Taking Stock of the Cross-Linguistic Data: Spatial Frames of Reference and Their Effect on Thought

LINDA AABARANELL  
Department of Psychology  
San Diego State University  
Email: labarbanell@mail.sdsu.edu

PEGGY LI  
Department of Psychology, Harvard University  
Laboratory for Developmental Studies  
Email: pegs@wjh.harvard.edu

Spatial frames of reference (FoR) have been one of the most promising yet controversial areas to test for linguistic relativity. A primary distinction is between languages like English that primarily use an egocentric frame (e.g., left/right), and like Tseltal Mayan that use a geocentric frame (e.g., uphill/downhill). In studies across more than 20 languages, researchers from the Cognitive Anthropology Research Group (CARG) at the Max Planck Institute for Psycholinguistics found a striking correlation between the predominant FoR used by a language and speakers’ preferences for encoding small-scale spatial arrays in memory on certain tasks. For example, in the “animals” task, participants view an array of toy animals at one table and then turn to face a second table where they are asked to make the “same” array. When turning, your body axes turns with you but the environment does not, creating at least two viable solutions. Speakers of languages like Dutch aligned the animals from the same egocentric perspective, while speakers of languages like Tseltal maintained their same geocentric orientation (Brown & Levinson, 1993). These results led some researchers to conclude that linguistic FoR (re)shape speakers’ non-linguistic spatial representations, making it difficult for them to use their language-incongruent system (Levinson, 2003; Majid et al, 2004; Pederson et al., 1998). Not all researchers, however, agreed with this conclusion, taking issue in particular with the open-ended nature of the tasks which leaves it up to participants to decide what is meant by the “same” (Li & Gleitman, 2002; Li et al., 2011; Newcombe & Huttenlocher, 2000; Pinker, 2007). Two competing accounts have been proposed: a “linguistic relativity” account, where language actually (re)shapes non-linguistic cognition, and a “pragmatic inference” account, where language affects speakers’ interpretation of the task. In this paper, we attempt to reconcile the data collected since the original CARG tasks, which we argue supports the latter account.

Before we describe our own data, it is worth pointing out there are other studies that do not quite support a linguistic relativity account. For example, Mishra et al. (2003) found that Hindi speakers who use an egocentric FoR in their language and Hindi, Nepali and Newari speakers that use a geocentric FoR all preferred the geocentric response on the animals task involving a static array but an egocentric response on a maze task involving a motion path. The same pattern was found among Balinese speakers who use a geocentric FoR in their language (Wassman & Dassen, 1998), suggesting that we encode different types of spatial information using different reference frames. Even some of the original CARG members sometimes struggled to reconcile inconsistencies in their results. In his work with Kilivila, Senft (2001, 2007) noted that many “uncontrolled parameters” could affect the results (2007: 241). Minor differences in procedures
such as whether participants carry the animals to the second table (Cottereau-Reiss, 1999) and the wait time between the two tables (Brown & Levinson, 1993) have been found to affect the results.

In our work with Tseltal and English speakers (Abarbanell, 2010; Li et al., 2011), we adapted some of the original CARG tasks to have two matched conditions, egocentric and geocentric, with clear, correct solutions. By comparing the error rates across these conditions we were able to actually test which system is easier for speakers to use. We found that Tseltal, like English-speakers, could reason equally well using either reference frame and even did better in the egocentric condition on some tasks. Some have argued that we are merely demonstrating speakers’ competence but not their preference (Bohnemeyer & Levinson, 2011; Haun et al., 2011). However, the error pattern on our tasks illustrates that this is not the case. In our “swivel chair” task (Li et al., 2011, Exp. 3), Tseltal-speakers watched as an experimenter hid a coin in one of two boxes to their left/north or right/south side. They were then rotated, eyes closed, to face another direction, and then asked to indicate, eyes open, the location of the coin. Importantly, the number of errors in the geocentric condition varied by the degrees of rotation, with the most errors at 180°, that is, when the view of the environment was the most mismatched from participants’ initial orientation. In contrast, their performance on the egocentric trials was robust regardless of rotation. We did not force them to reason in a way they did not prefer, rather the error pattern confirms that Tseltal speakers take in such spatial information from a body-based perspective, the same as you or I.

A second critique (see Bohnemeyer & Levinson, 2011) concerns the fact that in some of our tasks (e.g., Li et al., 2011, Exp. 1 & 2) participants carry the stimulus array, covered, from the first to the second table, either rotating it with their bodies in the egocentric condition or holding it stable with the environment in the geocentric condition. They then uncover the array to check their responses. Might this afford an alternative strategy in the egocentric condition? For example, could the Tseltal speakers have simply tracked which item was closest to this thumb or that, which can be easily expressed in Tseltal? We note that this would be difficult to do on the multi-legged motion paths (Exp. 2). Moreover, our results held even when participants no longer carried the array (see the “leave box” and “leave maze” trials in Exp. 1 & 2), when the experimenter moved the array (Exp. 4), and even on tasks that required no carrying at all. Recently, for example, we tested Tseltal-speaking children on the CARG group’s more difficult transitive inference task where the relationship between three objects is revealed two at a time across two tables using the transitive property (e.g., if A is left/north of B, and B is left/north of C, then A is left/north of C). In our version, we used models of fronted buildings rather than symmetrical forms, such that their facing orientation across the two tables indicated which FoR participants were expected to use. We found no difference in performance between the two conditions ($F(1,23) = 1.67, p = .21$). If anything, the children did better in the egocentric than the geocentric condition (66.7% vs. 52.5% correct).

A final challenge to our results came from Haun et al. (2011) who tested Hai//om (Namibia) and German-speaking children on an animals-type task and found that a difference in
performance between the two groups persisted even on instructed trials that, like our tasks, had correct solutions. On closer inspection, however, their instructed trials used left/right terms that are rarely used in Hai/om, and they did not control for a perseveration effect among the German children who always received the egocentric before the geocentric trials. Using a similar task with Tseltal and English-speaking children, we found that once we eliminated left/right language from the instructions, the Tseltal children did as well as the English speakers in the egocentric condition, and curiously, both groups did better on the geocentric trials (Abarbanell, Montana & Li, 2011; Li & Abarbanell, revise & resubmit). How do we reconcile these results with the egocentric advantage found by Li et al. (2011)? The answer involves the distance and degrees of rotation between the two tables. With a 90° rotation and the tables close together so participants can see the same environmental landmarks, the children do better in the geocentric condition, but with 180° rotation this advantage disappears (Li & Abarbanell, revise & resubmit, Exp. 3). This finding concurs with studies in the spatial cognition literature (Rieser, 1989; Presson, & Montello 1994; Farrell & Robertson, 1998; Simons & Wang, 1998). It also explains the findings of Haun et al. (2006) who reported a geocentric preference among three species of great apes and prelinguistic human infants. When Rosati (2015) performed a similar experiment with the tables far apart and a hallway in-between, rather than abutted as in Haun and colleagues’ task, non-human primates favored the egocentric solution. We are sympathetic to the position that the habitual use of a FoR in language might influence speakers’ cognitive preferences by making the underlying concepts more salient or better packaged for use, although this seems to be more plausible for spatial relations that are less readily available, such as the development of non-egocentric left/right (Abarbanell & Li, 2009, 2015). The body of findings as outlined here, however, argue decisively against the strong claims of linguistic relativity that were based on the original CARG tasks (Levinson, 2003). Navigation and spatial reasoning require multiple FoR (see e.g., Burgess, 2005; Gallistel, 2002). Is it really sensible to think that the lack of linguistic expressions to express a FoR means that the underlying representations are not sufficiently exercised, practiced, or used? Given the extant data, we are inclined to believe speakers of different languages encode spatial scenes in much the same way, relying on the same cognitive hardware and processes, with task structure, rather than habitual language use, determining which system is easier to use in any given context.

References


Cottereau-Reiss, P. (1999). L’espace kanak, ou comment ne pas perdre son Latin [Kanak space, or how not to lose one’s Latin], Annales Fyssen 14: 34–45.


We present a system of linguistic representation residing in a spatial situation type ontology, which provides a reference point for language comparison, independently of the particular strategies employed in the grammars. We illustrate the design with constructions expressing direction and location in Germanic and Kwa languages. In our analysis we highlight the extensive use of multiverb expressions in the latter versus single-verb-headed constructions in the former, expressing the same types of content. The overall design spans three levels, viz., a spatial type ontology, a formal (large scale computational) grammar, both formalized in terms of a typed feature system employed in constraint based grammars (cf. Pollard and Sag 1994, Copestake 2002), and a format of online corpus annotation and databasing of natural language hosted in TypeCraft (Beermann and Mihaylov 2014), where morpho-syntactic information is made accessible and interpretable at multiple analytic levels, from data-mining to formal analysis.

![Figure 1. A type hierarchy related to arguments of prepositions.](image)

The content of our analysis reflects traditions of cognitive semantics as represented, e.g., in Talmy 2000, Jackendoff 1990, Pustejovsky 1993; see especially Davis 2000, and Trujillo 1995 for approaches similar to the present in this respect. Following Jackendoff 1996, we assume a basic distinction between prepositions residing in whether their arguments represent one-dimensional entities or not. We refer to one-dimensional entities as line items, as opposed to xdim items (subsuming both “individuals” and “events”). The distinction applies to both the spatial and the
temporal domain, and the following diagram indicates some of the types in the spatial domain, the branches under oriented object representing a verb argument or “external” argument of preposition representing a “path” role (a “Figure”), and those under spatial-entity typical roles of the governee of a preposition (a “Ground”):

In the domain of locative relations, features include (cf., e.g. Trujillo 1995):

<table>
<thead>
<tr>
<th>Topological features</th>
<th>Definitions:</th>
</tr>
</thead>
<tbody>
<tr>
<td>FRONT</td>
<td>FIG is in front of GRND</td>
</tr>
<tr>
<td>BACK</td>
<td>FIG is behind GRND</td>
</tr>
<tr>
<td>EMBEDDED</td>
<td>FIG is embedded in GRND</td>
</tr>
<tr>
<td>CONTAINED</td>
<td>FIG is contained in GRND</td>
</tr>
<tr>
<td>SCALAR</td>
<td>Relation between FIG and GRND can be quantified</td>
</tr>
<tr>
<td>TRANSITIVE</td>
<td>If R(A,B) and R(B,C), then R(A,C)</td>
</tr>
<tr>
<td>UPSIDE-OF</td>
<td>FIG is upside in a vertical relation to GRND</td>
</tr>
<tr>
<td>DOWNSIDE-OF</td>
<td>FIG is downside in a vertical relation to GRND</td>
</tr>
<tr>
<td>INTEGRATED</td>
<td>FIG is integrated into GRND</td>
</tr>
</tbody>
</table>

These are all features that may be assumed to have significant cross-linguistic relevance. It is well known that they can in principle be carried not only by prepositions, but also by nouns and by verbs, and in languages where there are no prepositions, we may expect transitive verbs of roughly the same type as reach or pass to function in similar ways as prepositions do in English. In the following example from Akan, we see these patterns illustrated, with a relational noun mu (“inside”) in a function similar to that of a postposition, representable as “CONTAINED + TRANSITIVE +”:

(2) John tuu ɔboɔ no faa ntokura no mu. (“John threw the stone through the window”)

<table>
<thead>
<tr>
<th>John tu-u ɔ-boɔ no fa-a ntokura no mu.</th>
</tr>
</thead>
<tbody>
<tr>
<td>John throw-PST SG-stone DEF pass-PST window DEF inside</td>
</tr>
<tr>
<td>N V1 N DET V2 N DET N</td>
</tr>
</tbody>
</table>

The V2 in the Serial Verb Construction would translate as a preposition in English; its status as a verb in Akan is demonstrated, for instance, by its tense marking. In terms of ROLE features as represented in Figure1, the V2 would be encoded as having “the stone” as a locomotor item, and “the window” as viapnt.

Within the formal model in question, the semantic analysis will involve two levels, one where the semantic features of the word units are represented relative to the words as such, and one where they are pooled onto a more abstract level of representation – “Situation Structure” - where, e.g., the sentence in (2) and its English translation will have the same representation. While formally well defined, the aspiration of such a level to serve as an “interlingua” of course faces well-known challenges relating to such a construct; however, the domain of spatial reference is restricted and well enough understood to be modeled by such a design.
References


Spatial Reference: Studying the Interplay of Language, Culture and the Environment

JÜRGEN BOHNEMEYER
Department of Linguistics
University at Buffalo
Email: jb77@buffalo.edu

Introduction—Recent advances in the availability of affordable computational power have made it possible to subject large-scale crosslinguistic and crosscultural data samples to sophisticated statistical analyses that can isolate the effects of language, culture, and the environment in spatial cognition. The use of spatial reference frames in discourse and nonlinguistic cognition offers an ideal test case for such studies.

Background—One of the oldest and most persistent questions in the history of science is that of nature vs. nurture, or the respective role of genetics and personal experience in shaping the individual’s behavior. The latter in turn presumably reflects influences of the environment, some of which may be mediated by culture. Two widespread assumptions in the cognitive sciences (especially artificial intelligence, psychology, and linguistics) are, first, that the study of the mind should focus on those aspects of cognition that are determined by nature, i.e., are innate, and secondly, that variation in cognitive traits across human populations largely responds to environmental and cultural factors and therefore falls outside the study of “cognition proper.” As a result, comparatively little empirical research into population-specific cognitive traits has been conducted. More specifically, we know a great deal about certain pieces of the larger puzzle of the role of biology, culture, and the environment in human cognition. But these pieces have been studied in isolation, and no studies have been carried out that examine the interaction of all of them. In addition, much of this research has proceeded qualitatively, arguing for example for effects of physiography on dialect differentiation on the basis of the pronunciation of individual words and sounds, rather than quantitatively.

Recently, two collaborative projects under my direction, funded by the National Science Foundation (NSF awards BCS-0723694 and BCS-1053123) and collectively known under the acronym MesoSpace, have been investigating for the first time how a single aspect of cognition—the use of spatial reference frames (Carlson Radvansky & Irwin 1992; Gallistel 1990; Levelt 1990; Levinson 1996)—is shaped by language, literacy, education, and two environmental variables, topography and population density. The research of the MesoSpace team for the first time presents a fine-grained picture of how these variables interact in influencing human behavior. The results point to a far more powerful role of culture in the mind than most cognitive scientists have assumed.

Spatial reference frame use as a cognitive anthropology laboratory—What makes reference frames so suitable for studying the interplay of biology, culture, and the environment in cognition is a combination of four properties: (i) they are indispensable in identifying
nontopological regions of space and thus can be assumed to be evolutionarily ancient and to have a biological basis (Gallistel 1990); (ii) yet, there is considerable variation across human populations in the types of frames customarily used for reference at the small scale; (iii) a given population’s linguistic preferences fairly narrowly predict its preferences in nonverbal tasks, including in inferences and memory (Pederson et al 1998; Levinson 2003; Mishra et al 2003; Majid et al 2004; Haun et al 2011; Le Guen 2011; Bohnemeyer et al 2014); and (iv) geocentric frames are sensitive to the environment in that their axes are defined with respect to landmarks or gradients of the environment (with varying levels of abstraction; Wassman & Dasen 1998; Levinson 2003; Polian & Bohnemeyer 2011; Bohnemeyer & O’Meara 2012; Palmer 2015). It was in the context of research probing the covariation between frame selection in discourse and nonverbal cognition (property (iii)) that the question of the factors driving frame use across populations first came up. Pederson et al (1998) hypothesized that this covariation was the result of different languages influencing the nonverbal cognition of their speakers in different ways—a language-on-thought effect in line with the Linguistic Relativity Hypothesis (Whorf 1957). In contrast, Li & Gleitman (2002) argued that the alignment between frame use in language and nonverbal cognition was epiphenomenal: participants’ behavior in both types of tasks was driven by the same set of nonlinguistic variables, including education and literacy, but also topography and population density.

The MesoSpace studies—Bohnemeyer et al (2014, 2015, under revision) investigate how speakers of eight indigenous languages of Mexico and Nicaragua and L1-speakers of the dominant contact language, Spanish, in Mexico, Nicaragua, and Spain talk about and memorize the location and orientation of objects in space. These studies have for the first time demonstrated quantitatively the impact of topography and population density on frame use. The statistical models employed by the group (mixed effects logistic regression models) also showed that the role of the first language cannot be reduced to any combination of the other factors. Furthermore, the indigenous participants proved to be more likely to use the “relative” subtype of egocentric frames (Levinson 1996) in their native languages the more frequently they use Spanish as a second language. This points to Spanish serving as a conduit for the diffusion of egocentrism in the area.

In unpublished work, the MesoSpace team has extended this investigation to a population sample that includes speakers of English, Vietnamese, and two Mesoamerican languages (Isthmus Zapotec and Yucatec Maya), as well as members of two Taiwanese populations (monolingual Mandarin speakers and Mandarin-Taiwanese bilinguals) and four Japanese populations (rural vs. urban speakers from Honshu vs. Okinawa). This is the largest and most diverse study of the use of reference frames in language to date. Preliminary results confirm the non-epiphenomenal role of language. The linguistic study also showed effects of literacy and population density, while the recall memory study showed in addition to language topography as a significant factor, but this apparent effect is at present still being probed.
Evidence of a pan-simian geocentrism bias and the rise of the small scale—Several of the MesoSpace studies produced evidence of a cognitive geocentrism bias in populations that show no clear preference in linguistic tasks. This surprising finding is consistent with the hypothesis of an innate pan-simian geocentrism bias that can be reshaped through the effect of language and other observable cultural practices (Haun et al. 2006). In the context of the other MesoSpace findings, a possible scenario for the cultural evolution of egocentrism emerges. According to this scenario, egocentrism has been culturally “selected for” by an ever-expanding importance of control of the small scale in human behavior with the advent of tool use, manufactured walled-off spaces, and eventually manufactured visual representations, especially writing. Observable cultural practices such as speech, gesture, and writing serve as transmission systems that allow the members of a community to converge on the non-innate practice of egocentric frame use.

Selected references


Reference Frames as Mechanisms for Mapping Language onto Space

LAURA CARLSON
Department of Psychology
Vice President, Associate Provost, and
Dean of the Graduate School
University of Notre Dame
Email: lcarlson@nd.edu

JENNIFER KOLESARI
Department of Psychology
University of Notre Dame
Email: jkolesar@nd.edu

Reference frames are considered mechanisms for mapping language onto space (Carlson, 1999; Landau & Jackendoff, 1993; Levelt, 1984; Levinson, 1996, Logan, 1995). A typical mapping example involves a spatial description of a perceptual event. For an example from Carlson (2003), imagine a speaker telling a listener who is holding a coffee pot: (1) “The coffee mug is below the coffee pot.” Each of these objects plays a distinct role in this spatial description. The coffee pot serves as a reference object, acting as a landmark from which to describe the location of the coffee mug, also known as the located object. The spatial description thus assists the listener in finding the located object by reducing the area that needs to be searched to the space around the reference object. This space is demarcated through the application of a reference frame, a family of representations (Shelton & McNamara, 2001) that are instantiated through a set of parameters that apply the representation to a particular perceptual event (Logan & Sadler, 1996). A reference frame is typically thought of as consisting of a set of coordinate orthogonal axes whose intersection point is called the origin. The origin is imposed upon the reference object and defines the surrounding space through the orientation and direction parameters. Orientation specifies whether a given axis is horizontal (front/back or left/right) or vertical; direction specifies the endpoint of a given axis (for example, left vs. right). These axes also have a scale that indicates the units of distance applied to the space. Finally, a spatial template further parses the space around the reference object into regions for which the spatial terms offers a god, acceptable or unacceptable characterization of the located object’s placement (Carlson, Regier & Covey, 2003; Carlson-Radvansky & Logan, 1997; Logan & Sadler, 1996).

Most of the research on setting the parameters of a reference frame has been done with English speakers. Below, I discuss the factors that impact these parameters, and address the possibility of cross-linguistic variation.

**Origin.** Previous research has shown that the identity of the located object, the reference object and the functional interaction between the objects play a role in defining the origin—that is, where the reference frame gets placed within the reference object (Carlson-Radvansky et al., 1999; Carlson & Kenny, 2003). For example, in a neutral context in which the speaker in (1) is drawing the listener’s attention to the mug as a souvenir from a trip, its relationship to the coffee pot is not emphasized, and the located object is assumed to be geometrically below the center of
mass of the coffee pot itself. However, in the context of a speaker making an indirect request of the listener to pour a cup of coffee (Clark, 1996), the ideal location of the coffee mug is not in fact under the pot at all, but under the spout, off to the side. Thus, the role of the objects and their interaction may play a critical function in defining the origin. Coventry, Prat-Sala & Richards (2001) (see also Carlson, 2000) have shown that the strength of this functional influence may vary across types of spatial term (for example, over vs. above). This within language variation suggests the possibility of cross-language variation in the relative strength of geometric and functional information.

Orientation and Direction. Orientation and direction together assign directions to space around a reference object. Different sources of information can be used to set these parameters, resulting in different types of reference frames. For example, Levinson (1996) proposes that the features in the environment define the absolute reference frame, the speaker or listener defines the relative reference frame, and the reference object defines the intrinsic reference frame. Often times, these sources of information are in conflict, resulting in different mappings for a given spatial term. Some work from my lab shows that for English speakers initially all reference frame mappings are considered, followed by an inhibition of the non-selected reference frame (Carlson-Radvansky & Jiang, 1998). Looking at the locus of this inhibition, it appears that particular preferred axes are always inhibited, and less-preferred axes inhibited only selectively (Carlson & van Deman, 2008). Because cross-linguistically there are different preferences for using different types of reference frames (Levinson, 2003), this suggests that locus of inhibition and the manner in which a reference frame is selected, and more particularly, the locus of inhibition, may differ cross-linguistically.

In addition, there is evidence that orientation and direction are separate representations. For example, Logan (1995, 1996) observed savings in response time in a spatial cueing task in which participants could respond on the basis of orientation, with additional time needed when direction had to be further specified. Relatedly, Hoffman et al. (2003) observed impairments in patients with Williams Syndrome in a placement task, such that errors were more likely to occur at the wrong endpoint of the correct axis, rather than at a random location, indicating some preservation of axial structure without a further refinement by endpoint. These findings have important cross-linguistic implications, particularly for languages that do not explicitly demarcate left vs. right, but rather use the more general “side”. For these speakers, it may be possible that the endpoints remain unspecified until needed.

Scale and Spatial Templates. The scale and spatial extent of the region that is demarcated by a spatial term has been woefully under-studied, both within a given language and across languages. Morrow and Clark (1988) observed that the size of the located and reference objects significantly impacted the distance that was inferred between them for spatial descriptions containing the verb “approach.” Carlson and Covey (2005) built on these findings and demonstrated that English speakers were influenced by the properties of the objects in inferring
their distance for topological (e.g., “near”) and projective (e.g., “left”) spatial terms. Importantly, the spatial term also influenced distance estimates. To the extent that terms are associated with different distances cross-linguistically, one may thus expect to see variation in the spatial extent and scale of these regions (for example, see Regier & Carlson, 2002).  

References  
Coventry, K., Prat-Sala, M., & Richards, L. (2001). The interplay between geometry and function in the comprehension of over, under, above and below. Journal of Memory and Language 44: 376–398.  
How flexible are spatial reference frames? Do individuals within a culture shift their spatial referencing in response to different environmental contexts? Are cultural differences in spatial referencing adaptive responses to local navigational challenges?

We are newcomers to this field, but our impression is that the emphasis has been on the constraining role of language in shaping spatial referencing. However, spatial frames of reference affect navigation, and navigation is frequently a matter of life (resources from travel) and death (costs and risks associated with travel). We should have evolved to get it right. Within some constraints of language, therefore, we might expect individuals to use the one most suitable for the problem at hand.

If different frames of reference are adaptive in different environmental contexts, spatial referencing should respond flexibly in response to those environmental contexts. For example, some interesting work has shown how people in areas of sharp topographic relief use those topographic cues in spatial referencing. More generally, geocentric (absolute) frames of reference facilitate a survey knowledge of the environment, and should be adaptive in areas where appropriate cues (distal landmarks, celestial markers) exist and individuals frequently traverse large ranges with unpredictable routes. Viewpoint-centered (relative) frames of reference should be most adaptive where distinctive proximal landmarks are available and individuals frequently travel along established routes.

Whether this adaptive flexibility explains existing variation in spatial referencing is an empirical question, and we are not in a position to answer it. But as human evolutionary ecologists, our bias is to look in that direction for an answer.

We began this in Tonga, where we elicited spatial frames of reference with an “animals in a row” test (our version assessed absolute and relative but not intrinsic reference frames). Tongan has native terms for left and right as well as for cardinal directions. We wanted to see whether there were individual differences in reference frames that reflected differences in mobility experience and local context, as well as navigational accuracy. Local context clearly matters: We chose different conditions for testing, and all the people who were tested outdoors and did the task on the ground used an absolute frame of reference, the same was true for most (85%) of the people who were tested outdoors but did the task on a table, whereas those who were tested indoors in a rectangular meeting room were split about evenly in their responses: 56% (n = 35) answered as Westerners would, using a relative reference frame, while the rest (n = 27) answered as the outdoor Tongans did, using an absolute reference frame. Tongans differ in their English language competence (from none to fluent), but this did not seem to explain the variation
among people tested indoors. We do not yet know whether the variation reflects functional differences in peoples’ navigational experience, but we will have an answer by December.

We hope to explore these issues further in our other field sites, beginning with the Tsimane, forager-horticulturalists in Bolivia. In the tropical forest habitat of the more remote Tsimane villages, geocentric cues (sun position and distal landmarks) are often obscured due to heavy canopy and cloud cover. Previous findings suggest that these are cues men tend to favor where they are available, which may be why we see no sex difference in navigational ability in this population. We may find that this also affects spatial referencing, perhaps placing a premium on relative frames of reference in the inter-riverine villages, while villages along the rivers take advantage of the rivers themselves as a reference frame. Navigational differences are also found in villages near the market town, where the environment is more open due to felled trees, travel takes place along roads, and Tsimane have greater Spanish fluency and access to formal education. We plan to return to the field in October 2016 to investigate differences among these villages in both navigation and spatial reference frames.
Medical education imposes a specific universal international vocabulary to describe anatomical structures, positions, and relationships upon the students. This vocabulary is consistent with the Terminologia Anatomica: International Anatomical Terminology and establishes a common, consistent language among medical professionals regardless of the individual’s country of origin or native language (Whitmore, 1999). This terminology is rooted in the Latin and Greek languages. Very rarely do students enter medical school with a background in these languages. Those that do typically have only had a basic medical terminology course, which is not a requirement for matriculation into medical school. Other courses in which they would be exposed to medical terminology – anatomy, histology, physiology, and neuroscience—also are not prerequisites to entering medical school. As a result, students are required to learn a new language for orienting the structures of the body in space while concurrently attempting to learn the clinically-relevant material necessary to be a competent physician.

This anatomical referencing system is based on a standardized orientation of the body—the anatomical position—in which a person is standing with their arms at their sides, palms facing forward, and toes facing forward. The terminology used to describe the spatial orientation of anatomical structures includes both relative and absolute terms. For example, a structure that is located above another structure can be described as either superior or more cranial. Superior would then be a relative term; while cranial would be considered an absolute term.

The extent to which students think about the spatial organization of the body in anatomical terminology versus their respective native languages is expected to vary significantly. One question of interest then is: What factors determine how quickly, effectively, and efficiently students adopt anatomical terminology and incorporate them into their schemas? Several potential factors include: (1) students’ familiarity with the language; (2) students’ level of experience; (3) students’ measured spatial ability; and (4) students’ enrollment in an osteopathic versus allopathic medical program.

Familiarity with Language
An individual’s native language could play a role in how well they are able to assimilate spatial anatomical terminology into their schemas. Those whose native language is most similar to Latin and Greek may have an easier time learning anatomical terminology. Those whose native language is vastly different from Latin or Greek might struggle to incorporate anatomical terminology into their schema. Instead, they might use their own language as the main reference frame, with the anatomical spatial language simply added on. This could be seen as someone redefining the word “medial” as “close to the middle.”
Novice vs Expert
Those students who have taken prior elective coursework that emphasizes Latin or Greek languages may be more adept at navigating anatomical terminology. Those who have taken prior courses in the anatomic disciplines—anatomy, histology, neuroscience, and embryology—may also have an advantage compared to novice learners who might be expected to rely on memorization of terms or the use of mnemonics in order to assimilate the new spatial terminology. Additionally, as students progress through their medical education from pre-clinical to resident to experienced physician, they encounter more complex examples of spatial anatomical relationships through clinical cases, patient interactions, and imaging studies (i.e., MRI, CT, ultrasound). Through these experiences it is assumed that they implicitly build upon their schema and more effectively incorporate anatomical terminology into that schema.

Spatial Ability
Those who score high on standardized assessments of spatial ability may be able to utilize new spatial terminology more effectively than those whose scores are low. A study investigating the differences between first-year medical students’ mental models found that students who scored high on the Purdue Visualization of Rotations Test consistently used more spatial anatomical terminology in their explanations than those students who scored low on the same test (Chatterjee, 2011). Replication of these results with additional spatial tests would provide further evidence that spatial ability is directly related to effective and efficient use of new spatial language.

Osteopathic vs Allopathic
Students attending osteopathic medical schools (schools granting a DO degree) might be able to apply anatomical terminology faster than those attending allopathic medical schools (schools granting an MD degree). Students at osteopathic medical schools receive additional hands-on training in osteopathic manual/manipulative medicine. This training reinforces understanding of the spatial relationships of anatomical structures. This kinaesthetic approach may lead to more robust schema that incorporate anatomical terminology.

These factors are not likely to occur in isolation of each other. Different combinations of these factors might account for individual differences in students’ abilities to incorporate anatomical terminology in their understanding of anatomical spatial relationships.

The focus of this narrative was specifically on anatomical spatial referencing as opposed to clinical terminology in general. Although Terminologica Anatomica is considered a universal vocabulary, it is not static. Over time there have been changes and updates to accommodate new discoveries, common trends, and simplification. For example, a nerve in the lower extremity was previously known as the common peroneal nerve. This has recently been renamed the common fibular nerve to indicate its spatial location on the fibular/lateral side of the lower extremity. This can complicate communication between those who learned the old terms and those who have learned the new terms. Additionally, Terminologica Anatomica does not include all clinical terminology. Clinical terminology includes many eponyms, in which the name of a structure is derived from the name of a person. These terms are much less intuitive and do not follow a
systematic naming convention, as such it is less likely that clinical terminology has spatial applications.

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One topic that interests me as a linguist is the interaction between the content of general concepts and deviations from that content that arise in particular contexts. A simple example would be the meaning and use of the prefix *kilo-*-, namely 1000. However, a *kilobyte* is not 1000 bytes, but rather 1024 bytes. In this case the usage is conventionalized (*kilobyte* cannot mean 1000 bytes), as well as having an obvious motivation, namely the fact that bytes are counted as powers of 2 ($1024 = 2^{10}$, which is moreover the power of 10 closest to 1000). An example closer to the thrust of this paper is the identification of hot and cold faucets. The surest way of identifying each faucet is to run the water and test its temperature. In addition, each faucet may be identified by the word “hot” or “cold,” or an abbreviation thereof, or an icon such as red color for hot and blue color for cold—these thus stand for the result of applying the direct temperature test. In addition, many cultures have a convention for arranging the two faucets, e.g., in the U.S. the hot tap to the left, the cold tap to the right. Someone accustomed to this arrangement may well take left position to indicate hot, right position to indicate cold, even in the absence of any explicit indication on the faucet, indeed even contrary to such indication. Left-right position thus “hijacks” conceptually the actual temperature of a faucet—until, of course, one feels the water.

With respect to space, a fair amount of attention has been paid recently to shifts between different frames of reference in shifting between different tasks, as witnessed by several contributions to this special meeting. My own interest is somewhat different, concerning as it does shifts in the orientation of an individual frame of reference in shifting between different tasks. While I have presented this phenomenon to an audience of linguists (Comrie 2003), and to a broader audience in a 3-minute talk under the auspices of the UCSB Center for Spatial Studies, I would welcome feedback from and discussion with a broader spectrum of specialists from different disciplines with an interest in spatial reference systems. Both examples cited here come from my own experience. Although they have been confirmed anecdotally by others, suggestions for more systematic investigation are welcomed.

The first concerns left-right orientation. In general, I do not have problems with “left” versus “right,” and can orient myself systematically and correctly when given directions in these terms. It was therefore somewhat disconcerting, when I moved from the UK to the US, to find that I would often confuse the two directions when receiving instructions while driving, turning to the right when told to turn to the left and vice versa. I did not experience the problem in contexts other than driving, nor had I experienced similar problems when driving in the U.K. A moment’s
thought revealed why the problem had arisen, although unfortunately it did not provide a solution.

In the UK, traffic drives on the left-hand side. This means that a left-hand turn is (other things equal) easier than a right-hand turn, since the latter comprises all the factors involved in the former plus the additional factor that one is driving across the line of oncoming traffic. In the U.K., therefore, a left-hand turn is an “easy” turn, while a right-hand turn is a “difficult” turn. This provides a mechanism for the concepts “easy turn” and “difficult turn” to hijack the content of the terms “left” and “right” respectively when driving. The change from “left/right” to “easy/difficult turn” makes no practical difference in a context such as the U.K. where traffic drives on the left, indeed it had never occurred to me that I had made the change. However, in the context of the U.S., where traffic drives on the right, the change has the predictable outcome, namely confusion of left with right and vice versa—but only in the context of driving. Indeed, mixed contexts, e.g. describing the interacting behavior of a vehicle and pedestrians, can lead to recognition of the conflict, a perceived contradiction. Recognition of the conflict does not, however, necessarily provide a practical solution. The shift from “left/right” to “easy/difficult turn” is so powerful that, even though I have not driven in the U.K. or any other country that drives on the left for more than a decade, I still have to concentrate, when driving, on instructions that involve “left” and “right” if I am not to veer off in the wrong direction.

The second example concerns the cardinal directions. Although I do not regularly update myself on the cardinal directions of my environment, I have no problem in principle with the concepts involved and can orient myself successfully, for instance, in a grid system that is oriented to the cardinal directions. When I moved to Los Angeles I was therefore surprised to find that I systematically confused the cardinal directions, more specifically confusing “south” with “north” and “east” with “west”. I had never experienced this problem in my home region around the city of Sunderland on England’s North Sea coast, nor before or since in most other places where I have lived for an extended period at various periods of my life: Schondorf (southern Germany), Cambridge (England), Moscow (Russia), Aradip (highland Papua New Guinea), Leipzig (Germany), Tokyo (Japan).

My home region is located on a coastline that runs north-south, with the sea to the east. This thus provides a fertile base for the sea to hijack the cardinal directions—“east” is towards the sea, “west” away from the sea, “north” to the left as one faces the sea, and “south” to the right as one faces the sea. All of this works perfectly on an east coast. But on a west coast, as in California, it systematically gives the wrong results. Interestingly, in places that are far enough from the sea, or that do not obviously orient themselves to the sea, such as the other places listed above, the problem does not arise—there is no sea to cause confusion, just as when not driving there is nothing to hijack the usual interpretations of “left” and “right.” And in Santa Barbara, where the freeway runs west-east but is said to run north-south, I just have to concentrate, welcoming the habitual use of explicit single directions such as to the north, towards the mountains. These observations, though surely valid, require more general investigation, more explicit grounding, and more rigorous testing.
Reference

Spatial language is part of a broader ecology. How we talk about space is woven in with how we gesture and reason; with the natural and built worlds we inhabit; with our cultural conventions and practices; with the myths we tell and metaphors we live by. My interest is in understanding these rich ecologies—in identifying the invisible threads connecting spatial language to everyday behavior and everyday thinking. Investigating these ecologies will ultimately help us answer a big, two-part question: What are the *causes* of the diversity we see in spatial language across speech communities, and what are the *consequences* of such diversity? But we shouldn’t get ahead of ourselves. Before we can sort out cause and consequence, we need a better understanding of the *concomitants* of linguistic diversity: those aspects of everyday behavior and thought that go hand in hand with cross-linguistic differences in spatial language.

Spatial gestures

One concomitant of spatial language that remains to be fully understood is spatial gesture. Spatial representations evident in gesture sometimes overlap with—but other times depart from—those evident in language (for discussion, see Cooperrider & Goldin-Meadow, 2016). A major reason for this departure is that gesture has representational obligations that language does not. When we describe a recently observed event in words (e.g., “The child ran inside”), we do not have to specify a perspective on the event or a frame of reference (FoR). But when we gesture about the same event, there’s no getting around it: gestures unfold in space and thus specify a perspective and an FoR *obligatorily*. This fact raises a number of tantalizing questions for researchers interested in cross-linguistic diversity. For example, will speakers show a reliable FoR preference in gesture even when not using overt FoR language? One of my fieldwork projects addresses this issue by examining the gestures that bilingual speakers of Juchitán Zapotec and Spanish produce when describing simple, table-top motion events. My collaborators and I ask two questions: (1) Do such gestures reliably reflect a preferred FoR, even though they are rarely accompanied by FoR language? (2) If so, what factors predict the FoR used? The project also examines how the same speakers perform on a variant of the “Animals in a Row” task (Marghetis, McComsey, & Cooperrider, 2014), allowing us to compare the FoR preferences revealed by motion gestures with those revealed by a classic memory paradigm. Ultimately, this work will help us better understand the ecology of spatial language in Juchitán. Is it spatial language *per se* that drives people to gesture and reason in different ways? Or are differences in gesture, memory, and language all driven by some other factor?
Spatial concepts for abstract thinking

Another dimly understood concomitant of spatial language is abstract thinking. The canonical use of spatial language is, of course, to communicate about the concrete—for example, to describe the location and movement of people and objects. But spatial concepts are also pressed into service much more broadly, for construing non-canonical spatial settings and for structuring purely abstract concepts. But which spatial schemas do we call on for these more abstract purposes, and why? An emerging hypothesis is that communities will favor the same concepts for abstract thinking that they favor for concrete spatial reference. Exploring this possibility is one of the primary aims of my other fieldwork project, in the Yupno valley of Papua New Guinea. In Yupno, as in many languages in the interior of New Guinea, *uphill-downhill* contrasts run throughout the core grammar, cropping up in demonstratives, in basic motion verbs, and beyond. Using a variant of the “Man and Tree” task, my collaborators and I have investigated how uphill-downhill concepts are deployed for describing location and orientation outdoors, amid the rugged terrain of the valley. But we have also used the same methods to investigate how the system is used indoors, within the flat-floored Yupno house. Though the houses lack slopes of their own or views of the slopes outside, speakers nonetheless press uphill-downhill contrasts into service, projecting a set of conceptual “slopes” onto the house’s interior (Cooperrider, Slotta, & Núñez, 2016). This is an example of a perhaps widespread phenomenon in which speakers parse objects and settings by projecting their most familiar spatial schemas onto them.

Another line of my work has focused on how people use spatial concepts to think about time, a famously ethereal and ineffable dimension of experience. English speakers conceptualize the past, present, and future through egocentric spatial schemas (Walker & Cooperrider, 2016), but these patterns are not universal. Yupno speakers draw instead on their trusty uphill-downhill concepts, with the future conceptualized as uphill and the past as downhill (Núñez, Cooperrider, Doan, & Wassmann, 2012). In both English and Yupno, these patterns of temporal thinking can be glimpsed in certain linguistics expressions—but, interestingly, they are seen especially vividly in *gesture*. Here again, of course, cause and consequence are tricky to sort out. Do people around the world think about time a certain way because of how they think about space? Or do both habits of thought spring from some other, hidden source?

Outlook

Some of the biggest questions that remain for the cross-linguistic study of spatial language are not about language *per se*. Rather, they are about why we see the diversity that we do and about how this diversity shapes the life and mind of speakers. As we puzzle over these questions in the coming years, a promising tack is to focus on *ecologies of spatial language*, on how spatial reference is interwoven with communication, culture, and cognition. Like other researchers in the field, I suspect that spatial language is a powerful player in these ecologies—a *keystone species*, if you like. But this remains to be demonstrated.
References


Finding the Universal in and around Variation

Michele I. Feist
Department of English
University of Louisiana at Lafayette
Email: feist@louisiana.edu

Across a sample of languages, in and on (and their equivalents) are amongst the earliest words that a child will begin to produce (Johnston & Slobin 1979; Slobin 1982). This early use suggests the salience of containment and support relations as a potential cognitive universal (cf., Piaget & Inhelder 1967), a suggestion that may be further strengthened amongst Western researchers by the natural coherence that they, like other native speakers, tend to attribute to the spatial concepts encoded in their languages. However, a closer look at the semantics of spatial relational terms across languages raises two problems with this interpretation. First, containment and support relations, as encoded in the English words in and on, do not emerge as coherent named concepts across a broader sample of languages (Bowerman & Choi 2001; Levinson & Meira 2003). Second, there is wide variation in the range of spatial relational situations that may be described by translation equivalents of in and on (Bowerman & Choi 2001; Feist 2008, 2013; Gentner & Bowerman 2009; Zhang, Segalowitz, & Gatbonton 2011; inter alia), suggesting that what “counts as” containment or support differs substantially from language to language.

The existence of languages that do not encode a distinction between containment and support in their spatial relational terms has long been noted. As a case in point, the Korean distinction between tight and loose fit crosscuts the containment/support distinction, categorizing both a Lego on a Lego stack and a cassette in a cassette case as examples of tight fit (Bowerman & Choi 2001). The coherence of support as a universally salient concept has been similarly contradicted by cross-linguistic evidence. Across their sample of nine unrelated languages, Levinson and Meira (2003) found evidence for a small set of universal conceptual “attractors” – but support relations were split across two of the attractors, with relations involving small, movable figure objects supported by relatively low ground objects (such as a cup on a table) clustering with a different set of scenes from the scenes clustered with relations involving larger, more elevated figures (such as a tree on top of a hill). These results suggest that there is not a unitary support concept that is cross-linguistically valid.

Finally, close examination of the uses of spatial language in English and Mandarin reveals that the details of the concepts of containment and support themselves may likewise vary across cultures (Feist & Zhang 2016). Like English, Mandarin encodes a contrast between terms encoding containment and terms encoding support. However, the uses of this set of terms differ from the uses of related English spatial terms, particularly with respect to the categorization of part-whole relations and of figures which are partially embedded in a ground (Zhang et al. 2011). Indeed, looking at descriptions of 71 pictures in the two languages for which there was high within-language agreement on the applicable spatial term, Zhang and her colleagues (2011)
found that 20% were categorized differently by the two languages, suggesting that the contrasts encoded in the languages, while related, are drawing upon different conceptual information regarding the nature of containment and support.

Along with the striking variation that has been noted in the meanings of spatial relational terms, there is compelling evidence that languages may overlay lexicalized distinctions upon a universal conceptual space. In addition to the universal “attractors” and the attendant conceptual space noted by Levinson and Meira (2003), Feist (2008) found that spatial descriptions across 24 languages could be fit to a two-dimensional similarity space structured by the ground’s ability to control the location of the figure and by the relative vertical positions of the two objects, suggesting that languages may encode distinctions along dimensions that are universally salient. Taken together, these findings point to a set of broad universal constraints on the conceptual distinctions encoded in spatial language.

Comparison of the evidence of cross-linguistic variation and the suggestion of conceptual universals highlights a gap in our knowledge about spatial reference. Whereas fine-grained studies of the semantics of individual spatial relational terms has revealed much about cross-linguistic variation in the encoding of meaning, more coarse-grained studies of the conceptual space suggest constraints on that variation. To truly understand the nature of both the variation and the constraints, it is important to understand how the constraints function within the spatial reference systems of individual languages, hence bringing together the strengths and insights from both lines of research.

One universal of human experience is the need to note, remember, and communicate about the locations of objects in the environment. One of the most compelling observations about spatial language is that there is a stark contrast between the native speaker’s intuition that the categories encoded in their language are conceptually basic (and, hence, potentially universal), and the prodigious cross-linguistic variation in the mapping of words to spatial situations. One of the most interesting challenges for us is to understand why.

References


The basic hypothesis of the present study is that the form of an expression describing an event in relationship to space depends on (1) whether the grammatical system of a given language has a functional domain, conventionally called “altri-locative point of view” that encodes movement or position in relationship to a place other than the deictic center, which is often, but not necessarily, the place of speech; and (2) whether the grammatical system has a functional domain that encodes movement in relationship to the deictic center, conventionally called “directionality from the point of view of deictic center,” “directionality” for the sake of brevity.

Some languages code only altri-locative point of view (1), some languages code only directionality (2), some languages code both (1) and (2), and there are languages that do not code either. The description of a physically identical event, such as “movement from X to Y,” thus has different forms across languages, depending on whether the language codes locative predication, directional predication, both, or neither. The present study demonstrates the importance of the existence of functional domain only with respect to altri-locative point of view.

Languages differ with respect to how they represent “locative events,” i.e., events involving movement to or from a place and events or states occurring at a place. The differences observed raise the following questions:

**Question 1:** Why, within the same language, do some clauses coding locative events involve prepositions while others do not?

**Question 2:** Why, in expressing the same locative event, do some languages use prepositions while others do not, even if there are prepositions in the language?

**Question 3:** Why do some languages have the distinct lexical category “locative predicator” while others do not?

**Question 4:** Why do the syntactic properties of verbs that refer to the same activities, such as equivalents of “come,” “go,” “run,” “swim,” “jump,” differ significantly across languages?

**Question 5:** Why do prepositions involved in coding the same locative events differ significantly, across languages, in their semantic and syntactic properties?

The aim of the present study is to explain differences across languages that have the same lexical categories, particularly prepositions and postpositions, and that have lexical items referring to the same types of events or states. The foundation of the explanation is the discovery, described in Frajzyngier with Shay (2016) and Frajzyngier (in press), that some languages have the function “locative predication” encoded in their semantic structure while others do not, and that, in a language that has encoded the function of locative predication, the formal means used to code this predication are distinct from the formal means used to code all...
other predications in the language. As a consequence of encoding the function of locative predication, some verbs and nouns in the language are inherently locative and others are not. When the verb is inherently locative, no additional means are used to mark it as the locative predicate in a locative predication (all examples here are from Mina (Frajzyngier and Johnston with Edwards 2005), but similar phenomena have been observed in other languages; see Frajzyngier (in press)):

(1) yá i-bə̀ ndə̀ tə̀ b í ŋ
call PL-ASSC go 3PL.POSS room
“They went into their room.” (the verb ndə̀ is inherently locative)

When the predicate is not inherently locative, as is the verb yà “call,” the verb phrase must be followed by the predicator á to mark the locative predication:

(2) nd-á yà ngùl ngàn á biŋ
go-GO call husband 3SG PRED room
“And [she] called her husband into the room.”
(nd-á is a sequential marker and á is the locative predicator, not a preposition)

Note that the translations of (1) and (2) use the preposition “into,” evidence that the nature of the predicate plays no role in the coding of the locative expression in English.

If the complement of the locative predicate is inherently locative, i.e. if it refers to referents such as “house,” “room,” or “village,” it does not require a locative preposition in the locative predication (see examples (1) and (2)). If the complement is not inherently locative, it requires the locative preposition nə̀:

(3) hídì wà mə̀ nd-á-kù dèɓ nə̀ kítà
man DEM REL-beat-OBJ-1SG lead PREP justice (Fula)
“It was this person who hit me. Take him to be judged.” (lit. “take him to justice”)

Note that the English version requires a locative preposition regardless of whether or not the locative complement is inherently locative, as illustrated in the translations of examples (1–3).

The preposition nə̀ has only a locative function; it does not have a directional component, as evidenced by the fact that it can be used in clauses involving movement to a place (ex. (3)), movement from a place (ex. (4)), and in clauses involving the presence of an entity or the occurrence of an event at a place (ex. (5), where the place is represented by an inherently non-locative complement. Note that example (5) also contains the locative predicator á, since the main predicate of the clause, dáfà “exist,” is inherently non-locative. This example also shows that á is not a preposition:

(4) sèy ábà nd-á ngaŋ nə̀ yàm zá
so ASSC go-GO 3SG PREP water FACT
“Then, he came out of the water.”
The **existence of locative predications**, as distinct from other types of predication, has the following implications for the questions posed above:

1. Some nouns and verbs are inherently locative and others are not. No such distinction exists in languages that have not encoded locative predication (Question 4).
2. Within an individual language and across languages, prepositions are not used when the complement is inherently locative (Questions 1 and 2).
3. When the predicate is not inherently locative, a locative predicator is used in locative predications (Question 3).
4. There exist prepositions that have only the locative function, i.e. they do not code spatial relationships with respect to the complement. Spatial relations are coded by another set of markers (not illustrated for lack of space). In languages without locative predication, the locative function is fused with spatial relationships, as in English “in,” “out,” “from,” “to” (Question 5).

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Spatial Demonstratives in English and Japanese: Universal or Variation?

HARMEN B. GUDDE  
University of East Anglia  
Email: h.gudde@uea.ac.uk

KENNY R. COVENTRY  
University of East Anglia

Spatial language is crucial to almost every aspect of our lives, yet languages vary considerably in how they carve up space (Kemmerer & Tranel, 2000; Levinson, 2004). We used demonstratives as a vehicle to explore the relation between languages and spatial cognition. Although spatial demonstratives (this, that) are a small class of referential expressions, a growing body of research shows the important role they play in language. Demonstratives are present in every language and are among the most frequent words in languages (Diessel, 1999, 2006, 2014; Heine & Kutteva, 2002). Hitherto, little empirical research has been done to experimentally determine the function of spatial demonstratives. Early research found empirical evidence for a proximal/distal contrasting function of demonstratives (Coventry, Valdés, Castillo, & Guijarro-Fuentes, 2008), suggesting that this is used for referents in peri-personal (near) space and that for referents in extra-personal (far) space (cf. Clark & Sengul, 1978; Diessel, 2006; Talmy, 1983), in contrast to Peeters, Hagoort, and Ozyürek (2014). Building on this body of work, current research at the University of East Anglia is exploring how people use demonstratives, and whether they affect spatial memory. Specifically, using a memory game procedure, participants are asked to name objects, placed at various distances from them, using a demonstrative, for example “this/that black cross.” This allows us to test whether parameters that are encoded by demonstratives in other languages (e.g., distance, ownership (encoded in Supyire), visibility (West Greenlandic, Sinhala), familiarity (Yoruba), affect English demonstrative use (cf. Chandralal, 2010; Coventry, Griffiths, & Hamilton, 2014; Diessel, 1999). An adaptation of this procedure, can test the influence of object knowledge on memory for object location by analysing the memory error (the difference between the actual and memorized location).

Results showed that object knowledge affects demonstrative use and similarly influences memory for object location—even though the contrasts are not explicitly encoded in English. When participants owned, saw (during encoding), or knew an object, they were more likely to refer to the object with this than if they did not. Objects were also remembered to be closer by when they were owned, seen (during encoding), or known by the participant. In other words, referents that were preferentially referred to with this were remembered to be closer to the participant, relative to that. As such, Coventry et al. posited that memory for object location is a concatenation of the actual and the expected location of an object (the Expectation model), consistent with theories of predictive coding (Bar, 2009; Friston, 2003).

More recently, we have extended the limits of the Expectation model by investigating whether the mere use of demonstratives affects spatial memory (Gudde, Coventry, & Engelhardt, 2016). In this study, participants read out instructions for object placement (e.g., “Place
this/that/the [object] on the [location]”), followed by a spatial memory trial. By analysing the memory error, this study was able to tease apart different models predicting an influence of language on memory for object location. The Expectation model suggests that language elicits a prediction about the object location. The model therefore predicts a main effect of language on spatial memory, in which objects placed with that are misremembered to be further away than this, irrespective of the distance from the participant. In contrast, the Congruence model, based on the embodied cognition framework (Barsalou, 2008), assumes that an effect would be driven by an (in)congruence of language and space. A plethora of studies showed that when language is congruent with a spatial situation, participants’ responses are for example faster or more accurate (cf. Bonfiglioli, Finocchiaro, Gesierich, Rositani, & Vescovi, 2009; Stevens & Zhang, 2013). The congruence model predicts a similar interaction between language and distance in memory (Hommel, Musseler, Aschersleben, & Prinz, 2001). That is, congruent trials in which objects are placed close by with this or out of reach with that, should be remembered more accurately than incongruent trials (this for objects out of reach, that for objects within reach). In three experiments, results showed a main effect of language, but no interaction, supporting the Expectation model, and we found evidence that the effects were not driven by a difference in attention allocation.

However, in order to test whether there is a universal demonstrative system, other languages than English need to be tested. The most recent study tested Japanese vs. English (Gudde & Coventry, in preparation). Results showed that Japanese demonstratives encode distance from a speaker and the position of a hearer, and an effect of position was found in English as well. Furthermore, gender seemed to influence the weight of the parameters; men (both in Japanese and English) were more strongly influenced by an interlocutors’ position, women by distance. The fact that English demonstrative use is affected by position supports the notion that demonstrative systems are reliant on a universal set of underlying non-linguistic parameters, even though these parameters are not explicitly coded in all languages. However, explicit encoding, for example of position of an interlocutor, could lead to a slightly different weighting across languages as a function of the parameters that are explicit.

References


The Use of Informational References in Spatial Descriptions

STEPHEN C. HIRTLE
School of Informational Sciences
University of Pittsburgh
Email: hirtle@pitt.edu

One of the persistent difficulties in generating spatial descriptions comes from desire to create compact, efficient directions that are accurate, complete and accessible to the navigator. This can be particularly difficult when there are different cultural and linguistic norms, even within the same general geographical area. In previous research, we examined this issue by documenting cases where published directions are flagged as being “tricky” due to inherent navigational difficulties[1]. The potential confusions could be a result of a number of reasons, including an unusual geometry of the space, inconsistent labels assigned to roads and surrounding landmarks, or simply the failure of meeting certain expectations. Consideration of this kind of expectancy is a major factor in the engineering standards for location and style of warning signs, while at the same time expectation is dependent on the navigator’s culture and background[1].

Of further note, spatial expectations often build on local knowledge of the design options. For example, directions in northern New Jersey might not flag taking a left turn from the right lane using a jug handle as unusual, given its common use for connecting roads. In other areas, where such junctures are relatively rare, this kind of intersection would most likely be a candidate for being tagged as an unusual (or tricky) connection. Thus, the role of expectation varies greatly from region to region and country to country.

In the same spirit, Firth[2] used the term configurational grasp mapping for the process of articulating how the structure of a road network works at a macro level to both provide and restrict access to a given area. Tomko, Winter, and Claramunt[3] took a similar approach to defining what they call an experiential hierarchy of streets. The resulting representations would suggest that further investigation of route directions aimed at systematic differentiation of conceptual aspects is needed. This might include establishing a consistent set of cognitive elements to use as building blocks in route directions, involving start and end points, route segments, action and movement descriptions, reorientations, landmarks, regions and areas, and distances. Further research has highlighted different levels of granularity and the impact of relevance on the ways in which these elements are chosen and represented in a description. It is argued that these various influences can be comprehensively captured by understanding the activity at hand[4].

Thus appropriate and suitable route directions are not created independent of the navigational task. In this spirit, Hirtle, Timpf and Tenbrink[4], argued that from an ontological point of view, activities and tasks produce partitions of reality. For example, in changing mode of transportation (bus, tram, subway), the rider needs additional information, which ideally is in the form of signage at the exchange points. Moreover, it is often easier to change to a more global mode (e.g., bus to subway) than to a more local mode (e.g, subway to bus), in part due to the number of options at the transfer point. Even in straight-forward travelling situations, there are often what Hirtle et al[1] called
the persistent endpoint problems. That is, while the general location of the final destination may be clear, the appropriate office, parking lot, entrance way, etc., may not be well-marked.

Together, the vocabulary, amount of detail, presentation mode, and completeness are dependent as much on human and cultural factors, as they are on the geographic features of the space. When an geographic information broker adds the ability to provide spatial location in terms of verbal, visual and spatial information, one is faced with the potential of information overload\[5\].

Understanding these stated limitations can lead to the development of more user-friendly directions, such as “follow the winding road until you get to the city center,” instead of detailed directions that specify every bend and turn. Likewise identifying the notable dimension, such as visual, verbal, or spatial uniqueness, would allow for compact directions that are fined-tuned along the individual differences (both linguistic and cultural) that exist among wayfinders.


\[2\] Firth, R. Configurational-grasp mapping. In You-Are-Here Maps: Creating a Sense of Place Through Map-like Representations (Freiburg, Germany, 2008).


\[5\] Ellard, C. (2009). You are here: Why we can find our way to the moon, but get lost in the mall. Anchor.
Frames of Reference

Different aspects of Frames of Reference (FoR) have been analyzed in detail since (at least) the early 1990s. Researchers have studied cross-linguistic variety (Levinson, 1996; Levinson and Wilkins, 2006; Pederson et al., 1998), given detailed accounts of individual languages (François, 2003; Haviland, 1993; Hoffmann, 2011; Schultz-Beinert, 2006), considered the impact of landscape and cognition on FoRs (Bohnemeyer and O’Meara, 2012; Danziger, 2010; Levinson, 2003, 2008; Palmer, 2015), explored usage patterns (Hoffmann, sub), and provided regional overviews (Bohnemeyer, 2013; François, 2004, 2015).

I am interested in how languages express absolute Frames of Reference focusing particularly on the Australian continent. How do genetic affiliation, location and landscape features, climate zone, typological area, and cultural overlap influence choice and usage of these types of spatial reference? What happens at boundary areas and which factors are the most influential?

Absolute Frames of Reference in Australia

Absolute FoR requires fixed bearings that are instantly available to all members of the community (Levinson and Wilkins, 2006, 21). There is a wide variety of absolute systems in Australian languages, including compass- (e.g., Warlpiri (Laughren, 1978)), wind- (Kala Lagaw Ya (Stirling, 2011, 182; Bani, 2001)), river drainage- (Dyirbal (Dixon, 1972)), ocean- (Iwaidja (Edmonds-Wathen, 2011); Edmonds-Wathen, 2012, 142–143), and tide-based (Bardi (Bowern, 2012, 30). Recently, Blythe et al. (2016) described the Murrinh-Patha system where no absolute directionals are present, but speakers instead utilize named landmarks, demonstratives and pointing in spatial descriptions. Finally, for some languages, a number of systems overlap, for example in Gurindji sun- and river-drainage-based systems as in (1) (Meakins, 2011) and in MalakMalak wind-, sun-, and riverbank-based systems (2) (Hoffmann, 2016).

(1) **Gurindji: River drainage and sun-based system**

ngu-rnalu ya-ni **kanimparra**, kaarnimpna nyawa. Nangala-lu paraj pu-nya cat-1pl.excl go-pst downstream east.along this subsect-erg find pierce-pst ngu-Ø-Ø ngarlu.
cat-3sg.sbj-3sg.obj honey

“We came downstream along the eastern side here. (Then) Nangala found some bush honey.”

(2) **MalakMalak: Wind- and sun-based system**

yinya nende **dangid-en** pud wu-runguny, **miri-nen**
man thing/person southeasterly-dir chest 3pl-go/be.ipfv, sun-dir payi-ga-ma change.location-cont

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1 Abbreviations used are the following: cat = catalyst, cont = continuous, dir = directional, erg = ergative, excl = exclusive, ipfv = imperfective, obj = object, pst = past, pl = plural, sg = singular, sbj = subject
“the men are facing towards the southeasterly wind direction, towards the east (where the sun comes up)” (Hoffmann fieldwork, 2012)

Furthermore, there is variation within absolute systems. For example, wind-based systems can either be seasonally dependent or fixed. In Kala Lagaw Ya there is evidence for a system bound to winds at specific times of the year, even though the younger generation is now shifting towards a fixed system (Stirling, 2011, 186–87; Bani, 2001, 477). On the other hand, the system employed by MalakMalak and Matngele winds from the (distant) sea and inland blowing at distinct times of the year is used year-round with fixed reference-points (Hoffmann, 2016). Additionally, such wind-based systems are common in small island communities, especially in Oceanic (François, 2003, 2004, 2015) and Austronesian languages (Adelaar, 1997), but also in Polynesian (Svorou, 1994), some African (Brauner, 1998; Mietzner and Pasch, 2007) and a Tibeto-Burman language (Post, 2011). However, their existence in mainland Australia has been largely overlooked with the exception of Hoffmann (2016) and Nash (2013).

Finally, usage patterns for these absolute directionals have only been tentatively described. Edmonds-Wathen (2012, 90) determines that non-Pama-Nyungan languages, such as Jaminjung and Warrwa use the absolute frame in small scale space only when other resources are not available, while Pama-Nyungan languages make widespread use of absolute systems in large- and small scale descriptions. Furthermore, in some languages with a number of absolute systems there is systematic usage variation based on different contexts. For example, in MalakMalak the wind-based system is limited to motion and orientation settings (in Terrill and Burenhult (2008)’s sense), the sun-based system can additionally be used in deictic FoR settings, and the riverbank system is most flexible in allowing for deictic and non-deictic FoR settings in addition to orientation and motion descriptions (Hoffmann, sub).

**Questions to address**

In previous studies of spatial language and absolute directionals in Australia, much attention has been paid to compass-directions and their usage in either only large- or both small- and large-scale settings. Other systems have been described for individual languages, but so far no comparative study has been conducted taking into account what possible influences on absolute systems across linguistic and cultural areas exist. I am currently preparing a manuscript on this subject.

Another area of particular interest are absolute systems employed by newly emerging languages such as the varieties of Kriol, an English-lexified creole spoken across indigenous language boundaries all across northern Australia, or mixed languages such as Gurindji Kriol and Light Warlpiri (Meakins, 2011; OShannessy and Meakins, 2016). Are the systems used similar to those of their substrate or superstrate languages? To what extend are they dependent on extra-linguistic factors? What cognitive and linguistic shifts are taking place? Additionally, are there universal uses of absolute directionals across the Australian continent or can systematic variation be found with regards to genetic and/or typological variation? What roles do landscape and geographic conditions, climate and seasonal patterns play (Palmer, 2015)? Finally, what wider implications for cross-linguistic generalization are evident from
observing spatial frames of reference in a typologically and culturally relatively homogeneous, but genetically diverse area such as Australia?

References


The Role of Perception in *Situated* Spatial Reference

JOHN D. KELLEHER
Adapt Research Centre
School of Computing
Dublin Institute of Technology, Ireland
Email: johndkelleher@gmail.com

My research is inspired by exploring the interface between language and perception, and spatial reference in situated dialog is a natural area of study for this topic of research. My Ph.D. [20] studied spatial reference in situated dialogue. Part of this research focused on modelling visual attention as a mechanism to help resolve underspecified references [11, 9]. Another theme of this research, informed by the Logan and Sadler’s *spatial template* concept [25], involved designing and running psycholinguistic experiments to study the spatial templates of projective prepositions and the impact of frame of reference ambiguity on these spatial templates [10]. Using the results of these experiments a computational model was developed that modelled the geometric semantics of projective prepositions and that was able to accommodate the impact of frame of reference ambiguity [18].

My Post-doctoral research at DFKI (Saarbruecken) was on the CoSy project (http://cognitivesystems.org/) where I worked in the area of Human-Robot Interaction and Dialogue Systems. Continuing the theme of spatial language in situated dialogue and the role of perception on linguistic reference I did work on computational models of multimodal information fusion, including the integration of spatial information as expressed through spatial linguistic references and visual perceptual information [23, 24]. Questions relating to the grounding of spatial reference in perception were at the core of this work and for the CoSy project a key task was to develop computational models that would enable the qualitative information expressed in linguistic spatial references to be grounded within the quantitative representations of the environment that a computational agent, such as a robot, would construct information it received through its (perceptual) sensors [1]. During this research I became more interested in exploring the spatial semantics of topological prepositions. For me a key problem with previous computational models of the spatial semantics of topological prepositions had been the relatively arbitrary mechanisms used to define the maximum extent of the spatial template of these prepositions. This led me to consider the impact of *distractor* objects defining the extent of the spatial templates of these topological prepositions. To explore the impact of these distractor objects I (and my co-authors) designed and ran some psycholinguistic experiments [2]. The results of these experiments indicated that distractor objects did impact on the spatial templates of topological prepositions. Building on these results I developed a computational model of proximity that was sensitive to distractors

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1 By the term distractor objects I am denoting the set of objects that are in the perceptual frame of an agent but which are neither the landmark nor the located object in a locative expression the agent in currently resolving)
objects \cite{14,12}. In my opinion one of the most interesting aspects of my work on distractor objects and locative expressions is that it provides another illustration of how perceptual information affects the semantics of the spatial reference; in this case the perceptual information related to objects that are in the context but which are not mentioned in the spatial references. Integrating the computational models of the semantics of projective prepositions that I developed during my Ph.D. with the computational models of topological prepositions that I developed during my Post-doctoral research I developed an algorithm for generating locative expressions \cite{13,21}. This algorithm extended Incremental Algorithm of Dale and Reiter\footnote{The Incremental Algorithm is a well-known algorithm in Natural Language Generation research that generates referring expressions.} in two ways: (1) it defined a preference order over spatial relationships based on Cognitive Load; (2) it integrated a mechanism for utilising visual attention to help generate linguistically underspecified but contextual clear spatial references. Again, this work illustrated the role of a perception, in this case an attention mechanism, on spatial reference.

In my more recent research I have explored a number of other aspects of spatial reference. For example, semantics of topological prepositions in spatial reference \cite{19}; the impact of the topological prepositions on the semantics of composite spatial terms (e.g., the difference between at the front of versus on the front of etc.) \cite{15}; the role of analogical reasoning in spatial reference \cite{6}; resolving frame of reference ambiguity \cite{28,5}; and using corpus based analytics to explore the functional and geometric semantics of prepositions in visually situated spatial reference \cite{4}. However, throughout this time I have continued to explore perceptual factors on spatial reference. Indeed, some of my most recent work has explored the impact of perceptual errors on spatial reference and the mechanisms people use in dialogue to repair these communication breakdowns \cite{29}. Other examples of recent research on perception and spatial reference include experiments that examined the role of perspective on the semantics of projective prepositions \cite{16} and the preposition between \cite{27} and, also, the role of perceptual occlusion on the semantics of projective terms \cite{17}.

In conclusion, I believe that an interesting avenue of exploration on universals and variation in spatial reference is to address this topic in terms of the universals in human perception and attention and to explore how these universals impact on spatial reference across cultures and languages.

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Universals and Variation in Spatial Referencing

MARIA KHACHATURYAN
Department of Anthropology
University of California, Berkeley
Email: mashaha@gmail.com

Recognitional function of (distal) demonstratives cross-linguistically

In recent years, a growing number of works have appeared which critically analyze deictic markers (e.g. English *this* and *that*, Russian *etot* and *tot*, Mano *tɔ́ɔ̄*, *dḭ̄̀ā̰*, *ɓɛ̄*, *yā* . . .) beyond mere spatiality (Hanks 2005, 2011; Enfield 2003; Jarbou 2010, inter alia; for a recent overview, see Peeters & Özyürek 2016). Instead of a linear approach to deictic markers as encoding relative distance, a multimodal approach was suggested, where the psychological proximity (Peeters & Özyürek 2016), or accessibility (Hanks 2011), replaces mere physical proximity. Crucially, according to this theory of deixis, the speaker and the addressee establish referents’ accessibility jointly, through joint attention focus (Clark et al. 1983, Diessel 2006), which is opposed to the widespread egocentric approach to deixis.

That deictic markers often have anaphoric (discourse-referential) function is well known. However, this function is often seen as a metaphorical extension of spatial deixis proper (Anderson & Keenan 1985). On the contrary, Hanks (2011, inter alia) argues that anaphora, being an instance of cognitive access to the referents, functions alongside with perceptual access, which includes, but is not restricted to, spatial (visual) access.

In this paper, I explore the function of recognitional deixis, which has not received much scholarly attention, on a preliminary cross-linguistic sample. Deictic markers in the recognitional function (Schegloff 1972) serve to identify referents which are not immediately accessible on the interactive scene. These referents are rather accessible cognitively. Unlike anaphora, however, they are not directly mentioned in the discourse immediately prior to the utterance in question. The access is enabled via the common ground of the interlocutors, which is constructed in previous interaction experience. Therefore, recognitional function is a primary example of cognitive access to referents, established jointly. See an example of English demonstrative *that* in the recognitional function:

(1) (A yoga teacher to her students): *Widen those collar bones.*

“Widening” the collarbones (and opening the chest) is a common element of yoga postures. Without pointing to any of the students’ collar bones, and without mentioning them in the discourse immediately preceding the utterance, the teacher assumes that the students, already familiar with the practice, will recognize and implement the movement.

In what follows, (1) I introduce recognition among other functions of cognitive access to referents (anaphora, and also bridging); (2) I then argue that there is a cross-linguistic tendency for the recognitional function to be expressed by deictic markers which, in the spatial axis, express relative distance from the object (distal deictics); (3) The common
ground being a socially constructed phenomenon, I introduce social-pragmatic usages of 
recognitional function.

**Cognitive access to referents: recognition, anaphora, bridging**

Recognitional function is a function of cognitive access to the referents, along with the 
widely-studied function of tracking reference in discourse, or anaphora (Fox 1996), and also 
bridging (Clark 1975). In case of anaphora, the referent is mentioned in the prior discourse. 
Thus, in Crow narratives salient characters are often referred to with the use of proximal 
marker *hinné*:

(2) hinne iisáakshee-sh hinne bachée-sh dúuxalu-ok bin-nàaske aa-ii-ák

“this young man dragged this man and brought him to the bank of the stream.” (Crow; Graczyk 2009: 70)

In the case of bridging, the referent is inferable by proxy: from a frame or other bridging 
context mentioned in the immediate prior discourse. Consider ex. 3 from Mandarin, where 
the distal demonstrative *nei* functions as a marker of bridging:

(3) Zuotian wanshang wo shui bu zhao
     Gebi de nei tiao gou jiao de lihai

“I couldn’t sleep last night. The dog next door was barking.” (Mandarin, Crosthwaite 2014:463).

Both anaphora and bridging involve previous discourse; bridging also involves some broader 
contextual knowledge shared by the interlocutors. However, as illustrated in ex. 1 and in the 
forthcoming examples, recognition is based solely on common ground. Scheme 1 illustrates 
the types of knowledge involved in anaphoric, bridging and recognitional expressions:

**Scheme 1. Types of knowledge involved in cognitive access to referents**

<table>
<thead>
<tr>
<th>Anaphora</th>
<th>Bridging</th>
<th>Recognition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Previous discourse</td>
<td>Previous discourse</td>
<td>Common ground</td>
</tr>
<tr>
<td>Common ground</td>
<td>Common ground</td>
<td>(frames, contextual knowledge)</td>
</tr>
</tbody>
</table>

**Recognitional function and distal deictic markers**

Recognitional function, as well as other functions of cognitive access, is in many languages 
conveyed by the same means as the more straightforward function of demonstratives, namely, 
visual access. The recognitional function has a chance to be universal: it is possible that in any 
language at least some (demonstrative) marker will have the recognitional function (possibly, 
among others). Moreover, medial and distal demonstratives seem to be preferred for the
A boy is missing, and his mother cannot find him.

(4) bacheeíćhe bacheé xaxúa bachaahii-ák óoppii-ak “éehk shikáak-kaata-m xapíi-o-k”

lost-CAUS,PL-DECL

“the chief gathered all the men together,” he smoked, “they lost that little boy” [he said] (Crow, Graczyk 2009: 72)

Yucatec Maya is another case at hand: the recognitional function is often marked with the non-immediate enclitic –o’:

(5) Father arrives home from travel and notices that one of his four children is not around and so asks his spouse:

kux tuún le pbdal o’, tz’ú chan xantal má’a tinwilik

“How about that kid, it’s been a while since I’ve seen him” (Hanks 2016)

Russian has a specialized marker –to, restricted to recognition. This marker grammaticalized from the distal demonstrative tot:

(6) A conversation overheard in a bus:

- Pomniš? On-to. Znaeš, pravdá! - Da?

remember.2SG he-TO know.2SG truth yes

“- Do you remember? The man. You know, it’s true! – Really?” (Bonnot 1986:115)

Recognition in interactional context

In Yucatec Maya, stereotypical referents are often introduced with the non-immediate marker -o’.

(7) chokow le K’lín o’

“The sun is hot” (Hanks 2005:207).

Compare ex. (7) with a stereotypical referent “the sun” with (8), where “this wind” encoded by use of the immediate marker –a’ has a value of focus associated with it: the speaker emphasizes that the wind is stronger than the days before (and takes it as a sign of the approach of the hot season):

(8) k’àam e ’ik’ a’ (pointing up) astah bey u tàal camyon e’

“This wind is loud. It’s as if a truck were approaching” (Hanks 2005:207).

Therefore, in Maya recognized and stereotypical referents are contrasted with truly discourse-new and focalized ones, which is supported by the paradigmatic opposition between immediate and non-immediate deictic markers.

Deictic markers in the recognitional function can be used strategically, as a means to formulate an utterance that would presuppose the existence of common ground between the interlocutors and, in some cases, their joint community membership. This is the strategy that I frequently observed in the native Bible translations by the Catholic community of Mano (Mande; Guinea). These translations occur spontaneously, during the Sunday service, when the catechists
orally translate from the French Bible. Note the translation introducing (Lc 4:21) below. There was no previous discourse on the subject, so the usage of the distal demonstrative yā “that” cannot be explained by the anaphoric function; neither the objects in question were present at the interaction scene or otherwise accessible.

(9) wálàkà lé é kë Nazareth yā wi ā, yē ē nè gbààbô ṣáîa lè sëbè yā gèè à kà à . . .
“(In) the house of God that was in THAT Nazareth, when he finished reading THAT book of Esaiah…”

(own data [service_nza0_0131_00:40:28])

By using the demonstrative yā in the recognitional function, the catechist, who was orally translating the Bible, backgrounded the referents and made them appear as already known by the congregation. The effect was that the listeners were stepping into an ongoing story (Clark & Haviland 1977:37). Common ground is a property of a social community (Enfield 2006); in this case, a religious community. Thus, presupposing the common ground, the catechist simultaneously presupposes the existence of a religious community.

References


Universals and Variation in Spatial Referencing

ALEXANDER KLIPPEL
Department of Geography
The Pennsylvania State University
Email: klippel@psu.edu

Referencing something in the world always relates one entity to another. While possible to develop artificial systems such as latitude and longitude to locate an entity at an absolute location on earth, in natural language and in human concepts of location a ground object is either implicit or explicit. This means that the question turns more directly to the relation between entities. The simplest case is the relation between two entities such as the “the gas station north of campus” or “I am at the coffee shop.”

Research in my group has addressed questions of the relation between spatial entities in language and from the perspective of conceptualization both in controlled experiments as well as in a crowdsourcing environment. Both approaches have shown to be of value for a deeper understanding of spatial referencing, identifying universals, and in exploring cross-cultural and cross-regional variation. I see my contributions to the specialist meeting as both topical as well as methodological.

Brief overview of topics addressed in my team

Our research has addressed spatial relations between spatial entities of different dimensions for both static and dynamic scenarios in the geo-spatial realm (i.e., we are usually not focusing on table top spaces). For controlled behavioral experiments addressing spatial relational concepts and spatial relational language we often select qualitative spatial formalism as a starting point. As briefly discussed below, the advantage is the identification of spatial equivalence classes which lend itself to the formulation of hypotheses. Hypotheses can be tested and correspondence between formal and cognitive equivalence classes can be established. Additionally, availability of equivalence classes / formalisms for various types of spatial relations such as topology, directions, entities of different dimensions such as line-line or line-region relations, or the possibility to characterize trajectories allow for covering a variety of possible spatial relations. One example (see Appendix A) are direction relations between entities such as airplanes. In our research (Klippel, Wallgrün, Yang, & Sparks, 2015) we systematically looked at direction concepts that people apply to characterize the direction relation between the two airplanes, how direction concepts are linguistically externalized, and how they differ at the level of individuals. Our results clearly show that humans have mutually exclusive direction concepts, that is, some of them apply sector-based direction concepts while others use cone-shaped approaches. Only acknowledging these differences allows for validating results from a statistical perspective. In other words, there are no intuitive universal direction concepts.

Other examples revealed through controlled behavioral experiments are linguistic and non-linguistic turning concepts at intersections showing that they are not identical (Klippel & Montello, 2007), the influence of domain semantics on relational movement concepts for both
translation and scaling and how semantics changes the importance of certain topological relations (Klippel, 2012; Yang, Klippel, & Li, 2015), the cross-linguistic comparison of overlap relations showing a universal distinction of non-overlapping, overlapping, and proper-part relations in English, Korean, and Chinese (Klippel, Wallgrün, Yang, Mason, & Kim, 2013), or the comparison of conceptualizing static versus dynamic path relations revealing a stronger focus on ending relations in the static case (Li, Klippel, & Yang, 2011).

A second line of research in my team has addressed the interpretation of natural language in a crowdsourcing, often corpus-building environment. Crowdsourcing, or what we call passive crowdsourcing (collecting data available on websites, tweets, etc.), has the advantage of creating massive amounts of data and in combination with geo-referencing tools can provide insight into regional variation of referencing expressions. We studied the use of cardinal versus relative route directions across the United States (Xu, Klippel, MacEachren, & Mitra, 2014) finding significant differences between the coastal (more relative directions) and interior states (more cardinal directions). We also generated a corpus approach for ground-truthing the use of a variety of spatial relational expressions such as near, next to, or close by (Wallgrün, Klippel, & Baldwin, 2014). This approach is using geo-referenceable entities to create triplets such that the geo- location of figure and ground are known allowing for identifying a distance measure for terms such as near. A large enough corpus then allows for identifying contextual factors such as the size of the entities. This work is ongoing.

A brief perspective on universals
My personal perspective on universals is that they can and should be grounded in the concept of invariance. Researchers in many scientific fields from the cognitive to the spatial sciences have addressed the topic of invariance in the context of cognitive information processing as well as to formally distinguish fundamental concepts of space and time. Worboys and Duckham (2004), for example, utilize the concept of invariance as a framework for their chapter on Fundamental Spatial Concepts. Proposed first by Felix Klein (see Erlangen program (Wikipedia, 12/3/2011)), geometries can be distinguished based on invariant properties under certain transformations. This approach allows for differentiating Euclidean geometry from set-based geometry as well as topology. Alongside formal approaches, perceptual and cognitive invariants, which we also find to be associated with conceptual primitives, have long been of interest to the cognitive science community. Klix (1971) states that the human mind, in adapting to its environment, identifies invariant characteristics of information that form the basis for cognitive processes. Likewise, the classic work by Gibson (1979) refers to temporally constant characteristics of environments as structural invariants. If we seek to identify universals, invariants in human perception of environmental characteristics and ideally their formal characterization seem to be an excellent starting point.

A brief perspective on methods
Over the last 10 years we have placed substantial effort on improving methods for understanding both referencing concepts and referencing language. We have developed a framework comprising of a highly efficient way to collect data on human concepts and human language. This
framework consists of CatScan (for controlled behavioral data collection) and CatAnalysis (for in-depth data analysis). Examples: in two recent articles we developed A) an approach to validate human cognitive concepts from a statistical perspective (Wallgrün, Klippel, & Mark, 2014). This approach is grounded in approaches on cluster validation and uses a bootstrapping methods to identify stable (maybe universal) concepts; B) we develop a way to quantify variation of concepts using the statistical measure of variance. Appendix B shows two images of landscape concepts, one with high variance and one with low variance. Quantifying variation this way may allow for better understanding universals and variation. In the example shown in the Appendix greater conceptual variation corresponds to greater linguistic variation.

References


Appendix A: Example stimuli from two direction experiments.

Appendix B: Examples of landscape concepts (method can be applied to relational concepts, too) with high or low variance.

These images form highly consistent categories. High variance (last value) indicates small variation, that is, images are conceptualized similarly by all participants.

These images form highly inconsistent categories. Low variance (last value) indicates small variation, that is, images are conceptualized differently across participants.
Some Observations on Spatial Referencing in Yindjibarndi Culture and Language

DAVID M. MARK
Department of Geography
University at Buffalo (SUNY)
Email: dmark@buffalo.edu

ANDREW G. TURK
School of Information Technology
Murdoch University, Perth
Email: a.turk@murdoch.edu.au

This position paper reports on spatial referencing in the Yindjibarndi language. Yindjibarndi is spoken by about 500 people in the Pilbara region of Northwestern Australia (Wordick 1982; Mark and Turk 2003; Mark, Turk, and Stea 2007). Yindjibarndi belongs to the Coastal Ngayarda language group, within the southwest group of Pama-Nyungan languages David Mark and Andrew Turk conducted landscape and language fieldwork with Yindjibarndi speakers on field trips between 2002 and 2009.

Spatial Referencing
Spatial referencing in Yindjibarndi is represented by several different parts of speech and linguistic structures, including locative suffixes, directional nouns, and other nouns.

Locative Suffixes
“Languages of the Pama-Nyungan family are entirely suffixing in their morphology . . . . Suffixes serve also to derive new words, and among them those meaning ‘having’ and ‘lacking’ are almost universal in Australian languages.” (Gutman and Avanzati 2013). Anderson (1986) listed 141 suffixes in the Yindjibarndi language. Anderson classified seven of these as “locative case.”

Directional nouns
Wordick (1982) and Anderson (1986) identified five classes of nouns. Two of those classes contain only three nouns each, and were named “Directional nouns (north type) (NDN)” and “Directional nouns (south type) (NDS) by Wordick.

The three “north type” directional nouns (from Anderson 1986) mean “in or at the north,” upstream/interior, and downstream. The three “south type” directional nouns mean “in the south,” “in the west,” and “in the east.” The principal river of traditional Yindjibarndi country, known as the Fortescue River in English, has intermittent or seasonal flow. For most of its length, the Fortescue flows west. The two groups of directional nouns are grouped in a way that is unexpected to an English speaker: “In the north” is grouped with the two riverine directionals, whereas the other three cardinal directions are in the other group. This begs for further investigation.

Qualitative Distance Noun:
“Wana refers to ngurra (ground) in the middle distance, such as the side of a marda (or perhaps a flat area)—where you can still see something (like a kangaroo) but it is much too far away to throw a stone at it (or shoot the kangaroo). Wanangga could refer to the location of something in the middle distance.” (Turk and Mark 2008).
Transcripts and word counts for locatives:
In June 2006, we showed (40) photographs of Australian landscapes, mostly from traditional Yindjibarndi country or the area where the people now live (Roebourne), separately to four groups of Yindjibarndi speakers. One “group” consisted of just one person, the oldest speaker living at the time. Others were small groups of two or more speakers. People were asked to “tell us what’s on the picture, in Yindjibarndi language” or something similar. The four sessions produced almost five hours of audio, and were transcribed by the authors. The transcripts contained 26,211 words.

Word Counts for locatives: The Yindjibarndi dictionary (Anderson) included 19 terms ending with the locative suffix –ngga. The combined transcripts contained at total of 64 terms ending with –ngga. The suffix was attached to 28 different nouns within the transcripts. Only four of the 28 terms from the transcripts appeared in the dictionary. Most or all of the others presumably were formed from –ngga as a productive locative suffix. Thungga is the most common –ngga word in the transcripts, occurring 40 times total, and also appears in the dictionary. But thungga is said to mean “soil, dirt, sand” and in this case, –ngga does not seem to be the locative suffix; “thu-” does not seem to be a root in Yindjibarndi. Similarly, bungga means “fall”. Wirrangga is a term for Red River Gum trees, and again the –ngga does not make sense as a locative, although since wirra means boomerang, perhaps there is a semantic connection. The other two –ngga words that were found both in the transcripts and in Anderson’s dictionary were: ngarlingga (downwind) and gardangga (down, low, below). The most common other –ngga compound nouns in the transcripts were wirgangga (wirga = gap), bawangga (bawa = water), biyungga (biyu = dry), and thalungga (thalu = ritual site).

Summary
Yindjibarndi speakers are able to communicate locations in the environment through a variety of elements of their language. Landscape terms themselves refer to entities in the environment. Locative suffixes are a way to use landscape entities as grounds for locating other entities (figures). Two closed classes of nouns denote directions. Four of the directional nouns appear to denote the four cardinal directions while to refer to upstream and downstream. The use of these six directional nouns would be a high priority if future research with speakers becomes possible.

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Universals and Variation in Spatial Referencing

KATE MESH
Department of Linguistics
The University of Texas at Austin
Email: kate.a.mesh@gmail.com

To locate an item in the world, we typically perform two linked behaviors: we use a spoken language expression—often a spatial deictic term like here or there that carries limited semantic information—and we use some combination of our hands and head to point to the item in question.¹ These behaviors are linked in that they both indicate: that is, both direct the interlocutor’s attention to a more or less narrowly circumscribed search space (Clark 1996, discussed in Cooperrider 2015). What’s more, these behaviors are linked in production: they occur together more often than alone, a fact often interpreted as evidence of their intrinsic connection (see e.g., Diessel 2006; Levinson 2003).

Of the two types of indicating strategies, the spoken variety has received substantially more scholarly attention in linguistics, psychology, and related disciplines. Nevertheless, a sufficient number of studies on gestural spatial referencing have been performed to allow for early arguments for and against possible universals in the behavior of pointing (see, e.g., Kita 2003).

The very act of manual pointing—the behavior of extending an arm and hand to designate an intended referent—has been described as a possible universal of human communication. But while pointing as a broad phenomenon may be universal, it remains to be shown whether any of its forms is universal. Consider the example of pointing handshape: an extended index finger is a form that recurs in many of the world’s pointing systems, perhaps because it is the hand configuration motorically easiest for humans to produce (Povinelli & Davis 1994). Index finger extension has been described as the preferred configuration in pointing produced by children (Liszkowski et al 2012). But Wilkins (2003) argued against the notion that the index finger handshape remains privileged in adult pointing behavior cross-culturally. He observed that adult speakers of Arrernte control a variety of pointing handshapes, the use of which encodes information about the pointing referent. While the extended index finger handshape is present in the Arrernte system, it does not have special status within it. In making this observation, Wilkins drew attention to the potential conflict between (motoric or cognitive) motivations shaping pointing and the demands of a semi-arbitrary semantic encoding system.

¹ Users of signed languages, of course, locate objects exclusively in the visual-manual modality. Their indicating behavior remains complex: like speakers, signers typically combine pointing strategies with gaze direction to pick out their target.
I am interested in the question of whether some motivations are sufficient to ensure morphological universals in manual pointing because my own work investigates one such potentially universal feature. Since 2012 I have worked with speakers of San Juan Quiahije Chatino (Zapotecan, Oto-Mangeuan) in Oaxaca, Mexico. Using the ‘local environment interview’ method of Kita (2001), I have video recorded over 11 hours of multimodal spatial referencing behavior used to locate landmarks inside the village of San Juan Quiahije and in its environs. Analysis of these videos reveals that Chatino speakers use the height feature of manual pointing gestures to encode information about the distance of the intended referent (Hou & Mesh 2015; Mesh in prep). Referents located inside the community are indicated with a low or unelevated elbow height, while referents outside the community are indicated with an elevated elbow. When pointing accompanies the name of a landmark, this height modulation is perceptible but subtle. When speakers make spatial referencing the focus of their talk (as for example when giving route directions or answering a question about a landmark’s location), the height modulation is amplified.

Meaningful modulation of pointing height to convey information about referent distance has been documented for a handful of other pointing systems. Kendon (1988) observed this type of distance-indexing in the pointing of Warlpiri and Warramungu speakers. Wilkins (2003) found evidence for a three-way distinction in Arrernte pointing height that maps to the three-way distance distinction in the spoken Arrernte demonstrative system. de Vos (2014) found that users of the signed language Kata Kolok use height to distinguish distal and proximal referents of pointing signs. And Eco (1976), without connecting the observation to a specific cultural pointing system, noted that points to distal targets require greater “energy” (p. 119), describing energy in a way that suggests that the term is a proxy for pointing height.

That this phenomenon occurs across manual pointing systems is not coincidental: distant objects generally appear higher in the visual field (Gibson 1950) and this sensory experience can be reflected in pointing height. Additionally, pointing height mirrors a feature of one human practical action: propelling an item to a distant location by hand. To throw an item in this way necessitates raising the arm, and the increased arm elevation required to launch an item farther can be reflected in pointing gestures that ‘throw’ nothing more than an object-indicating vector.

Could pointing height index referent distance cross-culturally? Phrased differently: is this motivated feature of manual pointing robust enough to persist cross-culturally—even when pointing height is exploited to express additional meanings? To address this question, and many analogous ones about motivation, arbitrariness, and universals in pointing behavior, requires the collection of substantially more data than we have at present. The responsive plan of action is

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2 Enfield et al. (2007) observe that pointing height distinguishes location-focus from other pragmatic features in Lao discourse. They are silent, however, on the question of whether pointing height also encodes referent distance in Lao pointing, and on the potential for interaction between these two semiotic dimensions of pointing.
clear: a full account of spatial referencing requires a rigorous program of cross-cultural and multimodal data collection—a program that the language documentation community has the tools, and the incentive, to begin.

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Variations in Verbal Spatial Referencing: Factors Besides Culture and Language

DANIEL R. MONTELLO
Department of Geography
University of California, Santa Barbara
Email: montello@geog.ucsb.edu

There is a long history of academic debate about the relationship between human language and human thought, and the debate continues. Many of the deep psychological and philosophical issues that make up this debate are surprisingly subtle and complex, and at some point, can become tedious to some of us. We once asked if people spoke differently about core properties of the physical world. Documenting that they did, we asked whether these differences meant that people think differently or just superficially use different verbal labels for essentially equivalent thoughts. Finding evidence that these verbal differences, at least in some cases, apparently did correspond to differences in the way people think nonverbally about the world, we asked whether these nonverbal cognitive differences were profound and fundamental, or just relatively superficial consequences of the way language focuses attention. In the latter case, the cognitive differences could be overcome relatively readily by training people to focus their attention differently. For example, it is likely that people who typically use relative (egocentric) systems can be taught to use absolute (abstract allocentric) systems fairly easily; people who practice this will develop the ability to maintain orientation with respect to such absolute systems. And so on.

In this position paper, however, I want to redirect our attention to variations in linguistic spatial referencing besides the common issues of culture and language. In a given physical situation (i.e., a particular environmental setting with particular objects, actors, etc.), people vary in their use of spatial referencing terms in ways that do not correlate only with language and culture. I believe there are important and interesting things to recognize about spatial language—including its reference system(s)—besides the fact that it varies to some degree with culture and language. I develop this position here in the form of three issues for discussion:

1. language and culture are vague concepts and have an ambiguous relation to each other;
2. there are variations in spatial reference usage between individuals that correlate with factors besides language and culture; and
3. there are variations in spatial reference usage within individuals over time/situations that cannot derive from cultural or linguistic variation, by definition.

First, language and culture are rather vague concepts, more vague than many other natural language concepts. Linguists and others are well aware of the ambiguity of differentiating language families, groups, languages, dialects, jargons, and so on. Likewise, culture can refer to any group characteristics that are passed on through intentional or unintentional learning, and not determined by genetic or physical environmental causes. But this leaves many ambiguities, including that the group could be as small as two people. Furthermore, the relationship of
language and culture is ambiguous. They only partially overlap. Members of different cultures may speak the same language; they may be different dialects or jargons, or maybe they are not even that different. One could also argue that members of the same culture may speak different languages; again, perhaps they are only different dialects or jargons, perhaps they are full-fledged languages. Of course, a person who considers language (even dialect) to be a defining component of culture will not be able to accept this last claim.

Second, variations in spatial reference usage between individuals do not correlate only with language and culture, the ambiguity of those concepts notwithstanding. People with the same culture and language sometimes use referencing systematically differently. We have evidence that plains and mountain folks who speak the same language nevertheless tend to differ in spatial referencing. We have evidence that rural and city folks tend to differ. We have evidence that folks living in cities with orthogonal grid networks speak differently than folks living in cities with irregular networks. I believe that some important part of the evidence that is presented for cultural and linguistic differences is really evidence for environmental differences. Of course, if one wants to use the concept of culture at a higher resolution than nationality (in the sense of a nation, as opposed to a state or country) or ethnicity, then one could say that any systematic difference in the way people live is an expression of culture or “sub-culture.” The conceptual ambiguity of culture again.

Third, there are variations in spatial reference usage within individuals. A given person does not consistently use the same reference terms in all situations. They may use relative systems indoors but absolute systems outdoors. Or they may use relative systems with figural spaces (including “table-top” spaces) but absolute systems with environmental spaces; spatial scale likely matters to reference system use. People do not always use the same reference system in the same situation at different times. They do not always use only one system, but may redundantly say something like “turn right, toward the ocean.” It happens every day here in Santa Barbara. By definition, the intra-individual variation in this final paragraph cannot derive from cultural or linguistic factors. It’s the same person with the same culture and language.

References:


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Lexical Splits and Asymmetries Spatial Referencing: Revealing Universals through the Study of Variation

TATIANA NIKITINA
Department of Languages and Cultures of Sub-Saharan Africa
Centre National de la Recherché Scientifique (CNRS)
Email: tavnik@gmail.com

Introduction

Early studies in the linguistic representation of space were commonly inspired by bewildering cross-linguistic diversity; they sought to systematize that diversity and to understand its underlying principles. The theoretical fruitfulness of these efforts notwithstanding, much stands to be gained by looking closely at patterns of variation that recur with surprising regularity in language after language but have not so far received much attention from typologists. In this paper, I explore three of the major aspects of cross-linguistic variation, focusing on the ways alternative strategies co-exist within one language. I believe that by shifting the emphasis from sweeping typologies to language-internal variation new insight can be gained into the way different cognitive strategies compete for becoming conventionalized in grammar and usage. In addition to traditional typological methods, such exploration requires the use of corpora, experimental techniques, and sometimes tools for fine-grained quantitative data analysis. In this talk I try to highlight the way general principles of spatial representation are reflected, in different languages, in lexical asymmetries, usage tendencies, and regularities in language change.

Overt encoding vs. contextual inference

One important dimension along which systems of spatial representation vary across languages is the extent of relying on overt encoding of directionality as opposed to leaving it to be inferred from context. In the study of motion expressions, that variation has been related most famously to the distinctions between verb-framed and satellite-framed languages, on the one hand, and Manner and Path languages, on the other (Talmy 1975, 1985; Levin et al. 2010). Individual languages, however, rarely restrict their motion expressions to just one strategy, and speakers are often offered a choice between overt vs. implicit encoding. The alternatives are illustrated by the variation between explicitly dynamic and static prepositional phrases in (1a,b), for English and Russian, and in (2a,b) for Ancient Greek.

(1) a. Put it into / in the box. [US English]
   “Put the keys onto / on the table.”

(2) a. hò d' en purì bålë thúdâs [Ancient Greek; Il. 9.220]
   he:NOM PRT in fire:DAT throw:IMPF.3SG offerings:ACC
   “and he threw sacrificial offerings in the fire”

b. kai tês oreías anthemòrruton gânos ksouthês melîssèς and
   ART mountainous:GEN flowing.from.flowers:ACC pride:ACC yellow:GEN bee:GEN
   puràn balô sêthen [Ancient Greek; Eur. IT 634-635]
   into fire:ACC throw:FUT.1SG you:GEN
“and I will throw into your funeral pyre the honey of tawny mountain bees that streams from flowers.”

In spite of a number of superficial differences, the variation seems to be constrained by the same factors in all three languages. One of the most important factors is manner specificity of the verb, as reflected in corpus distributions in English (Nikitina 2008), and in patterns of diachronic change in Ancient Greek and Russian (Nikitina 2012; Nikitina & Maslov 2013). Manner specificity is ultimately related to the probability of inferring the directional meaning in context. With verbs describing specific manners, and especially manners that represent highly unusual ways of getting to a new location (e.g., waltzing or crawling), Goals of motion are normally marked overtly.

The same probability of inferring the argument’s meaning is reflected in a different way in lexical restrictions on combinations of verbs and spatial adpositions with Source and Goal arguments (Nikitina 2009). In Wan (Mande), most motion verbs can only take one argument, and that argument can only describe the Source or the Goal of motion depending on the verb (cf. 4a vs. b). Several verbs, however, show flexibility in combining with either a Source or a Goal, and do not restrict their locative argument to any particular role (5).

(4)  a. è go’kalɛ̄ gö  
  “She went from / *to the forest.”
  b. è bo’kalɛ̄ gö  
  “She arrived in / *from the forest.”

(5)  a. è sia yrɛ̄ gö  
  “She fell from the tree.”
  b. è sia’ trɔ̄ mì  
  “She fell on the ground.”

The verb’s behavior can be predicted based on one particular aspect of the verb’s meaning: flexible role assignment is only allowed with verbs that describe asymmetric motion events, such as events of vertical motion (the Goal of motion must be located lower on the gravitational axis than its Source) or events of deictic motion (the Goal of motion is closer to the deictic center than its Source). The entailed asymmetries make it easier to infer the role of the particular locative argument: in (3b), with a verb of vertical motion, the particular location can only serve as the Goal of motion, and in (3a), it is likely its Source. Probability of inferring directional meaning is reflected in tendencies for overt Goal marking in English and in “rigid” associations between the verb’s meaning and its argument structure in Wan.

**Static relators vs. dynamic projections**

Another dimension along which languages vary is the extent to which dynamic descriptions are used to encode static spatial relations. English makes limited use of such expressions in this function (6a), but ancient Indo-European languages used them more regularly, cf. the Goal and the Source expressions in (6b,c), from Ancient Greek. (6) a. A big storage chest stood to the left of the door. (The British National Corpus)

  b. hoi tà epi deksià tôn kefalēn
  they:NOM ART:ACC.PL on right:ACC ART:GEN.PL heads:GEN
  komōsi, tà  d’ ep’ aristerà keipousi (Hdt. Hist. 4.191.4)
  let.hair.grow:PRES.3PL ART:ACC.PL PRT on left:ACC shave:PRES.3PL
  “They let their hair grow long on the right side of their heads and shave the left.”
  (literally, “to the right side, “to the left”"

Static relators vs. dynamic projections

Another dimension along which languages vary is the extent to which dynamic descriptions are used to encode static spatial relations. English makes limited use of such expressions in this function (6a), but ancient Indo-European languages used them more regularly, cf. the Goal and the Source expressions in (6b,c), from Ancient Greek. (6) a. A big storage chest stood to the left of the door. (The British National Corpus)
c. ek deksias d' auton leukadioi kai hoi alloi bårbaroi (Thuc. 2.81.3) from right:GEN PRT they:GEN L.:NOM.PL and ART.NOM.PL other:NOM barbarians:NOM “and on their right [were] Leukadians and other barbarians” (literally, “from their right”)

The dynamic expressions describe static locations by projecting paths of fictive motion (cf. Talmy’s notion of access path) leading away from the Ground (in the case of Source expressions) or toward it (in the case of Goal expressions). In languages where both the static and the dynamic strategies are available, the choice between them is again constrained by the same underlying factors. For example, the use of the dynamic strategy is correlated with the overall frequency of a particular spatial relator. More frequent spatial relators tend not to allow for the dynamic marking, the latter being confined to less conventional and rarely invoked spatial relations. Best candidates for dynamic encoding are relations for which no specialized preposition is readily available (“to the north,” “to the right,” etc.).

In Indo-European languages, specialized static prepositions compete with the old strategy of relying on directional adverbs, pushing it to the periphery of the spatial domain (Nikitina forthc.). The way individual languages are affected by that change can be predicted based on the close relationship between frequency of use and the degree of grammaticalization of spatial relators as a conventional means for describing static relations.

**Frames of spatial reference**

The last dimension to be discussed is the choice of a frame of spatial reference in descriptions of objects’ location. While speakers of European languages make extensive use of the relative frame of reference, many languages have been reported to hardly allow their speakers such an option (Levinson 1996, 1997; Bohnemeyer 2011). I present an experimental study of Bashkir (Turkic), which lets its speakers choose between three reference frames where English only allows for two. In descriptions of a ball’s relation to a chair (aligned along the horizontal axis), speakers of Bashkir may either resort to the relative reference frame or choose between two different subtypes of the intrinsic frame: one based on the chair’s function (the chair’s front is where the person sitting on it would be facing), the other based on the chair’s shape (the chair’s front is its more prominent and elevated part, i.e. the part normally used to support the person’s back). The complex three-way contrast leads to multiple ambiguities and extensive inter- and intraspeaker variation in reference frame use. I explore the structure of that variation and argue that the same factors are at play as previously reported for the choice of a reference frame in other languages. In particular, that choice correlates not only with the degree to which the Ground object is functionally asymmetric, but also with the choice of a particular lexical item used to describe the spatial relation. Lexical items referring to more natural and functionally prominent asymmetries (e.g., front/back) are more likely to be associated with the function-based intrinsic reference frame than lexical items referring to less prominent and human-specific asymmetries (e.g., left/right).
Conclusion
The study of major dimensions of cross-linguistic variation at a more fine-grained level can lead to insights into the way expressions of different types co-exist within one language. The same underlying principles can be seen at work behind different instances of language-internal variation. The principles discussed in this paper suggest that (i) in encoding motion events, speakers estimate how likely directional meaning is to be inferred from context; (ii) in choosing between more and less conventional expressions, speakers are sensitive to the spatial relation’s frequency; and (iii) in choosing the reference frame, speakers pay close attention to the prominence of certain aspects of the spatial relator’s lexical meaning.

The same principles show up as relevant to speakers’ contextual preferences, seemingly categorical lexical splits, and patterns of language change. They likely reflect general principles of human spatial cognition, and interact in complex ways with the heterogeneous lexical and morphosyntactic resources that the particular language has developed.
Variation in Spatial Language as a Form of Adaptation: An Evolutionary, Experimental Approach

JONAS NÖLLE
Centre for Language Evolution (CLE)
University of Edinburgh
Email: jonas.noelle@live.de

Why do languages differ so dramatically in grammatical and conceptual forms? Usually, linguistic diversity is attributed to random changes that accumulate and become conventionalized. However, over the past years an increasing amount of studies emerged suggesting that linguistic structure can additionally adapt to social, physical or technological aspects of the external environment (see Lupyan & Dale 2016 in press for a review). This includes climate or landscape, social factors like population size, language contact and even genetic predisposal due to ecological adaptation.

Spatial language is arguably one of the most fundamental domains of linguistic practice, as all humans inhabit a 3D space and therefore need to reference its qualities to interact successfully (e.g., locations, topology, relations between objects etc.). Different speech communities have found very different solutions to this problem leading to striking diversity in how motion, topological or distant relation (“Frames of Reference,” FoR) are expressed (Levinson & Wilkins 2006). This has often been cited as an argument for cultural evolution leading to diversity via conventionalization (Evans & Levinson 2009). However, since spatial language has also been used as prime argument for the claim that language restructuring general cognition, differences have usually been attributed to arbitrary conventions leading to language structure that, in turn, affects cognition (Haun et al. 2011). Accounts emphasizing the possibility of ecology-induced cognitive styles or the environment (e.g., urban vs. rural) affecting the choice in FoR have been criticized or accused of simplifying the issue (Levinson et al. 2002, Majid 2004). And yet, it remains counterintuitive that clearly geographically grounded systems should have emerged independently of the environment: Languages solely relying on the absolute FoR often directly integrate landmarks from the surrounding environment like slopes in Tzeltal (Levinson & Wilkins 2006) or rivers in Mian (Fedden & Boroditsky). Intuitively, a certain strategy should be more adaptive in a certain environment and get selected over time. Left/right may not be helpful in a desert where absolute directions seem more reliable. In a dense jungle or urban area, however, far sight is disabled; relative/intrinsic strategies might become adequate. Only recently, fieldwork has begun to crosslinguistically test for these relationships by comparing spatial language between related/same languages spoken in different environments and distant languages spoken in similar environments (Palmer 2015, Bohnemeyer 2015).

In order to test for relationships between spatial language and environment, I suggest to complement this recent correlational approach with experiments that attempt to model the evolution of spatial language per se, possibly uncovering mechanisms that contribute to the diversity we can observe. Recently, we conducted an experiment to test whether linguistic
conventions that emerge spontaneously in dialogue—the predominant mode of communication and arguably the starting point for most language change—are affected by the environment. We used Garrod and Doherty’s (1994) maze game, a collaborative task where dyads have to communicate about spatial locations in order to guide each other through virtual mazes. The original experiment showed that in this task-oriented dialogue, dyads automatically routinize a specific strategy to describe positions, which would even spread when partners were exchanged leading to “communities” that adhered to a specific convention. We introduced three conditions that systematically varied maze layouts (Fig. 1).

As predicted, different linguistic strategies became routinized in response to these environmental conditions. Players in the regular condition would rely more on the MATRIX strategy conceptualizing the maze as a coordinate system (“go to D2”), while players in the irregular and stratified conditions relied significantly more on figural shapes or horizontal displacements that were made salient (“Go to the head,” “The switch in the second row, left”). This suggests that linguistic interactions and routines are not only the result of automatic priming mechanisms, but also highly sensitive to factors of the shared task environment. Interaction in specific environments can influence how the very same coordination problem (in this case communicating spatial positions in the maze) is conceptualized and translated into linguistic conventions (outcompeting equally valid alternatives).

Following these results, an additional series of experiments is planned to test whether such mechanisms are not only at work in dialogue, but could constrain emerging communication systems as such (Nölle, in progress): Subject pairs have to describe spatial positions to each other to solve the same task in varying immersive, virtual environments, while the use of conventional language is restricted. They have to develop a novel, graphical communication system. Manipulating the environment, e.g. by contrasting flat vs. elevated, dense vs. sparse vegetation, or landmarks vs. none, allows testing whether such differences will systematically affect the “languages” that emerge and evolve in these settings. This work thus aims at showing that linguistic adaptation is a possible evolutionary mechanism that contributes to the diversity in spatial language that we can observe.

References
The Socio-Topographic Model: 
Socioculturally Mediated Responses to Environment Shaping 
Universals and Diversity in Spatial Reference

BILL PALMER
Endangered Languages Documentation, Theory, and Application Research Program
University of Newcastle
Email: bill.palmer@newcastle.edu.au

Considerable diversity in spatial reference across languages is well attested (Levinson 2003; Levinson & Wilkins 2006; Pederson et al. 1998). Nonetheless, universal tendencies can be detected within this diversity, and salient landscape and other external-world features seem to play a role in the detail of systems involving absolute Frame of Reference (FoR) (Palmer 2002, 2015), and even in FoR choice (see Majid et al. 2004; Bohnemeyer et al. 2014). However, those aspects of the environment that are perceived as salient vary across cultures, and the nature of the interaction between humans and their environment plays a crucial role, as seen in demographic variation within individual languages in tendencies in FoR choice (e.g. Pederson 1993), and in geocentric versus egocentric strategies more generally (Palmer et al. 2016).

Spatial relations of any type can be expressed using language. However, in perhaps all languages some spatial concepts are lexicalised or expressed in a grammaticized way, while others are relegated to periphrastic expression. These lexicalized and grammaticized expressions are key to understanding the extent to which spatial reference displays universal tendencies, and the extent to which variation is systematic.

Geocentric spatial reference, including the use of absolute FoR, invokes aspects of the external world, suggesting that linguistic systems are responsive to the environment in which a language is spoken (Palmer 2002). This in turn predicts that aspects of systems of spatial reference will correlate with salient aspects of the physical environment. Palmer (2015)formulates this as the Topographic Correspondence Hypothesis (TCH), a tool to test the extent to which linguistic spatial systems correlate to environment in ways that can account for aspects of spatial reference that are universal or vary in systematic ways. To test TCH, Palmer (2015) proposes the Environment Variable Method (EVM), an approach that treats environment as a controlled variable. TCH makes predictions along two parameters: (A) that a single language spoken in diverse environments will display commensurate diversity in spatial reference; and (B) that diverse languages spoken in a single environment will display commensurate similarities in spatial reference. EVM tests (A) by holding the language constant and varying the environment. Prediction (B) is harder to test, because while the environment is to be held constant and the language varied, the environment cannot be held constant to the extent of investigating diverse languages in a single location, as it would be impossible to rule out similarities between languages arising from contact. Instead, language loci that are as similar as possible are to be used.
To test TCH and cast light on the relationship between spatial reference and environment, a research team comprising Palmer, Alice Gaby, Jonathon Lum and Jonathan Schlossberg are investigating spatial reference in languages spoken in the topographic environment of the atoll, in a three-year project funded by the Australian Research Council. Atolls are an unusual environment for human habitation, comprising narrow strips of land around a central lagoon. A field-based preliminary study of spatial reference in atoll-based languages (Palmer 2007) found similarities in spatial systems in four languages, including an atoll-specific lagoonside-oceanside axis. We are testing TCH in atoll-based languages by investigating spatial reference in Marshallese (Oceanic, Marshall Islands) and Dhivehi (Indo-Aryan, Maldives). Following EVM, a baseline language-environment pairing of Marshallese spoken on an atoll is compared: along one parameter with Marshallese spoken on a non-atoll island and in urban Arkansas US; and along the other with Dhivehi spoken on an atoll topographically similar to the Marshallese site.

Identical experimental elicitation techniques including several newly devised experiments were used in all locations to ensure comparability of data, and data was subject to quantitative analysis.

The study’s findings weakly support TCH. For example, both languages employ a landward-seaward axis correlating to the boundary between land and sea. However, in Marshallese this is only used at sea, while in Dhivehi it is used on land, with only one term also used at sea. Further, the distinction between an island’s lagoonside and oceanside is lexicalised in both languages, but in Dhivehi these terms cannot participate in grammaticized constructions, while in Marshallese they frequently do. Some of our quantitative findings also support TCH. In atoll Marshallese, for example, 72% of location descriptions were geocentric or cardinal, and only 15% egocentric or intrinsic, while in urban Arkansas only 5% were geocentric or cardinal and 71% were egocentric or intrinsic, supporting earlier findings of an urban dispreference for absolute/geocentric reference.

However, our quantitative analysis revealed a more nuanced picture than TCH alone allows. While both languages provide a similar range of strategies for spatial reference, strategy preference varies significantly between the languages. For example, in atoll Marshallese, 72% of location descriptions were geocentric or cardinal and only 11% involved intrinsic FoR, while in environmentally similar Dhivehi, only 25% of location descriptions were geocentric or cardinal and 35% were intrinsic. Even more significantly, our findings introduced a crucial caveat to TCH: social and cultural factors mediate between language and environment, such that a simple predictable relationship between the two does not exist. Lexicalized and grammaticized systems of spatial reference may correlate to aspects of the environment, but the extent to which they do, and which aspects of the environment are invoked, varies on the basis of both affordance, and degree and nature of cultural interaction with the environment. For example, in Dhivehi fishing communities, 77% of orientation descriptions were geocentric or cardinal, while in non-fishing communities, engaged primarily in white collar work, only 35% were. Significant variation was also observed on the basis of gender and age.

In response to these findings we have formulated the Socio-Topographic Model (STM) (Palmer et al. 2016). Major environmental features tend to be salient to humans and appear
to play a role in constructing conceptual representations of space that then interact with linguistic spatial expressions. However, cultural and social factors, as well as the affordances of the environment itself, mediate in the relationship between humans and landscape. STM models the interplay of the physical environment of the language locus, sociocultural interaction with the environment, and the linguistic repertoire available to speakers (Figure 1).

Socio-Topography is defined in terms of: natural topography (broadly construed, including path of sun, prevailing winds etc); the built environment; affordance; and sociocultural interaction with the natural and built environment. Socio-Topography is culturally “constructed”: Humans modify their environment, and conceptualise existing topography in terms of use, associations and meanings attached to it. Consequently, elements of the local landscape that are not attended to by some cultures will be prominent to others, and factors such as scale may be attended to by some cultures but less so by others.

**Figure 1: The Socio-Topographic Model**

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Spatial referencing is unique to humans, as humans have the capacity to identify and communicate the location of landmarks via the use of language. Universally, it is a necessity that animals navigate to find landmarks important to their survival, such as food and shelter. However, most animals rely on bottom-up processes (i.e., their senses) to locate these landmarks because they do not have access to language as a means of communication. For example, a rat relies on its sense of smell to locate food but it cannot verbalize where the food source is located to other rats. Although humans share the ability to use their senses when encoding an environment, they also have access to top-down processing by using language (or maps) to communicate important geographical information to each other. Traditional navigation studies focus on how rats and humans use their senses to spatially encode an environment (e.g., vision). These studies depend on participants using bottom-up processes to learn the spatial layouts of environments. However, because humans have access to language, there must be differences in how humans code an environment compared to rats. Thus, it is integral to study the role language plays in human navigation.

Language is multifaceted, in that different languages rely on varying cues when describing location. For example, Brown and Levinson (1993) found that the frame of reference dominant in a language changed how someone who spoke that respective language coded an environment and that people who spoke different languages coded environments differently because their frame of reference was different. Similarly, Munnich, Landau, & Dosher (2001) found that people who spoke different languages coded spatial representations differently. However, when these same people learned these spatial representations non-linguistically, there were no differences in encoding. These studies show that our dominant language shapes how we locate landmarks in the world. Because there are so many languages, there is divergence in how we linguistically encode and reference landmarks. As such, some researchers have focused on how animals, who universally use their senses, locate themselves and landmarks in the world. All animals, including humans, must use their senses to locate themselves in the world. As such, some researchers have opted to study spatial memory in both humans and model organisms. Rats have been a preferred model organism of spatial memory research because of their similar neurophysiology to humans (e.g., the demonstration of place cells in both humans and rats, see Ekstrom et al. 2015). When rats locate a landmark or reorient themselves, they take many things into account, including the geometry and features of their environment (Cheng 1986). For example, in studies where a rat must locate a trained corner in a rectangular enclosure, it can use wall length (geometry) and wall color (feature) to identify the trained corner. There is an ongoing debate that surrounds whether rats and other animals focus more on the geometry or the features of an
environment. Many studies support that rats use geometry because when features of an environment are removed, rats will consistently return to a desired corner of the environment (Cheng 1986; Margules & Gallistel, 1988; Benhamou & Poucet, 1998). Yet how linguistic codes affect geometry versus features remains unknown and understudied.

Developmental studies attempt to contribute to the feature versus geometry debate as well. These studies show that children generally use geometry to locate a target (Learmonth, Newcombe, & Huttenlocher, 2001; Hermer & Spelke, 1994). There have even been cases where children neglect to use features at all, despite remembering them in recognition memory tasks (Hermer & Spelke, 1994). When adults are studied, however, we see more ambiguity in whether features and geometry are used. This is partially due to language: when adults undergo a verbal shadowing task, it is more difficult for them to use geometry to differentiate corners (HermerVazquez, Spelke, & Katsnelson, 1999). These results imply that language is integral for adults to orient themselves and to locate landmarks, which is where my experiments come into play. Yet exactly how this affects top-down coded preferences for geometry vs. features is not known.

My experiments propose to disentangle the role of language in how human adults orient themselves in the world with respect to geometry and features. Instead of focusing solely on spatial memory and bottom-up processes, these experiments attempt to see how language is used as a tool for humans to locate themselves spatially in the world. I propose to use a simple paradigm, where participants are instructed to use either the geometry or the features of uniform environments (each environment has the same geometry and features) to see how language affects how geometry and features are used. As I will be instructing participants whether to use the geometry or features of an environment, this experiment will also inform how verbal communication affects subsequent spatial encoding.

There are three potential interesting outcomes from this project. One is that, depending on the linguistic code (i.e., pay attention to the square or red wall), pointing accuracy is better depending for the attended (instructed) component. This would argue for the importance of top down coding irrespective of feature versus geometry. Other potential outcomes are that pointing accuracy is better for the geometry or feature regardless of linguistic codes. These two potential outcomes would suggest that features or geometry are bound in a more bottom up fashion and are not strong activated by top down cues. All of three of these outcomes, though, would be important to understanding how linguistic codes can interact with geometrical and feature binding when learning a spatial environment. These results will be ready to disseminate by start of the Universals and Variation in Spatial Referencing across Cultures and Languages. I am excited to receive input for future experiments to further understand how humans use natural language to locate themselves in the world, as I am a new graduate student in the spatial memory field.

References


Some Concerns about Methodology on Spatial Representation

ERIC PEDERSON
Discourse Lab, Department of Linguistics
University of Oregon
Email: epederso@cas.uoregon.edu

I would like to take the opportunity of this Specialist Meeting to raise a number of methodological concerns which have troubled me over the years. Many of these worries are not new to the field, but they remain largely unresolved in much of the work conducted today even while some of these concerns are strong enough to potentially invalidate the interpretations of the results. As my own work has concerned the relationship between linguistic representation and performance on ostensibly non-linguistic tasks, I would address each of these in turn.

Whether the goal is typology or comparison with non-linguistic performance, linguistic elicitation presumes relevant variation. As any second language learner can attest, one is biased to assume that translation equivalents across languages are uniformly equivalent in the absence of contrary indication. Unfortunately, when working with other languages, it is often years of work, if ever, before one discovers that terms across two languages which seem to have the same functional equivalence in most contexts, nonetheless may have substantially different underlying semantics. This wouldn’t be a problem if language elicitation did not rely so heavily on translation, but avoiding translation is a more difficult problem than just working monolingually. For example, I was occasionally corrected in my use of the Tamil deictic verbs “go” and “come.” It turned out that the translations are largely accurate, but the Tamils I was working with tended to use “come” as the more generic motion verb (e.g. for describing motion passing in front of the speaker) with “go” being more specialized for motion away from the speaker. I was sometimes corrected by Tamils who were fluent in South Indian English and they were puzzled by my confusion because they used English “go” and “come” in the same way as for their native Tamil—believing, like me, that these forms were naturally equivalent across all situations.

As another example, consider the problem of translating prepositions from one language to another. Without knowing the exact extensional set for the form in one language it is impossible to predict which would be the appropriate spatial term in another language. Indeed, the domain of Germanic prepositions is one of the last domains to be mastered even, e.g., by German speakers fluent in English. Even for analysis of naturally occurring language production, we cannot ever be certain of what an utterance can mean without translation unless we know not only the exact context of use. A common solution to this problem is to use an “etic” stimuli set such as the Topological Relations Picture Series or the “Tomato films” when comparing languages. However, even this can only be a solution if we are confident of the particular intended construal that the speaker is representing. (e.g., Is the ball in or on the field?) It is a rare study which explains what method was used to ensure clear and consistent interpretation of that which is being described.
A further problem is the nature of the usage of a form. Obviously, we can only compare forms when we can equate or at least identify the context of use. But what constitutes context for elicitation purposes? Are two “exact” translation equivalents identical if one is broadly used in one language, but only used in the other language in very specific circumstances? Can the semantics of two forms be even remotely similar if the one form has a number of paradigmatically contrastive alternatives, while the other form alternates with only another broadly used form? As a trivial example, English at is often used as a translation of the locative case in many languages. However, the use of at is remarkably specific and nuanced in ways quite distinct from the more general locative case in most languages.

This of course, leads also to the problem of translations of instructions to participants in non-linguistic tasks as well. I have been in countless hours of discussion with many researchers on how one might reliably translate concepts in experimental instructions such as “same” and “similar.” If one is uncertain how such translations are being interpreted in a task, then we must honestly say that that we don’t actually know what task the participants believe themselves to be engaged in.

As any experimentalist knows, much hinges on the interpretation of the task far beyond the problem of translating instructions. Perhaps no experimental paradigm brings this more to the fore than triads tasks in which participants are asked to group a pivot item with either of two target items—each of which clearly relate to the pivot in distinct but valid ways. In debriefing, participants commonly state that they alternate solutions, guess what the experimenter is really asking for, or just pick one solution when they feel that the other was an equally acceptable answer for them. (This is quite distinct from, e.g., AXB tasks in which the targets vary along a single perceptual dimension such as voice onset in a phonetics perception experiment.) One might think that this fundamental problem with triads tasks would render them nearly useless, yet they remain one of the more popular experimental designs especially in the challenging area of comparing linguistic and non-linguistic representations.

I will conclude with one final example: the Animals in a Row task, described in Pederson et al. 1998 and elsewhere. This task was a memory task in which subjects were presented with three animals (of an available four) in a line transverse to the participant on a table or mat in front of them. They were then taken to another room or substantially away from the first table and simply asked to rebuild the line of animals in the second location. The original design combined two critical features: First, the participants were presented with tables in a 180-degree rotation from the participants such that the orientation of the line upon reconstruction could be interpreted as consistent with either an egocentric or a geocentric memory encoding of the original display. Importantly, the 180-degree rotation was a simple consequence of traveling to a different and remote table and as such was not a particularly salient aspect of the experiment for the participants. There have been a number of quasi-replications of this original design which simply spun participants around 180 degrees making this rotation quite a prominent part of the design for them and presumably inviting an interpretation of this feature.
The second critical feature is that the dependent variable was not the order of the animals, but rather the facing orientation of the animals when the line was rebuilt. Participants clearly understood the task as about the selection and order of the animals and not particularly about the orientation. (I have recordings of subjects repeating “horse, pig, sheep; horse pig sheep” as they march from one room to the other, but no one adds “all facing to the East.” In other words, the dependent variable is covertly embedded in an otherwise transparent task, which reasonably ensures that the response in orientation is essentially an unreflective or “natural” response, presumably indicating an underlying representation of the orientation rather than an attempt to guess the purpose of the design. It is remarkable how many pseudo-replications of the Animals in a Row task have changed these two features—without explicit motivation—and received unsurprisingly different results. Witness the exchange between Li & Gleitman and Levinson et alibi. (2002).

At the Specialist Meeting, I would like to discuss these methodological issues and work toward a more common understanding to improve our future empirical designs.
Interactions between Strategies of Spatial Referencing: A Case Study on Diidxazá Spatial Descriptions

Gabriela Pérez Báez
Curator of Linguistics
National Museum of Natural History
Smithsonian Institution
Email: perezbaezg@si.edu

The present paper provides a synthesis of work carried out on spatial descriptions in Diidxazá (Juchitán/Isthmus Zapotec, Otomanguean). The research takes a semantic typology approach for the analysis of descriptions of topological and projective relations (frames of reference, FoRs). Data from elicitation and from linguistic and non-linguistic experimental tasks provides a comprehensive view of the strategies used by Diidxazá speakers to organize space and describe the location of objects in it. The analysis of topological descriptions provides initial data on the use of meronyms, mainly body part-derived meronyms, to describe the location of a figure in relation to a part of a ground. Further investigation on the mechanisms enabling the semantic extension of body part-derived meronyms and the extent of their use in spatial descriptions reveals an interface between a meronymic system of spatial relators and FoR preferences. This provides a wide-ranging understanding of spatial description strategies as implemented by Diidxazá speakers and of their division of labor. Further, this ramifies into new lines of inquiry such as the analysis of unexpected functions of otherwise dispreferred strategies, as well as language contact phenomena.

The use of body part-derived meronyms for spatial description is well acknowledged as a noteworthy feature of Mesoamerican languages (Campbell, Kaufman & Smith-Stark 1986 *inter alia*). This has been documented for Otomanguean languages including Zapotec languages (MacLaury 1989, Lillehaugen 2006, Pérez Báez 2012; see also chapters in Lillehaugen and Sonnenschein (eds.) 2012), Chalcatongo Mixtec (Brugman 1983, Brugman & Macaulay 1986) and Copala Triqui (Hollenbach 1987, 1988); for the Mayan languages Tzeltal (Stross 1976, Levinson 1994) and Tzotzil (de León 1992); as well as for Tarascan (Friedrich 1969, 1970, 1971), Totonac (Levy 1992, 2006) and Cora (Casad 1982). Pérez Báez 2012 and forthcoming, explore the process of semantic extension of Diidxazá body part-derived meronyms. Data from various elicitation tasks conducted between 2003 and 2009 with over 20 native Diidxazá speakers analyzed within the framework provided by the Structure Mapping Theory (Gentner 1983, *inter alia*) provide evidence in support of an analogy-based process of semantic extension compatible with the

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1The experimental tasks include a novel objects part identification task developed by the Spatial Language and Cognition in Mesoamerica project ([https://www.acsu.buffalo.edu/~jb77/MesoSpaceManual2008.pdf](https://www.acsu.buffalo.edu/~jb77/MesoSpaceManual2008.pdf)), and the Ball and Chair and New Animals in a Row tasks, also designed by the MesoSpace project after the Men and Tree and Animals in a Row tasks developed by the Cognitive Anthropology Research Group at the Max Planck Institute for Psycholinguistics (Danziger 1992, Levinson and Schmitt, 1993).

2Figure and ground are understood here as per Talmynote:184).
process proposed, for instance, in MacLaury 1989 for Ayoquesco Zapotec. Additional elicitation conducted notably with tools as stimuli suggests that the analogy-based process does not exclude an algorithm-based process such as the one proposed in Levinson 1994 for Tzeltal Maya. Beyond the description of the process of semantic extension of body part-derived meronyms, the analysis of these relators in spatial description uncovers the interaction between the meronymic system and a FoRs system. Data collected through referential communication tasks conducted in the field with 12 native speakers of Diidxazá show that the relative FoR is clearly dispreferred (Pérez Báez 2011). In orientation descriptions, the relative FoR was not used at all. In descriptions of figure-ground arrays, the relative FoR was used in only 3% of the documented descriptions. In a non-linguistic task administered to 19 native Diidxazá speakers, only one participant in one trial produced a response consistent with the relative (or the direct) FoR. This bias prompts the question as to what function(s) such a constrained FoR might have when used.

The notion that speakers of some Mesoamerican languages exhibit a bias against relative FoRs has been discussed in a number of works (Brown and Levinson, 1993; Levinson, 1996, 2003; Brown and Levinson, 2009; Pérez Báez 2011, Polian and Bohnemeyer, 2011, Hernández-Green et al 2011). However, there are no studies, to my knowledge, whether their constrained use might correlate with specialized function(s). The Diidxazá data suggests that the relative FoR serves an ambiguity resolution function: in cases where a meronym—used to refer to the part of the ground in relation to which the figure is to be located—might refer to more than one part (as when referring to one of the two sides of a chair, the relative FoR serves to identify the correct part. The relative FoR is not the only disambiguating strategy. However, it is only in this context that the relative FoR was used.

The relative FoR and the meronymic system interact in a similar way (Pérez Báez, forthcoming). Body part-derived meronyms in Diidxazá can be assigned to objects even in cases where an object might have few or no discernable parts, for example a sphere. In these cases, the relative FoR enables a structure mapping between an abstraction of the human body—and not the actual body—in canonical vertical position as the source domain and, say, the sphere as the target domain (Pérez Báez forthcoming). This mapping can only be done in the context of a projection from the observer/speaker’s perspective. In other words, on the basis of a relative FoR.

Further, the Diidxazá data shows that the relative FoRs are generally encoded by Spanish loan words referring to the ends of the sagittal and transversal axes rather than by native Diidxazá words. This suggests that the relative FoR has a particular function linked to the use of Spanish loan words. This finding points to yet another line of inquiry that has received little attention: spatial referencing in language contact situations. Hernández et al 2011 report a similar marked function of the Spanish word lado “side” in relation to the use of the relative FoR in San Ildefonso Tultepec Otomi (Otomanguean). McComsey 2015 reports on FoR use among speakers of Diidxazá, Spanish and both. Bohnemeyer et al 2015 report on contact diffusion of FoR preferences. Yet, reports on functions of linguistic spatial referencing strategies associated with language contact phenomena are lacking in the literature.
In sum, this paper demonstrates the value of comprehensive typology-based analysis of data collected in the field through a combination of elicitation and experimental tasks, both linguistic and non-linguistic. Further, it advocates for a systemic analysis of language in spatial referencing to uncover new lines of inquiry that may yield a more broad-reaching understanding of the relation between a variety of spatial referencing strategies as well as the relation between language, cognition and social and cultural contexts.
Universals and Variation in Spatial Referencing

MARCO RAGNI
Cognitive Computation Lab
University of Freiburg
Email: ragni@informatik.uni-freiburg.de

The interplay and conflict of spatial referencing in cultures by language and internal (preferred) mental models: Are preferred mental models universal?

Spatial referencing in cognitive agents such as humans often depends on internal mental representations that are formed by experiences, the formal structure of problems, cognitive limitations, and the interaction with other cognitive agents by using language. Such mental representations can be more visually (e.g., a landmark) or purely relational (e.g., an orientational relation between spatial objects on a map). Recent results in cognitive psychology show that using relational expressions may trigger more visual features that in turn can lead to an impedance effect (Knauff, 2013). This visual impedance effect has been often experimentally replicated in western cultures especially in English/German. A possible generalization of this probably universal effect (some explanations aim at a memory related source of additional activation) is still an open question. Currently, we are implementing this experiment in Chinese and aim to test it through Internet based experiments and to compare it with experimental results from a German sample.

To understand how such internal representations (that are influenced both by more universal features like the internal cognitive architecture and by potentially differing variable features that may depend on different cultural influences) we showed that there is a difference in topological relations (such as part of, or contained) between German and Mongolian students (Knauff & Ragni, 2011). Although topological relational information might be considered cross-culturally universal, we did find a difference in the variation of the mental models. That clearly hints at non-universal processes. On the other hand, the preferred mental model was stable across the cultures. These preferred mental models are formed based on spatial principles that apply for information that contains an implicit order (Ragni & Knauff, 2013). They allow, in fact, to explain systematic errors in representation and reasoning. It is important to consider different reference frames that in turn can imply different cognitive complexities. The language used was in its nature qualitative and formal features are known (Ragni & Wölfl, 2005). The advantage of a formalization of these natural language approaches was that even problems in robotic navigation could be solved (Moratz & Ragni, 2008) and so they seem to be possibly universally applicable and in some sense effective. But again, these findings are influenced by a western-style approach. It is still an open question if these representations extend to other representations that are used in other cultures.

By using transcranial magnetic stimulation (TMS) we were able to demonstrate that in uncertain relational reasoning the construction and manipulation can be neurally localized in the posterior parietal cortex (e.g., Ragni et al., 2016).
The mental representations formed in cases of uncertain spatial information is especially interesting as this case may apply most often in everyday spatial descriptions, e.g., for navigation. Spatial relational information can depend on the domain it refers to: There can be small-scale spaces (often table-top scenarios) or large-scale spaces that are connected to cardinal directions, for instance. Can principles for mental construction that are found for one domain easily be transferred to another one? This is another open question.

Finally, a recent analysis indicates that verbalizing spatial mental models indicate at “natural” relations as opposed to formal representations (Tenbrink & Ragni, 2012).

My core interest aims at a possible dissociation between the influence of spatial language (across cultures) and the internally built mental representations that are triggered by internal structural parts often considered to be universal. Taking these different levels together can be a necessary step towards a precise computational and cognitive theory for the human relational representation and reasoning and it is extended towards culture-specific and universal cognitive processing principles. A related question is: How can such universal differences in spatial cognition be tested across language and cultures? This may lead to an identification of potential benchmark problems that could be focused on to test the structural/language distinction.

**References**


approach cross-language universals and variation, in the spatial semantic domain as in others, by asking what cognitive and communicative forces may give rise to observed cross-language patterns. My colleagues and I pursue this question in large part using computational models and methods.

Recent work along these lines in my lab has focused on topological spatial relations, of the sort investigated by Bowerman, Pederson, Levinson, and their colleagues at the MPI Nijmegen. Earlier well-known analyses of these data have suggested a general picture of wide but constrained variation in spatial terms across languages—exemplified for instance by the in-on continuum noted by Bowerman and Pederson. They identified a continuum of spatial relations ranging from a prototypical English “in” relation at one end (an apple in a bowl) to a prototypical English “on” relation at the other end (a cup on a table), and found that although languages differ in how and where they partition this continuum into spatial categories, the resulting spatial categories always pick out connected regions of the continuum—yielding, in effect, a semantic map for a central part of the topological spatial domain. Our group has generalized this finding to a much broader range of spatial scenes, using an algorithm for automatically inferring a semantic map from cross-language data. Using this algorithm, we produced a novel semantic map of topological spatial relations over a larger set of stimuli than those considered by Bowerman and Pederson—and separately automatically produced the semantic map for indefinite pronouns that Haspelmath had produced by hand.

Research of this sort, based on cross-language semantic data, has answered some important questions: it has allowed researchers to specify descriptive generalizations over cross-language data, and to infer apparently underlying universal semantic structure. However, there is another relevant question that appears to require additional sorts of data as well: can one firmly link findings in the semantic typology of spatial relations to independently assessed non-linguistic forces, such as those of cognition and communication? Our group has been seeking such a link.

We have been computationally testing a hypothesis that is rooted in the functionalist tradition. That hypothesis holds that the wide but constrained variation seen in spatial semantic systems across languages may reflect a functional need for efficient communication: a need to communicate informatively, but at the same time simply—that is, with minimal expenditure of cognitive resources. These two forces trade off against each other: a fine-grained semantic system that partitions a domain using many distinct terms is highly informative in that it allows precise communication; but because it contains many terms, it is complex, not simple. In contrast, a coarse-grained system is comparatively simple, but does not support precise,
informative communication. We have been exploring the proposal that semantic systems across languages navigate a near-optimal trade-off between these two opposing forces, and thus achieve efficient communication. Concretely, we predict that semantic systems will strongly tend to be nearly as informative as possible for their level of complexity, and nearly as simple as possible for their level of informativeness. On this view, different semantic systems may constitute different language-specific solutions to the shared functional goal of efficiency in communication. Our group has found support for this idea in the domains of color, kinship, spatial relations, number, and artifacts. Here, I briefly sketch our findings in the spatial domain, and highlight some important questions left open for discussion and future research.

Testing the efficiency proposal in the spatial domain requires: (1) a cross-language sample of spatial semantic systems, (2) an independently assessed cognitive account of the spatial domain, and (3) a means to test the communicative efficiency of the semantic systems in (1) relative to the cognitive structure identified in (2).

Language sample. We have worked with a language sample comprising nine languages examined in an earlier study by Levinson and colleagues (Basque, Dutch, Ewe, Lao, Lavukaleve, Tiriyó, Trumai, Yélî-Dnye, and Yukatek), supplemented by two languages to which we had access: English, and Majiiki, an under-documented language of Peruvian Amazonia which is being studied by Lev Michael’s group at UC Berkeley. We thank our colleagues at the MPI and at Berkeley for providing access to these valuable data. For each of these languages, we considered naming data collected relative to the Topological Relations Picture Series or TRPS.

Cognitive characterization of the domain. We independently assessed the cognitive structure of this domain by asking speakers of English and Dutch to sort the TRPS stimuli into piles based on the similarity of the spatial relations portrayed. The resulting pile-sorts varied widely within language, but the overall similarity structure of the domain as revealed by the pile-sorts was broadly similar across speakers of the two languages. Still, the pile sorts did reflect the sorter’s native language to a limited extent—an interesting observation that deserves discussion in its own right and that we have pursued in a separate line of work. For present purposes however we approximated a presumed universal conceptual similarity space by averaging together the similarity structure revealed in pile sorts by speakers of these two languages. Subsequent pile-sort investigations with speakers of other languages, including non-Indo-European languages, have revealed much the same similarity structure, so we are reasonably comfortable assuming it as an approximation to a universal space.

Testing the efficiency hypothesis. We computationally assessed the informativeness of each language’s spatial system, and compared that to the informativeness of a large number of hypothetical semantic systems, all of which had the same complexity (number of spatial terms), and the same number of spatial relations per term, as the target language. These hypothetical systems were constructed by random graph traversal of the spatial semantic map mentioned above. Informativeness was defined as the extent to which a given system supports accurate mental reconstruction by a listener of a speaker’s intended spatial meaning; accuracy was
measured in terms of the empirically derived conceptual similarity space specified above. We found that for each language in our sample, the spatial semantic system of that language was more informative than almost all hypothetical systems considered—suggesting that these attested systems are each near-optimally informative about spatial meaning, given their level of complexity, relative to this comparison set. These findings mirror analogous results from other semantic domains such as color, kinship, and number. Our results are consistent with the view that spatial semantic categories across languages may adapt under functional pressure for efficient, informative communication.

These findings suggest certain answers, but they also raise questions. Does this account generalize to other languages? What exactly is the process by which categories (hypothetically) adapt themselves to functional needs? To what extent are communicative needs themselves culture-specific vs. universal—and to what extent do semantic systems reflect culture-specific communicative needs? Finally, what is the detailed character of the underlying universal spatial conceptual space, if indeed such a thing exists? We have assumed its existence and approximated it using similarity judgments—but is a more principled and firmer cognitive foundation possible? Our ongoing work is exploring some of these issues.
Toward Universals and Variation: A Comparative Analysis of Noun Categorization in Spatial Expressions

KONRAD RYBKA
University of California, Berkeley
Email: konrad.rybka@gmail.com

Cognitive geography asks the question whether “tabletop” entities (e.g. bowls, apples, tables) are cognized differently from entities on the geographic scale (e.g. mountains, villages, rivers) (e.g. Mark 1993; Smith & Mark 2001, 1999). Cognitive geographers such as David Mark and colleagues suggest that the answer is YES. They claim that geographic entities “are tied intrinsically to space in such a way that they inherit from space many of its structural properties” (Smith and Mark 1999: 248). They go on to assert that these “structural properties” may affect the way such entities are categorized. Independently of cognitive geography, a few semanticians, including Lyons, have also suggested an ontological disparity between geographic and tabletop entities. Lyons and Whorf foresaw, for instance, that the linguistic encoding of the two types of entities could be different (e.g. Lyons 1977; Whorf 1945; Landau & Jackendoff 1993). Keeping these theoretical points in mind, together with the participants of the meeting I would like to look at linguistic data from three unrelated languages: Lokono (Arawakan, Suriname), Makalero (Papuan, East Timor), and Marquesan (Oceanic, French Polynesia). The data show that in these languages geographic and tabletop entities are grouped into distinct linguistic categories. Importantly, spatial language—the locative phrase itself in fact—is the locus of the distinction in question. As such, the analysis of this grammatical phenomenon offers us insights into the types of parameters that are relevant to the cross-linguistic encoding of spatial relations and the spatial cognition in general.

Zooming in on the data, we observe that the three languages group nouns into two distinct grammatical categories defined on the basis of the locative marking they receive in a spatial expression. Let us first have a look at the central concepts of spatial language. In a spatial description there are three indispensable elements: the Figure—the entity to be located, the Ground, the entity with respect to which the Figure is located, and the spatial relation that holds between the Figure and Ground. On closer inspection, the spatial relation can be split into two elements: configuration and directionality (Lestradé 2010; Jackendoff 1990; Talmy 2000). Configurational elements encode the spatial relation that holds between the Figure and Ground. There are topological, relative, intrinsic, and absolute types of spatial relations. It is here that languages show the greatest variation of spatial forms and meanings. Directionality in turn encodes the change of configuration over time, and has only three primary distinctions:

(1) Location: the absence of change of configuration
(2) Goal: the change into a configuration
(3) Source: the change out of a configuration.
Lestrade (2010) claims that the three distinctions are universal in nature, although languages show quite some variation in how they express them linguistically. Let us illustrate the difference between configuration and directionality on English examples:

(1) Location: *The diver is at 50 meters under the sea level.*

(2) Goal: *The diver ascends to 50 meters under the sea level.*

(3) Source: *The diver descended from 50 meters under the sea level.*

In all three examples above *diver* is the Figure and *the sea level* is the Ground. The configurational element *under* tells us where the Figure is with respect to the Ground. The additional modifier *50 meters* makes it more specific. The Location directionality element *at* in (1) indicates that the Figure is at the Ground. When we change to Goal directionality, the element *to* signals that the Figure moves into the configuration. When we change to the Source directionality, the element *from* signals that the Figure moves out of a configuration.

Interestingly too, while configuration may be specified or not (try removing *50 meters under*), a directional choice is always required. The grammatical distinction that we will look at manifests itself only in the directionality component of the spatial expression, not in the configurational component. Let us look at examples from Lokono, in which there are two markers of Location directionality, exemplified below:

(4) *Dayo bithi-ka=de*
    
    my.mother LOC-PVF=1SG.S0
    
    “I am at my mother’s.”

(5) *Kasuporhi–n–ka=de*
    
    Cassipora–LOC–PFV=1SG.S0
    
    “I am at Cassipora.”

In both (4) and (5), the Figure is expressed by the enclitic *=de*, preceded by the perfective suffix –*ka* which is necessary to form a complete predicate. In both (4) and (5), there is no configurational element, which means that the relation is unspecified. In (4), the Ground is expressed by *dayo* “my mother” and the Location directionality element is *bithi*. In (5), the Ground is expressed by a place name *Kasuporhi* and the Location directionality element is the suffix –*n*. In sum, if we remove all the elements that are the same in (4) and (5), we are left with two Location markers *bithi* and –*n* that select different types of Grounds. Both markers encode Location directionality but select different noun types. Since *bithi* can combine also with the question word *hama* “what,” I call nouns that combine with it *what*-nouns. Since –*n* combines also with the question word *halo* “where,” I call nouns that combine with it *where*-nouns. The question arises which nouns combine with which marker and what motivates this type of nominal categorization? In order to answer this question, I look at two more languages, for which there are enough data on the *what/where* split and inventory which nouns take which marker. I would like to discuss with the participants of the meeting the patterns that emerge from the comparison of the three languages—shown in the table below—as well as data from more familiar languages such as English, in which a similar, though less conspicuous, pattern is attested.
The data suggest that a cline from tabletop entities to places (which include geographic entities) underlies the grammatical pattern. The cline shows the likelihood of a noun being categorized as a *what*- or *where*-noun. Yet, the cut-off point between the two categories is language-specific.

What motivates this distribution? Is it the ontological features of the referents as Mark and Lyons predicted? Yes, but not directly. Interestingly, in all three languages the *what*-marking is always more marked than *where*-marking, suggesting that the cline ranges from nouns that are quite marked in the function of Grounds to nouns that are unmarked as Grounds. Not forgetting that this is a linguistic categorization, the cline should be seen as a reflection of the Figure/Ground dichotomy, as generalized over the speakers of a language, rather than a direct translation of the ontological features of the entities. By analyzing the cline, we can observe the types of ontological features that change from prototypical Figures to prototypical Grounds. Instead of defining the concepts of Figure and Ground *a priori*, which has been the case until now, we can therefore let these concepts crystalize from the language data itself. Following this method and by enlarging the language sample, we can also analyze the language-specific cut-off points on the cline to investigate whether cross-linguistically speakers of different languages prioritize different features of Figures and Grounds, leading to the different *what*- and *where*-groupings, and whether there are any universal parameters to the categorization.

<table>
<thead>
<tr>
<th>Nouns denoting</th>
<th>Example</th>
<th>Lokono</th>
<th>Marquesan</th>
<th>Makalero</th>
</tr>
</thead>
<tbody>
<tr>
<td>animate beings</td>
<td>Mary, dog</td>
<td>what</td>
<td>what</td>
<td>what</td>
</tr>
<tr>
<td>objects</td>
<td>chair, tree,</td>
<td>what</td>
<td>what</td>
<td>what</td>
</tr>
<tr>
<td>structures</td>
<td>school, house</td>
<td>where</td>
<td>what/where</td>
<td>what</td>
</tr>
<tr>
<td>landscape features</td>
<td>island, mountain</td>
<td>where</td>
<td>what/where</td>
<td>what/where</td>
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<tr>
<td>places</td>
<td>Amsterdam, inside</td>
<td>where</td>
<td>where</td>
<td>what/where</td>
</tr>
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</table>
Neural GIS—Computing with Cognitive Spatial References

SIMON SCHEIDER
Department of Human Geography and Spatial Planning
University of Utrecht
Email: simonscheider@web.de

When people refer to a location in natural language terms, they use a variety of cognitive spatial reference frames to put this location into perspective [7]. The same place can e.g. be expressed in terms of a speaker centered, object centered or absolute frame of reference, and in a way that accounts not only for the inherent spatial vagueness, but also for the geometry of figure and ground objects [16]. For example, the expression “in front of” refers to a fuzzy location of different shape and size depending on whether the ground object is a church or a spoon on a table. Furthermore, the same location may be translated to “left of” when taking the observer as a ground object. In everyday communication, people effortlessly translate between these perspectives in order to understand what a speaker means [8]. While the different types of cognitive reference frames and their relevance for different language cultures have been studied in considerable depth [12], we still lack models that can be used to actually transform a geometric representation from one cognitive perspective to another [2,14,10,17], and thus to approximate the location that a natural language expression actually refers to [3]. We suggest one reason for this is that current Geographical Information Systems (GIS) are based on crisp reference systems [1], while cognitive reference frames require transformations that can take into account fuzzy locations, translations, rotations and scalings.

Fig.1: How to use neural field transformations in geographic maps?
Such transformation models can be inspired from neural fields [13,5] which are used in robotics and neural science to represent approximate relative locations in terms of arrays of interconnected firing neurons [9]. Inside a neural field, location, distance, direction (angle) and other geometric properties are not a result of crisp measurement, but of the way how neurons in this field are interconnected. For example, in Fig. 1a, the authors of [9] have wired two such fields together to transform a fuzzy absolute one-dimensional position (target field) into a fuzzy object centered position, relative to a fuzzy reference position (reference field). In the resulting field, the dotted center line represents the “origin,” i.e., the fuzzy location of the reference field, and the peak shows that the target location is “left of” the reference field. How can we apply such a method to describe the spatial configuration in a geographic map, such as the one in Fig. 1b?

The trick underlying this method is that the projection takes into account all combinations of fuzzy target and reference positions to determine the relative fuzzy position in the object-centered field. We propose to mimic this behavior with fuzzy vector spaces [6,11,18], which allow us to compute transformations based on fuzzy translations, rotations and scalings. Using this method, we have modeled 6 well-known types of cognitive spatial reference frames [4,7] in terms of fuzzy transformations, and applied them to the geographic map with an observer, a house and a tree (see Fig. 2). The fuzzy location of the tree can now be expressed relative to the positions, alignments and sizes of the observer and the house, without any need of prior discretization. The coordinate systems in Fig. 2 express relative frames of reference, with the
origin denoting either the observer or the house, and the vertical/horizontal axes expressing either Front-Back/Left-Right or (absolute) North-South/West-East directions. Note that the size, shape and location of the tree is transformed relative to the location, size and shape of the ground objects.

Since spatial reference systems and their transformations are fundamental for GIS [15], we suggest that being able to compute cognitive transformations may lead the way towards a Neural GIS. This is a new kind of GIS without a crisp geometry that effectively allows taking human spatial perspectives and computing with locations described in natural language texts. In a neural GIS, a coordinate field denotes fuzzy positions and directions relative to a particular cognitive reference frame, and transforming and intersecting fields allows checking to what degree spatial expressions apply.

References


It seems generally accepted that spatial reference frames are crucially involved in spatial referencing (Levinson, 2003; Logan & Sadler, 1996). Reference frames are means to mentally organize space and they enable distinguishing and labeling different parts of space as well as apprehending and distinguishing different spatial relations. As such, reference frames are indispensable prerequisites for spatial referencing in all cultures and languages. Previous research has distinguished a variety of reference frames that natural cognitive agents are assumed to draw on. In the spatial language domain an influential distinction of reference frames into relative, absolute, and intrinsic frames has been proposed by Levinson (2003, but see also Pederson, 2003) and much research in linguistics has focused on how languages and cultures differ regarding their proclivity to employ these different frames.

I argue that differences in which reference frame is selected need not be indicative of differences in how selection is achieved, that the mechanisms underlying reference frame selection in English are universal as mechanisms for reference frame selection across languages and cultures, more generally, that certain processing steps involved in spatial referencing and the mechanisms realizing them are universal, but that the parameterization or tuning of these universal mechanisms vary across languages and cultures.

Studies on English spatial language use have shown (e.g., Carlson & van Deman, 2008; Carlson, 1999) that spatial referencing requires selecting one of the available reference frames. A recent in-depth study of the mechanisms underlying reference frame selection has identified the leaky competing accumulator (LCA, Usher & McClelland, 2001) model as an accurate account of this subprocess of spatial referencing (Schultheis & Carlson, in press). LCA is a connectionist model with a single layer of units. Each of the units represents one possible reference frame. Each unit receives input from those available sources of information that support the frame represented by the unit. Unit activation increases by accumulating the received input, and decreases due to decay and lateral inhibition between units. Activation is furthermore influenced by unsystematic fluctuations (white noise). Once any unit’s activation grows beyond a prespecified threshold, reference frame selection stops. The selected frame is assumed to be the one represented by the winning unit.

I propose that—insofar as the LCA is an accurate account of reference frame selection for English—the LCA’s structure and workings are universal as a mechanism for reference frame selection across languages and cultures. Given that (a) reference frames are crucial prerequisites for spatial referencing and that (b) all natural cognitive agents have access to a multitude of reference frames, the necessity to select a reference frame for spatial referencing will, arguably,
be of little debate. But what of the more specific claim that reference frame selection is governed by mechanisms as implemented in the LCA? Obviously, there are differences in reference frame selection across languages and cultures. As, for example, the seminal work of Stephen Levinson and his colleagues has shown, there are many languages in which frames are selected for spatial referencing that would rarely be used in English (Levinson, 2003).

However, the observed differences are differences in which frame is usually selected and they need not be indicative of differences in how selection is achieved. Even if the mechanisms are the same, differences can easily arise by different parameterizations of the LCA such as, for example, different inhibitory strength, different rates of decay, and, most notably, different salience/strength of available competing frames. Accordingly, the mechanism underlying reference frame selection may be universal across languages and cultures, while the observed variation across languages arises from adaptations of the universal mechanism.

Are there any reasons to believe that the LCA constitutes a universal mechanism? I think there are, though a more direct test and corroboration certainly seems desirable (see below). One reason is the non-deterministic nature of the selection outcome. Even when strong preferences have been found for one particular frame, alternative frames are also selected for a (small) proportion of trials. This is true not only for English (Li & Gleitman, 2002), but also for languages that exhibit a preference for an absolute frame (Levinson, 2003). Such a pattern of selection outcomes is well in line with the type of competitive, noisy process realized by the LCA. The second reason is that reference frame selection is an important process not only in spatial referencing but also in spatial cognition abilities such as mental image reinterpretation (Peterson, Kihlstrom, Rose, & Glisky, 1992) and perspective taking (May, 2004): In fact, an LCA-like process has been successfully employed to model perspective taking (Schultheis, 2007). Accordingly, the LCA captures an aspect of spatial cognition that is not tightly tied to language and it seems natural to suppose that a mechanism not specifically deployed for language is universal across languages. It is worth noting that the applicability of the mechanisms realized in the LCA to both spatial referencing and spatial reasoning also suggests a new view on the question of linguistic relativity. While many proponents in the debate either argue for (some form of) the Sapir-Whorf hypothesis (Majid, Bowerman, Kita, Haun, & Levinson, 2004; Levinson, 2003) or the opposite (Gallistel, 2002; Li & Gleitman, 2002) the general applicability of the LCA indicates that observed correlations between language and thought may arise from common mechanisms and not from a causal influence of language on thought or vice versa.

As already stated above, it is desirable to more directly test the proposition put forth here by investigating the universality of mechanisms involved in spatial referencing in more detail in various languages and cultures. Questions of particular interest are, for example: (a) How well does the LCA account for selection in other languages and cultures? (b) How well do other mechanisms (e.g., the AVS, Regier & Carlson, 2001) transfer from English to other languages? (c) Is the way in which mechanisms of subprocesses of spatial referencing combine (e.g., LCA and AVS) also universal? (d) How do observed variations in spatial referencing map onto changes in parameterizations?
References


Lessons from Robotics Experiments

MICHAEL SPRANGER
Sony Computer Science Laboratories Inc.
Email: michael.spranger@gmail.com

Fig. 1: (a) spatial setup for robot-robot interactions, (b,c) example of evolution of spatial strategies (chunks), (d) formation of spatial lexicons, (e) acquisition of the German locative system in tutor-learner interactions.

It is probably safe to assume that all languages in one way or another allow speakers to express spatial locations of relevant objects or locations, for instance, for food, good hunting grounds or dangerous areas. It is also very conceivable that spatial language has entered our symbolic species quite early. But despite being so important in communication and also cognitively central to our experience of reality [4, 5], spatial language shows remarkable cross-cultural variation [1, 3, 4]. Through the tedious work of many typologists we now have estimates about the degree to which human spatial languages makes use of environmental and bodily features to develop ingenious strategies for talking about locations, places and spatial configurations. Some cultures use slopes, others salient landmarks, again others rely on projective categories. But languages also differ in how these various conceptualization strategies are expressed in natural language. Spatial knowledge is communicated through all sorts of devices spatial prepositions, adpositions, morphemes, case systems etc [16].

Our understanding of how humans process language from the viewpoint of psychology, psycholinguistics and language typology is getting better, and at the same time we see more work on trying replicate and study these processes using robotic and computational models of language. In this position paper we try to extract some basic principles that have guided our work in this area and try to draw some conclusions about what computational and robotic models can contribute to our understanding of universals and diversity of spatial language. In particular, we are interested in representations, algorithms and their computational properties for processing, their ability to learn and evolve spatial language.

We have developed a series of robotic experiments [14, 7, 8, 15, 9] that show that agents can self-organize spatial language systems similar (or at least approaching) in complexity to what has
been observed in human languages. The experiments show that from simple referential interactions about objects and places in the environment, paired with the right agent internal representations and algorithms various different spatial language systems can evolve. The evolving languages are influenced by environmental factors, as well as the perceptual apparatus, the cognitive capabilities and the communicative goals of the agents. Such experiments show that we can try to identify basic principles explaining spatial language diversity through robotic experiments (see Fig. 1 for some results from various experiments). The following paragraphs briefly introduce the most important principles.

**Spatial language strategies are procedural** Spatial utterances encode very specific instructions to the hearer that allow him to, for instance, find the referent of the utterance. We have found that such instructions are best represented as constraint-based programs (combinations of categories and conceptualization operators) with data flow instead of instruction flow as principle [13]. This allows agents to flexibly interpret utterances even if aspects of the utterance are not yet known (e.g., in acquisition). Various strategies for conceptualizing spatial reality can be modeled using this technique [10].

**Spatial conceptualization strategies are composed of cognitive building blocks** Spatial language conceptualization strategies are composed of cognitive building blocks, such as categorization, perspective reversal etc. These are general mechanisms that are useful outside of spatial language. For instance, perspective reversal can be useful to compute what another agent is seeing. Spatial language exapts these cognitive building blocks, which allows agents to incrementally construct complex conceptualization strategies [9].

**Syntax is a means for communicating differences in procedural spatial semantics** The best way to understand spatial language syntax is to understand how differences in spatial semantics correspond with differences in syntax. For instance, in German and English adjectival use of projective categories (e.g. front) require a group-based conceptualization strategy [6]. Prepositional use, on the other hand, requires region-based processing [2].

**Co-development of syntax and semantics** The tight connection between syntax and semantics of spatial language require that both are acquired (ontogeny) and evolved (phylogeny) at the same time. We have found in our experiment that a tight coupling between adaptation of conceptualization strategies (spatial semantics) and how they are expressed (spatial syntax) is crucial for allowing agents to learn and self-organize complex spatial language [14, 7, 8, 15].

**Spatial language evolves in a process of cultural evolution** Agents develop various forms of spatial language given a sufficient perceptual apparatus, cognitive capabilities and environment. This happens without any adaptation of the agent architecture. Learning and evolution operators are implemented inside agents and lead to remarkably complex systems in relatively few iterations. Variations in the environment or the stochasticity characterizing multiple runs of the same experiment can lead to different spatial language systems. For example, in one experiment absolute spatial relations emerge, in others projective systems emerge together with landmarks
etc. This shows that cultural evolution of spatial language is a possible explanation for the cross-cultural diversity observed in Natural language.

Spatial language is without doubt an interesting topic because it is so central to our experience of reality. Importantly, spatial language can impact other language systems and conceptualizations such as our understanding of time, but even abstract spaces such as politics and economics are in some languages closely connected with spatial language and talked about in spatial terms. Although we already have some initial computational and robotic experiments studying the emergence of such systems, much more work is needed to deepen our understanding of all the different processes involved. In particular, one area of concern at this point is how to combine the robotic models with models of grammaticalization and/or experimental semiotics (laboratory experiments on the evolution of language with people).

References


On Modelling Human Place Knowledge

STEPHAN WINTER
Department of Infrastructure Engineering
The University of Melbourne
Email: winter@unimelb.edu.au

1. Place graphs

Human knowledge about places can be expressed in verbal place descriptions containing spatial references. Spatial references are locating something in the world, as in “I am at the bus stop.” They can be extracted by language technologies, typically in the form of triplets of a locatum $L$, a relatum $R$, and the qualitative spatial relationship $r$ between them [6]. In English, $r$ can be expressed or indicated by a spatial preposition, verb or noun, or sometimes, in written text, just by a comma (as in “Cambridge, MA”). Accordingly, the language technologies are language-specific: a parser developed for extracting English spatial references does not work on Dutch place descriptions. The above example can be parsed into the triplet $<L: I, r: at, R: bus stop>$.

The triplets representing spatial references form a directed property graph [12], and since spatial references represent human spatial knowledge this property graph is a representation of human spatial knowledge, too. We will call the location of things places, and this property graph a place graph$^2$ [13]. Figure 1 illustrates the concept.

Figure 1. The place graph representing the spatial reference “I am at the bus stop.”

In this contribution, these place graphs will be investigated as tools for studying universals and variation in spatial referencing across cultures and languages. Even if place graphs are knowledge representations, not text, all represented knowledge has been derived from verbal descriptions.

2. Place graphs as knowledge representation

A triplet $LrR$ establishes a fact about the world: a relationship $r$ between two places $L$ and $R$. It is a fact in the sense that some agents—those involved in the conversation the place description was taken from—believe it to be true.$^3$

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1 While triplets represent only binary relationships, ternary relations can be covered by two triplets.
2 Place graphs, in one form or another, have been suggested for a while for the representation of human spatial knowledge, e.g., [8]. The presented place graph, however, is unique in its derivation from place descriptions.
3 Without limiting generality, we ignore that people can make wrong spatial references, and also that parsers can establish false relationships.
However, the triplet is an abstract, symbolic description of a fact. It has taken both the references to the two places as well as the relationship out of the embedding conversational.

1.2 On Modelling Human Place Knowledge

context. From the triplet alone it is now impossible to reconstruct the identity of I or the bus stop, and also to interpret at spatially.

Nevertheless, collecting large sets of triplets about the same environment allows merging triplets to connected graphs, in a manner such that⁴ [7]:

- Nodes can be merged if their labels refer to the same place. A merged node would keep all references to this place ("State Library," "library," "the building in Gothic revival style"). This node should also keep the role in which each reference was used (R: library, L: the building in Gothic revival style).

- The place graph can become a multi-graph (e.g., with <L: café, r: at, R: library>, <L: café, r: opposite, R: library>, <L: building in Gothic revival style, r: opposite, R: café>). Since the conversational contexts are lost (and thus, the reference frames of r) even seemingly contradicting edges (<L: café, r: near, R: library>, <L: café, r: far, R: library>) have to be accepted since they have been true in their respective contexts.

- The relationship r can be mapped to a standardized set of labels. This further generalization may enable inference engines to spatial reasoning [3, 9].

Since a place graph is a knowledge representation [1], and in combination with graph traversal as inference engine even a knowledge-based system [4], a place graph is language-independent for all languages. It can represent spatial references from any language that locates things in relationship to something already located, i.e., by binary or ternary spatial relationships.

3. Spatial referencing across cultures and languages

The place graph introduced above is a representation of configurational knowledge extracted from language. It had been suggested for Question Answering, although their capacity in this regard has not yet been explored. But since a particular place graph is representing triplets extracted from a corpus of place descriptions in one language (due to the limitations of language technologies) such a place graph is also only intended to answer questions in the same language.

From this observation two research questions can be derived:

1. Can a place graph constructed from descriptions in one language be used to answer queries in another language?

2. Can a place graph constructed from descriptions in one language be matched with a place graph constructed from descriptions of the same environment in another language?

The place graphs introduced above are also conceptually different to traditional spatial knowledge representations such as gazetteers (linking place names to coordinated locations; [5])

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⁴ Again, without limiting generality, we ignore that the matching process is imperfect.
and geographic information systems (managing crisp geometries with attributes; [10]). As an alternative representation they address some of the issues with traditional representations (e.g., [2]) that are deeply rooted in Western culture (e.g., [11]). Other cultures, and especially those with oral traditions, may find place graphs more appropriate to represent their knowledge of the land. Thus:

1. Is a place graph suited to capture knowledge from cultures with oral traditions?
2. In which ways would such a place graph be different from a place graph constructed from descriptions of the same environment in a Western language?

References