Spatial reasoning in bilingual Mexico: Delimiting the influence of language

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Abstract

What is the relation been spatial language and cognition? Across speech communities, linguistic preferences for particular spatial frames of reference (FoR) predict non-linguistic spatial reasoning strategies. This has been taken to imply a powerful influence of language on reasoning, but extra-linguistic factors may also matter. We present evidence from a bilingual community in Juchitán, Mexico, where the two languages contrast in how they encode space. In our spatial reasoning task, the population overall showed a mixed profile of FoR use. This naturally occurring variability provided a laboratory for asking, at a fine-grained level, what factors predict individuals' spatial reasoning. Contrary to suggestions in the literature, we found no effects of language dominance or of the language used for the task. Instead, reliance on an egocentric strategy for the non-linguistic task was predicted by mastery of egocentric spatial vocabulary. These results delimit the influence of language on spatial reasoning.

Keywords: linguistic relativity; space; bilingualism; cognitive diversity; spatial frames of reference

Introduction

In recent decades the domain of space has emerged as a critical proving ground for claims of *linguistic relativity*, the idea that an individual's habitual use of a particular language has a causal influence on non-linguistic thought processes. Much of the debate has centered on spatial *frames of reference* (FoR) and their use in everyday language and reasoning. FoRs are coordinate systems for relating objects separated in space: *egocentric* FoRs locate objects with reference to the observer's bodily coordinates (e.g., using terms such as "right" or "left"); *allocentric* FoRs are not observer based, instead locating objects with reference to another entity or landmark, or to a salient asymmetry such as a cardinal direction (e.g. using "north" or "west"). A surprising finding—and the subject of ongoing controversy—is (1) that language communities exhibit preferences for different FoRs, particularly in how they treat small-scale or "table-top" space and (2) that these linguistic preferences align with speakers' performance on non-linguistic spatial tasks (Majid et al., 2004). For instance, speakers of Dutch and Japanese—"egocentric" languages like English—tend to adopt an egocentric strategy on non-linguistic tasks; speakers of "allocentric" languages like Tseltal and Longgu tend to adopt an allocentric strategy (e.g. Levinson & Wilkins, 2006).

But can such findings be taken as evidence of linguistic relativity? Critics have suggested they cannot (Li & Gleitman, 2002). The communities studied have differed in their linguistic code but also in numerous extra-linguistic factors, such as their natural setting and built environment as well as numerous cultural practices. The "language you speak" is thus only part of a rich web of influences that might drive a speaker to rely on one spatial FoR over another. The current project was designed to untangle this web of influences, to the extent possible in a field situation, by testing bilingual speakers of languages that differ in how they encode space. Our data come from an urban, bilingual community of speakers of Spanish (Indo-European) and Juchitán Zapotec (Otomanguean), from Juchitán, Oaxaca, Mexico. Like other Mesoamerican languages, Juchitán Zapotec has been characterized as "allocentric" (Pérez Báez, 2011), while Spanish is expected to pattern with "egocentric" European languages. Because individuals within Juchitán differ in their levels of bilingualism yet share a common culture and environment, we were able to probe the relations between spatial language and cognition, decoupled from other extra-linguistic factors.

We considered several general patterns that might emerge in this bilingual population. Overall, the community could exhibit uniform FoR preferences, regardless of language of instruction, language dominance, or other individual dispositions. Indeed, previous research has reported surprisingly uniform preferences within co-located linguistic communities (Majid et al, 2004). On the other hand, we could find a more mixed pattern, with individual participants adopting strategies that differ from each other, adopting multiple strategies on a particular occasion, or perhaps changing preferred strategies from one occasion to the next. Such variability could come from a number of sources. First, the language being used in a particular setting could have a temporary effect, with bilinguals flexibly adopting a corresponding spatial reasoning strategy. This pattern would be consistent with the idea that speakers infer appropriate behavior from the language being used (Li et al., 2011). Second, an individual's dominant language might have a stable influence, with bilinguals adopting the spatial reasoning strategy characteristic of their dominant language (Majid et al, 2004). Finally, an individual's linguistic competence with specific semantic distinctions might have a targeted influence on tasks involving those distinctions. Teasing apart the influences of language of instruction, language dominance, and individual differences in linguistic competence will help us delimit the possible influences that language may have on non-linguistic spatial reasoning.

* All three authors contributed equally.

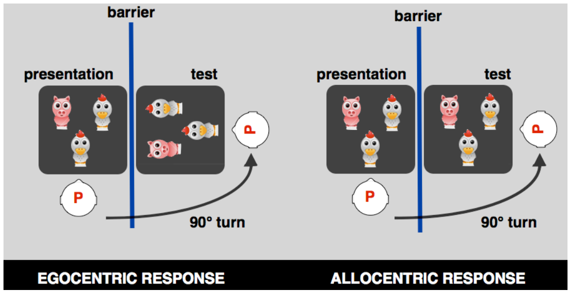

Figure 1: *Animals-in-a-Field* procedure. Egocentric and allocentric responses are distinguished by orientation.

Methods

Fieldsite and Languages

Juchitán de Zaragoza is a majority-indigenous, urban municipality located in southern Oaxaca, Mexico. Of its population of 74,825, a majority (58%) are speakers of some indigenous language (INEGI, 2010), the most widespread being Juchitán Zapotec (JCH). Because of ongoing language shift to Spanish, only 3.6% of indigenous language speakers are monolingual. JCH is a member of the Zapotecan branch of the Otomanguean language family. Juchitán Spanish is a local variety of Mexican Spanish shaped by several centuries of contact with JCH.

Participants

Potential participants were assessed for bilingual proficiency by one of the authors (MM), who conducted ethnographic research in the community for two years, using a language use interview. The interview was administered in JCH by a local research assistant. Interviewees were classified along a continuum of bilingual proficiency on the basis of self-reports of: language use by setting and interlocutor; self-assessment of proficiency; and researcher assessment of elicited Spanish narratives. 16 JCH-Dominant (JD) and 16 Balanced Bilingual (BB) participants were selected for participation. All were native speakers of JCH and natives of Juchitán. The two groups did not differ significantly in number of women (*JD*: 14; *BB*: 10; $p = .22$, Fisher's Exact Test) or age ($M_{JD} = 44$, $M_{BB} = 38$, $t_{(30)} = 1.22$, $p = .23$). Participants were compensated with a small gift.

Procedure

As part of a battery of tasks, participants completed the two analyzed here: *Animals-in-a-Field* and *Spatial Vocabulary Comprehension*. Sessions were conducted at the homes of participants or of author MM, in the semi-outdoor, covered patio that is a feature of almost all houses in Juchitán. JD participants completed all tasks once in JCH. BB participants completed all tasks twice—once in Spanish, once in JCH, in sessions separated by at least 7 weeks, with order of task language ("language of instruction") counterbalanced. JCH sessions were administered in JCH by a native-speaking assistant; Spanish sessions were administered in Spanish by author MM, who has native-like proficiency in Spanish. Sessions were video- and audio-recorded.

Animals-in-a-Field

Animals-in-a-Field is a variation of the Animals-in-a-Row task, commonly used as a measure of non-linguistic spatial reasoning (Pederson et al., 1998). It differs in two respects: (1) it is incrementally more complex, since complex tasks may be better than simple tasks at tapping FoR preferences (Haun et al. 2011); (2) it uses a 90º rather than 180º turn, so as to distinguish different possible allocentric responses.

Materials consisted of two identical sets of laterally symmetrical toy animals (chickens, sheep, cows, pigs). Two identical tables were arranged next to each other in the patio, parallel to the house, separated visually by a hanging sheet (Fig. 1). In the presentation phase, the participant was presented with an array of three animals (two same and one different) in the form of an equilateral triangle, with the base of the triangle always parallel to the participant's own left-right axis and away from the participant. The participant was instructed in the language of instruction to "remember how they are." Then, following an engineered pause of approximately 30 seconds—attributed to camera set-up—the participant was asked to move around the sheet to the recall table, thus rotating 90º. In the recall phase, the participant was handed a bowl containing all eight animals and asked to "make it again, the same." Each participant completed six trials. There were two lists of stimuli, used in both a standard and a reversed order. List and list direction were counterbalanced between subjects. BBs saw a different list on each session.

Spatial Vocabulary Comprehension Task

At the end of each session, participants were tested for comprehension of different uses of two egocentric terms ('left,' 'right') and allocentric uses of four cardinal direction terms ('north,' 'south,' 'east,' 'west'). They were seated at a table, facing in a cardinal direction. A bowl was overturned on the table, surrounded by four wooden blocks at the four cardinal points (*near* targets). Another bowl was overturned on the floor three meters away, surrounded by four toy animals at the cardinal points (*far* targets). The interviewer administered a series of 12 critical questions (plus 5 filler questions) that required participants to identify a body part, animal, or block whose location was described with one of the six spatial terms (e.g. "Show me your left hand" or "Touch the block that is to the north of the bowl on the table"). The questions were then repeated after a 180º rotation. We were careful to distinguish genuinely projective uses of egocentric terms, which relate distant objects (e.g. "the pen is left of that paper"), from so-called "direct" uses that are tied directly to the speaker's body (e.g. "the pen is in my left hand") (e.g. Pérez Báez, 2011). Therefore, the two egocentric terms were tested both with body-parts (*hands*) and in projective uses to identify *near* and *far* objects; two cardinal direction terms were tested *near*, and two, *far*, counterbalanced between rotations.

Coding

Animals-in-a-Field: orientations of the animals were coded as one of four directions by a naïve research assistant using overhead images extracted from the video. *Comprehension*: response accuracy was determined from video-recordings.

Results

Animals-in-a-Field Task

We performed a variety of analyses of the Animals-in-a-Field task. To start, for each session, we calculated the proportion of trials that were egocentric, allocentric, or other (i.e. neither of the predicted orientations in Fig. 1). We also identified the dominant FoR for each session, defined as the modal FoR (egocentric, allocentric, or other) used on 3 or more trials (following Bohnemeyer, 2011). Four sessions (out of 48) did not have a dominant strategy according to this criterion. Overall, participants adopted either an egocentric- or an allocentric-dominant response in 40 out of 48 sessions, much higher than expected by chance (binomial test, $p < .001$, Fig. 2). Participants produced more egocentric than allocentric responses ($M_{ego} = .48$ *vs.* $M_{allo} = .30$, paired t-test: $t_{(31)} = 1.83$, $p = .08$[†]), and there were more egocentric- than allocentric-dominant sessions (26 *vs.* 14, $p = .08$, binomial test), although these differences are only marginally significant.

More than anything, however, the population was characterized by its markedly mixed FoR strategy, in contrast to other populations that have been studied. The most common strategy—egocentric—was the dominant response only half the time (26/48). There was also evidence of individual flexibility, to which we return below.

Language Dominance and Language of Instruction

We next looked at the combined effect of language of instruction and language dominance on spatial reasoning (Fig. 2). Among Balanced Bilinguals, there was no effect of Language of Instruction: they were no more likely to adopt an egocentric strategy in Spanish than in JCH ($M_{SPAN} = 0.48$ vs. $M_{JCH} = 0.50$; paired t-test: $t_{(15)} = 0.12$, $p = 0.91$), nor, conversely, were they any more likely to adopt an allocentric strategy in JCH than in Spanish ($M_{JCH} = 0.38$ vs. $M_{SPAN} = 0.37$; paired t-test: $t_{(15)} = 0.06$, $p = 0.95$).

Similarly, there was no clear evidence of an effect of Language Dominance on preferred FoR. Balanced Bilingual participants were no more likely to adopt an egocentric strategy than those who were JCH-Dominant ($M_{JD} = 0.49$ vs. $M_{BB} = 0.47$; $t_{(30)} = 0.22$, $p = .83$). While there was a numerical trend towards more allocentric responses by Balanced Bilinguals ($M_{BB} = .38$) than by JCH-Dominant participants ($M_{JD} = .22$), this difference did not reach significance, $t_{(30)} = 1.55$, $p = .13$. Indeed, while there were numerically fewer allocentric sessions among JCH-Dominants, the distribution of responses did not differ between JCH-Dominants, Balanced Bilinguals in Spanish, or Balanced Bilinguals in JCH ($p = .12$, Fisher's Exact).

This pattern of results was confirmed by a mixed-logit model of FoR. We modeled FoR strategy on those trials for which participants used either an egocentric or allocentric strategy, with fixed effects of Language of Instruction (Spanish, JCH) and Language Dominance (BB, JD), and random effects of participants and items. Neither Language Dominance nor Language of Instruction was significantly predictive of egocentric responses (all *z*s < .9, *p*s > .4); the full model was no better than reduced models without either of those predictors (all $\chi^2_{(1)} < 0.5$, *p*s > .49). There was no evidence, therefore, that language of instruction or language dominance had a systematic influence on spatial reasoning.

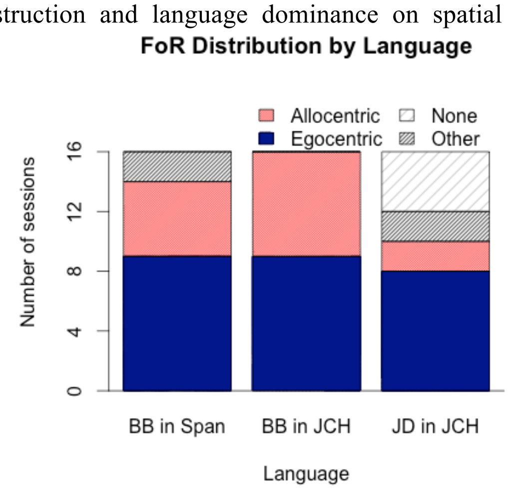

Figure 2: Variability in dominant strategy. Participants adopted a variety of dominant responses.

Flexibility Between Sessions

In addition to looking at the dominant FoR adopted by an individual within a session, we also looked at *flexibility*—that is, the degree to which individuals changed their dominant response between sessions. This analysis is necessarily limited to Balanced Bilinguals, who completed two sessions. Since responses were classified as one of four possible orientations, we should expect egocentric or allocentric responses in one out of four sessions by chance alone[‡]. Dominant responses were reliably repeated by a significant number of participants (8/16; binomial test, $p = .037$). The flip side, of course, is that the remaining participants changed their dominant response between sessions, a significant proportion (8/16; binomial test, $p = .037$). Among those who changed their dominant FoR between sessions, the change was not related to language of instruction: half adopted an egocentric strategy in JCH, and the other half, an allocentric strategy. Therefore, while Balanced Bilinguals as a population exhibited significant between-session stability, individually they also showed evidence of between-session flexibility.

[†] All reported t-tests are two-tailed.

[‡] This is conservative: sessions might lack a dominant response.

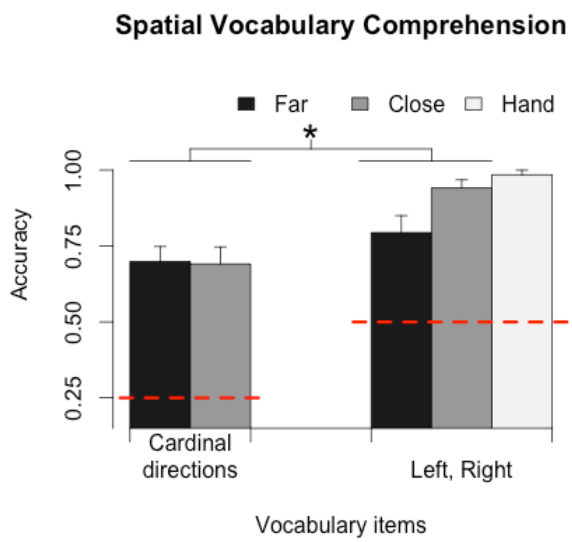

Figure 3: Vocabulary accuracy with egocentric terms (left, right) varied by use, while accuracy with the cardinal direction terms did not differ for near and far targets.

Spatial Vocabulary Comprehension Task

Overall accuracy§ was high (.82) and above chance for all vocabulary types and distances (all *t*s > 5, *p*s < .001). We first conducted a 3x2 mixed ANOVA, with Vocabulary Type (body-part egocentric, projective egocentric, allocentric) as a within-subjects factor and Language Dominance (JCH-Dominant, Balanced Bilingual) as a between-subjects factor. There was no effect of Language Dominance or interaction between Language Dominance and Vocabulary Type (all *F*s < 0.24, *p*s > .63), but there was a highly significant effect of Vocabulary Type ($F_{(2,60)}$ = 19.00, p < .001, η_p^2 = .39). Indeed, accuracy was nearly at ceiling for body-part uses of "left" and "right" (M = .98), and this was significantly better than accuracy for projective uses of "left" and "right" (M = .87), which in turn was significantly better than for allocentric uses of cardinal terms (M = .69) (all *t*s > 2.8, all *p*s < .01).

To investigate these differences further, we fitted a mixed-effects model to participants' accuracy on trials involving projective egocentric and allocentric uses of terms, with fixed effects of Language Dominance, Language of Instruction, Vocabulary Type (left/right or cardinal directions), and Distance (near or far), and random effects of participants and items. Only three factors had a significant influence on accuracy: Vocabulary Type, Distance, and their interaction. Accuracy was better for egocentric than for allocentric items (z = 6.2, p < .001; compared to reduced model without Vocabulary Type: $\chi^2_{(1)}$ = 11.8, p < .001), and better for near than for far items (z = 3.6, p < .001; $\chi^2_{(1)}$ = 11.7, p < .001). However, these effects were complicated by a significant interaction between the two factors (z = 3.6, p < .001; $\chi^2_{(1)}$ = 11.7, p < .001). Follow-up analyses revealed that accuracy on allocentric cardinal terms did not differ between near and far referents (M = .69 vs. .70, $t_{(31)}$ = -0.20, p = .84), while participants were significantly more accurate on egocentric items for near than far referents (M = .94 *vs.* .79, $t_{(31)}$ = 2.78, p = .009) (Fig. 2). Thus, distance had a selective influence on participants' comprehension of egocentric uses of terms, but did not affect comprehension of allocentric terms. There was no evidence that either Language Dominance (M_{JD} = .77, M_{BB} = .79) or Language of Instruction (M_{JCH} = .79, M_{SPAN} = .76) had any influence on vocabulary accuracy (all *z*s < 1.2, all *p*s > .23).

§ Data from 16 trials (8 from each Language Dominance group) was lost due to experimenter error, excess noise, children running in front of the camera, etc. These were removed before analysis.

Relations Between Vocabulary and Animals Tasks

We next investigated the possibility that participants' performance on the Vocabulary task would predict their performance on the reasoning task. We used individuals' performance on the Vocabulary task to classify them as high- or low-competence, for both projective egocentric and allocentric uses of terms, using a median split.

We first looked at the relation between vocabulary competence and the adoption of an egocentric strategy on the Animals task. We conducted a 2x2x2 analysis of covariance (ANCOVA) on the proportion of egocentric responses by each participant, with participants' Age as a covariate, and three crossed between-subjects factors: Language Dominance (Balanced Bilingual *vs.* JCH-Dominant), Egocentric Vocabulary Competence (High *vs.* Low), and Allocentric Vocabulary Competence (High *vs.* Low). The only significant effect was a main effect of Egocentric Vocabulary Competence. Participants adopted egocentric strategies significantly more often if they were highly competent in their use of egocentric vocabulary than if they were not (M = .59 vs. M = .32, $F_{(1,23)}$ = 4.3, p = .049, η_p^2 = .16; Fig. 4). By contrast, no other effect approached significance (all *F*s > .73, all *p*s > .4). This effect remained significant with a nonparametric Wilcoxon test (W = 63.5, p = .021), and a linear regression confirmed that accuracy for egocentric vocabulary items predicted egocentric responses on Animals (β = 0.60, p = .04, r^2 = .13, p < .04).

A very different pattern emerged when we looked at the

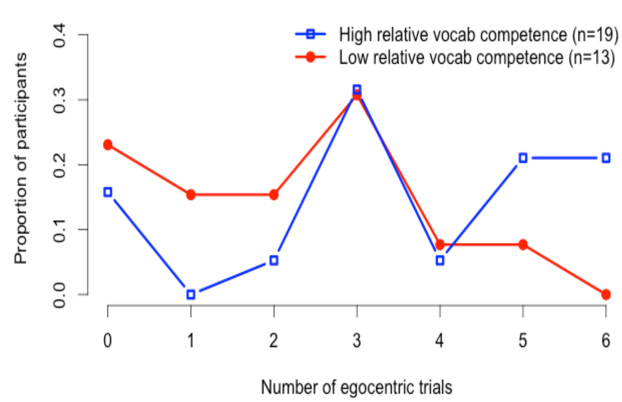

Figure 4: Participants with high competence with egocentric vocabulary produced significantly more egocentric responses.

influence of vocabulary competence on *allocentric* responses on the Animals task. The adoption of an allocentric strategy on the Animals Task was not related to vocabulary competence, neither for allocentric ($F_{(1,23)}$ = 1.47, p = .24) nor egocentric uses ($F_{(1,23)}$ = 0.14, p = .71). There was a privileged relation, therefore, between competence with egocentric uses of vocabulary and the adoption of an egocentric strategy.

Discussion

We investigated spatial cognition, spatial language, and the relationship between the two in a bilingual population of Juchitán, Mexico. Using a non-linguistic task designed to assess preferences for spatial frames of reference, we found evidence for a mixed profile of FoR use. This mixed profile manifested in two ways. First, it manifested as within-population variability: considering the population as a whole, there was a preference for egocentric over allocentric responses, but this preferred strategy still only accounted for slightly more than half of the sessions. Second, it manifested as between-session flexibility: even those Balanced Bilingual participants who did show a strong preference for one frame of reference in one session did not necessarily stick to it in the next, with half of participants switching their dominant response between sessions.

How are we to make sense of the overall pattern we observed as well as the individual variation within it? Below we argue against the possibility that bilingualism *per se* explains the overall pattern. A comparison with a neighboring community suggests that extra-linguistic influences may outweigh linguistic ones at this zoomed-out level. Next we zoom in on individual-by-individual variation to consider the finding that spatial reasoning strategies vary, not randomly, but in a way predicted by particular linguistic abilities—a *targeted* influence of an individual's linguistic competence. Taken together the results suggest an important influence of language on spatial reasoning, but one that may be more specific than commonly proposed and that co-exists with extra-linguistic influences.

Explaining the Overall Pattern in Juchitán: The Role of Extra-Linguistic Factors

A pattern like the patchwork one that we observed, with participants exhibiting a mix of strategies apparently drawn from both linguistic systems, has only rarely been reported in the spatial FoR literature. What drives it? At first blush, it mirrors patterns reported for some bilingual populations in other semantic domains (e.g. Pavlenko, 2002), suggesting that bilingualism *per se* may be a key factor. However, much of the previous research on spatial language and cognition has also been conducted with bilinguals, though this bilingualism was not systematically taken into account. Indeed, comparison with speakers of the same languages from a town just 15 km away undercuts the idea that bilingualism per se accounts for the patchwork pattern we observed. Pérez Báez (2011), who ran a variant of the classic Animals-in-a-Row task with JCH speakers in the town of La Ventosa, found that population to be predominantly allocentric in its spatial reasoning. She reports that 16 out of 19 participants used an allocentric strategy on at least 4/6 trials, and 10 of these used an allocentric strategy on 6/6 trials. Only *one* person in *one* trial used an egocentric strategy—a stark contrast with the highly variable and predominantly egocentric responses observed in the current study. But this contrast cannot be accounted for by differences in bilingualism: Pérez Báez reports that her participants were all bilingual in JCH and Spanish; levels of bilingualism are almost identical in the two places. Inhabitants of La Ventosa should presumably have access to the same mix of conceptual resources, and yet they exhibited a completely different pattern. This comparison across JCH-Spanish bilingual communities suggests that spatial reasoning is not reliably predicted solely by a community's linguistic codes. It further suggests that the mixed profile we see in Juchitán is either not the result of merging conceptual tools from different languages, or, if it is, that such a merged system is not an inevitable outcome for all communities who speak those languages.

Nor is the difference between communities due to a simple urban/rural divide, since both places are very similar on measures used to distinguish rural from urban (INEGI, 2010; c.f. Pederson, 1998). The overall pattern in Juchitán may instead be driven by extra-linguistic factors such as the salience of topographical features (Polian & Bohnemeyer, 2011). Residents of La Ventosa often travel to Juchitán and other nearby towns, while residents of Juchitán do not need to leave the city often, and when they do travel are likely to travel further distances to places like Oaxaca City. From La Ventosa, the horizon is usually visible; but from most vantage points within Juchitán, the density of the built environment obstructs such views. We suggest that these environmental features, and the practices they afford, may be responsible for the differences in spatial conceptualization across the two populations.

Explaining Individual Variation in Juchitán: The Role of Specific Linguistic Abilities

Language alone may not be able to explain the overall pattern of spatial reasoning strategies in Juchitán, but can it help explain the variation we observed from one participant to the next? Yes and no. Of the three possible sources of variability we considered at the outset, only one proved predictive. Language dominance and language of task did not predict spatial reasoning, a finding that is surprising in light of accounts of linguistic relativity that appeal to the temporary or stable effects of the "language you speak" on non-linguistic reasoning. What did predict spatial reasoning was competency with specific spatial language. This finding is consistent with recent developmental findings that suggest that the acquisition of specific spatial terms is correlated with improved non-linguistic spatial abilities that require the newly acquired concepts (e.g. Gentner et al., 2013). Indeed, if a word encodes a novel semantic distinction, acquiring it may highlight the distinction. Once acquired, its habitual use may entrench the distinction. And once mastered, the word itself may become a ready-to-hand conceptual tool, even when a task is not explicitly linguistic. Mastering projective uses of "left" and "right," therefore, might highlight, entrench, and routinize the use of egocentric spatial relations.

While previous research has found that knowledge of spatial language may scaffold spatial cognition, the pattern we observed was specific to *egocentric* spatial language and cognition: knowledge of projective uses of egocentric terms predicted egocentric responses in a non-linguistic task, but knowledge of allocentric terms did not predict allocentric responses. What could explain this curious contrast? One possibility is that, in humans, egocentric and allocentric reasoning simply do not require the same degree of scaffolding. It may be that, consistent with findings on the preference for allocentric encoding in non-human primates (Haun et al., 2006), allocentric spatial reasoning emerges spontaneously while egocentric spatial strategies must be scaffolded by various cultural practices. However, such an account fails to explain why speakers of predominantly egocentric-encoding languages show diminished ability to use an allocentric FoR when explicitly required to do so (Haun et al., 2011). Even if allocentric reasoning is in some way basic, it appears to benefit from habitual use.

Another possibility is that both egocentric and allocentric spatial reasoning depend on various forms of scaffolding, but that this scaffolding need not be strictly linguistic. Indeed, previous work has shown that allocentric responses on tasks similar to the one used here do not require mastery of allocentric vocabulary (Le Guen, 2011). In the case of Juchitán, it could be that allocentric reasoning is supported by non-linguistic cultural practices, such as gestural conventions, while egocentric reasoning is largely—or even uniquely—supported by linguistic practices. This possibility raises the interesting question of what kinds of non-linguistic practices, both in Juchitán and beyond, might support allocentric encoding.

Conclusion

Where does this leave the relation between language and cognition? Our results help delimit the relation. At the population level, environment and sociocultural factors, not language, seemed to explain differences between the inhabitants of Juchitán and those of nearby La Ventosa. At the individual level, non-linguistic reasoning was flexible and seemingly unaffected by language dominance or language of instruction. It was, however, predicted by competence with specific lexical items, as if acquiring and mastering the associated semantic distinctions shaped non-linguistic reasoning. In the web of influences that shapes spatial reasoning, language may play a powerful but also more selective role than is commonly claimed.

Acknowledgments

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References

Bohnemeyer, J. (2011). Spatial frames of reference in Yucatec: Referential promiscuity and task-specificity. *Language Sciences,* 33, 892-914.

Gentner, D., Ozyürek, A., Gürcanli, O., & Goldin-Meadow, S. (2013). Spatial language facilitates spatial cognition: evidence from children who lack language input. *Cognition*, *127*, 318–30.

Haun, D., Rapold, C. J., Call, J., Janzen, G., & Levinson, S. C. (2006). Cognitive cladistics and cultural override in Hominid spatial cognition. *PNAS*, *103*, 17568–17573.

Haun, D., Rapold, C., Janzen, G., & Levinson, S. (2011). Plasticity of human spatial cognition: Spatial language and cognition covary across cultures. *Cognition*, 119, 70-80.

INEGI (2010). Instituto Nacional de Estadística y Geografía. Conteo de Población y Vivienda. Online. http://www.inegi.org.mx/sistemas/consulta_resultados/iter2010.aspx?c=27329&s=est

Le Guen, O. (2011). Speech and Gesture in Spatial Language and Cognition Among the Yucatec Mayas. *Cognitive Science*, 35, 905–938.

Levinson, S. C., & Wilkins, D. P. (Eds.). (2006). *Grammars of space: Explorations in cognitive diversity*. CUP.

Li, P., Abarbanell, L., Gleitman, L., & Papafragou, A. (2011). Spatial reasoning in Tenejapan Mayans. *Cognition*, 120, 33–55.

Li, P., & Gleitman, L. (2002). Turning the tables: language and spatial reasoning. *Cognition*, 83, 265-294.

Majid, A., Bowerman, M., Kita, S., Haun, D., & Levinson, S. C. (2004). Can language restructure cognition? The case for space. *Trends in Cognitive Sciences*, *8,* 108-114.

Pavlenko, A. (2002). Bilingualism and Emotions. *Multilingua*, 21, 45-78.

Pederson, E. (1998). Spatial language, reasoning, and variation across Tamil communities. In P. V. Zima & V. Tax (Eds.), *Language and Location in Space and Time* (pp. 111–119). Munich & Newcastle: Lincom Europa.

Pederson, E., Danziger, E., Wilkins, D., Levinson, S. C., Kita, S., & Senft, G. (1998). Semantic Typology and Spatial Conceptualization. *Language*, *74*, 557–589.

Pérez Báez, G. (2011). Spatial frames of reference preferences in Juchitán Zapotec. *Language Sciences*, *33*, 943–960.

Polian, G., & Bohnemeyer, J. (2011). Uniformity and variation in Tseltal reference frame use. *Language Sciences*, *33*, 868–891.