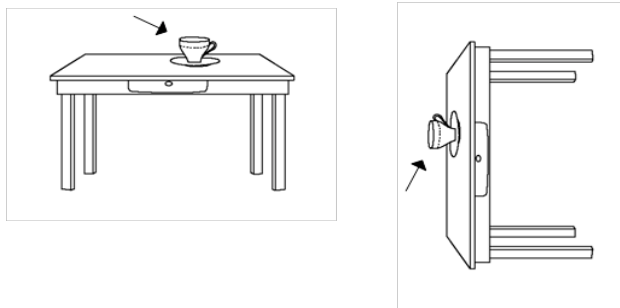


Figure 5. Scenarios that satisfy (13) in an absolute FoR (left) and a (dis-aligned) intrinsic one (right) (images based on Bowerman and Pederson 1992)

Such ‘disaligned’ intrinsic interpretations (Carlson-Radvansky and Irwin 1993) of vertical place functions are in fact common in Yucatec discourse (cf. Bohnemeyer and Tucker 2010). Example (17), uttered as a description of Figure 6, illustrates.⁶

- (17) 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 (...)’

An important wrinkle concerns the distinction between two subtypes of the relative frame type that differ from one another in terms of whether the projection of the selected axis from the anchor onto the ground involves reflection, as in

⁶ Abbreviations in morpheme glosses: 1/2/3 – 1st/2nd/3rd person; A – ‘set-A’ (ergative/possessor) pronominal clitic; B – ‘set-B’ (absolutive) pronominal suffix; CL – (numeral/possessive) classifier; D1/D2/D4 – proximal/distal-anaphoric/place-anaphoric clause-final particle; DADV – demonstrative adverb; DET – determiner base; DIM – diminutive clitic; DIS – dispositional stative predicate form; EXFOC – extrafocal ‘status’; EXIST – locative/existential/possessive predicator; HESIT – hesitation; IMPF – imperfective aspect; IN – inanimate (classifier); INC – incomplete ‘status’; INCH – inchoative derivation; MIDDLE – middle voice; PL – plural; PREP – ‘generic’ preposition; REL – relational derivation; RES – resultative stative predicate form; SG – singular; TOP – topic.



Figure 6. *Ball & Chair 1.6*

English-style relative frames, or translation, as in Hausa-style relative frames (Hill 1982). This is illustrated in Figure 7:

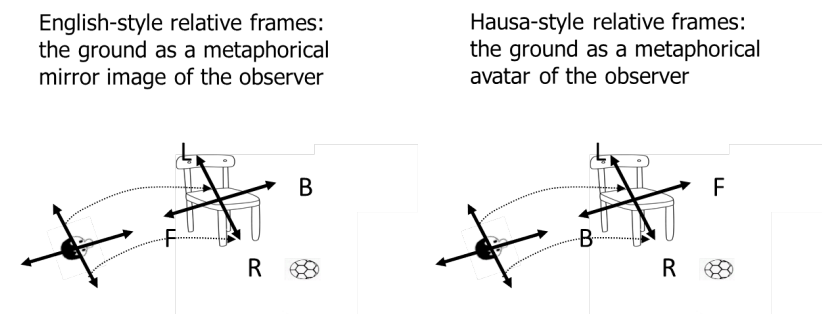


Figure 7. *English- and Hausa-type relative frames*

A related issue arises in the case of absolute frames, where the axes of the frame are *abstracted* from concrete geomorphic and landmark-based systems (cf. Levinson 2003: 47-50). The anchor of absolute frames does not change with the context. In both 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.

A precursor of the analysis developed here is the DRT approach to reference frames sketched by Maillat 2003. Maillat's proposal shares with the present one the idea that reference frames are determined by single (half)-axes represented by vectors. And Maillat cites VSS to explain this idea. The present formalization has the advantage of preserving the compositionality of VSS and of making the indexicality of projective representations explicit in a way the DRT analysis does not.

6. Reference frames in Yucatec

Yucatec is a Mayan language spoken on the Yucatan peninsula, in the Mexican states of Yucatán, Campeche, and Quintana Roo and the adjacent districts of Belize. The data summarized here were collected by me in the summer of 2008 in the village of Yaxley and the town of Felipe Carrillo Puerto in central Quintana Roo. Like the present paper, this field work was part of the project Spatial Language and Cognition in Mesoamerica

(MesoSpace) funded by the National Science Foundation (see acknowledgments). The tool I used to collect the data presented below (and in greater detail in Bohnemeyer 2011 and Bohnemeyer and O’Meara in press) was the ‘Ball & Chair’ task. The stimuli consist of four sets of 12 photographs each, all featuring a ball and a chair in various spatial configurations. Figures 2 and 6 above show examples of these pictures. Pairs of participants match the corresponding pictures in two identical but differently ordered sets through referential communication while a screen between them prevents them from sharing a visual field. I administered this task to five men in their 30s through 60s and five women in their late teens through 40s.

Figure 8 shows a breakdown of the results by dyad of participants and frame type frequency in terms of the number of picture descriptions involving propositions that encode the location of the ball vis-à-vis the chair (left) and the orientation of the chair (right).⁷

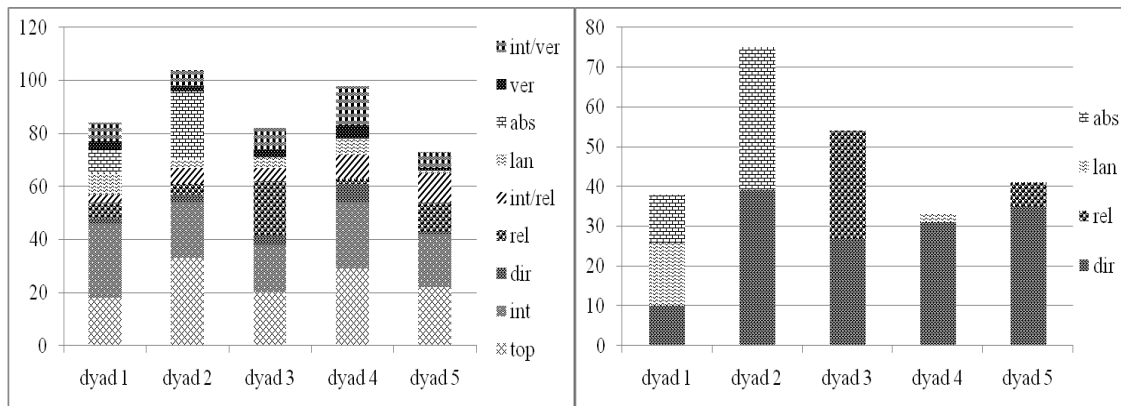


Figure 8. Numbers of locative (left) and orientation descriptions by frame type top – topological; int – intrinsic object centered; dir – intrinsic direct (Danziger 2010); rel – relative; int/rel – object-centered/relative ambiguity; lan - landmark-based; abs – cardinal direction terms; ver - absolute vertical; int/ver – object-centered/absolute-vertical ambiguity

Examples (18)-(19) illustrate cardinal direction terms in locative (18) and orientation (19) descriptions:

- (18) Te’1 **chik’in**=o’, náats’ te=lu’m=o’,
DADV west=D2 near(B3SG) PREP:DET=earth=D2

⁷ These charts involve a distinction between two subtypes of intrinsic frames not discussed above: the ‘object-centered’ type, in which the ground and anchor is some entity other than the speaker/addressee/observer, and the ‘direct’ type (Danziger 2010), in which the ground and anchor is the body of an observer, most commonly the speaker or addressee. Direct frames are egocentric, but nevertheless intrinsic. They differ from relative frames in that they do not involve translation or reflection of the observer’s body axes onto a distinct ground, but merely scaling, as in all intrinsic frames, extending the axes of the anchor = ground outward into space. An example of a direct description is *The ball is in front of me*.

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ti'=pek-ekbal hun-p'èel 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.'

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

The parallelism between these examples suggests that orientation descriptions, like locative descriptions, may be interpreted with respect to reference frames. Bohemeyer and O'Meara (in press) argue that orientation descriptions are in fact necessarily projective and extrinsic. The truth conditions of orientation descriptions can be captured in the framework developed here in terms of an alignment of a suitable axis of the described object – the figure – with the axis of the anchor selected by the anchor function. The reference frame is centered on the figure rather than the ground in orientation descriptions. In English and Yucatec, the default for orienting an object is to align its front axis with the anchor.

Both locative and orientation descriptions may also be landmark-based, as illustrated in (20)-(21):

- (20) 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]'

- (21) (...)u=frèente tu'x k-u=kutal máak=o',
 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.**'

Example (20) describes the ball as 'toward the volleyball court' from the chair and example (21) the chair as facing the volleyball court. The anchor in this type of descriptions is frequently the (body of the) speaker or addressee, as illustrated in (22) (a locative description) and (23) (an orientation description):

- (22) 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

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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 is a ball lying
 on the ground.'

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

In (22), the ball is described as ‘toward us’ from the chair and in (23), the chair is said to be turned ‘toward your front’. In Figure 8, descriptions such as those in (22)-(23) are subsumed under the ‘direct’ – egocentric intrinsic – type. However, Bohnemeyer and O’Meara (in press) point out a striking difference between the truth conditions of representations such as (20)-(23), which depend on the location of the anchor, but not on its orientation, and those of relative, geomorphic, and object-centered intrinsic frames, which depend on the orientation of the anchor, but not on its location. Levinson (2003: 50-53) in fact uses dependence on the orientation of the anchor as a heuristic to distinguish his three frame types: if the truth conditions depend on the orientation of the ground, the description is intrinsic; if they depend on the orientation of the observer, it is relative; and if they depend on the orientation of the figure-ground configuration (in locative descriptions), it is absolute. However, representations such as (20)-(23) – all of which are intrinsic in Levinson’s classification – clearly do not meet the criterion for any of the three types. Bohnemeyer and O’Meara propose that such descriptions involve **head-anchored** reference frames, whereas relative, geomorphic, and object-centered intrinsic descriptions involved **angular-anchored** frames. The latter are constituted in the way discussed above: one (semi-)axis of the frame is derived from a (semi-)axis of the anchor by translation, reflection, or scaling. (As mentioned, the case of absolute frames is distinct, involving abstraction.) In contrast, in head-anchored descriptions, the axis function defines a set of vectors whose endpoints are on the anchor rather than to select an axis of it.

7. Summary

I have argued that spatial frames of reference are not a part of the lexical meaning of spatial relators. Rather, projective spatial relators are indexicals. A vector-based semantics as developed by Zwartz and Winter 2000 makes it possible to flesh these ideas out. It furthermore readily supports extensions to the role of reference frames in orientation descriptions and in ‘head-anchored’ representations, in which an axis of the frame is defined as pointing toward or away from the anchor. Data from Yucatec Maya suggest that these hitherto neglected types of projective representations may play an important role in spatial language and cognition.

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