How to speak "geocentric" in an "egocentric" language: A multimodal study among Ngigua-Spanish bilinguals and Spanish monolinguals in a rural community of Mexico

Erendira Calderon, Stefano de Pascale, Evangelia Adamou

How to speak "geocentric" in an "egocentric" language: A multimodal study among Ngigua-Spanish bilinguals and Spanish monolinguals in a rural community of Mexico

(2019, *Language Sciences*)

Eréndira Calderón[1], Stefano De Pascale[2], and Evangelia Adamou[3]
INALCO[1], KU Leuven[2], and French National Centre for Scientific Research (CNRS)[3]

Abstract

It has recently been shown that individuals residing in rural, indigenous communities rely on geocentric conceptualizations of space, e.g., north/south/east/west, even after they have shifted to a language that is known to favour egocentric conceptualizations, e.g., right/left. In this paper we explore how this combination works in practice by conducting a study in a previously non-investigated indigenous community of Mexico, the Ngiguas. We used a verbal localization task for community-scale relations. We filmed the responses of early bilinguals in Ngigua (Otomanguean) and in Spanish as well as of a control group of Spanish monolinguals from the same rural community. Statistical analysis of speech and co-speech gestures reveals that bilinguals favour geocentric gestures and direct pointing in both languages, associating them with topological and deictic terms. Against our predictions, Spanish monolinguals also use high rates of geocentric gestures that they frequently combine with cardinal terms. In sum, the Ngigua data show that geocentric conceptualizations can be transmitted to monolingual generations via co-speech gestures, including in a language where egocentric conceptualizations prevail in other settings.

Keywords: co-speech gesture; bilinguals; frames of reference; linguistic relativity; Ngigua; Spanish

1. Introduction

1.1. Theoretical background

The linguistic relativity hypothesis, or Sapir-Whorf hypothesis, holds that our language habits largely shape the way that we perceive the real world. In particular, for the concept of space that is the focus of the present paper, Whorf concluded that even though "the apprehension of space is given in substantially the same form by experience irrespective of language (…) the concept of space will vary somewhat with language" (Whorf 1956: 158). Over the last twenty years several cross-cultural and cross-linguistic studies have shown that people preferably rely on the most frequent linguistic encoding in their language to respond to memory tasks (e.g., Brown and Levinson 1993; Pederson et al. 1998; Bowerman and Levinson 2001; Levinson 2003; Haun et al. 2011). Authors of this so-called "neo-Whorfian" approach interpret these findings as evidence that language has a strong impact on human cognition. In contrast, psychologists argue that multiple types of spatial representations are innate and readily available in order to allow for an adaptation to environmental needs, including on the language in use (Gallistel 2002; Li and Gleitman 2002; Li et al. 2011). According to this "universalist" approach, languages draw on pre-existing cognitive representations. Alternatively, Bueti and Walsh (2009) argue that space shares common cortical metrics with time, number, and other magnitudes which develop from action. Recent research reconciles these views and proposes that mental representations result from a combination of both top-down predictions, related to linguistic abstractions, and bottom-up processes, related to perceptual experience, as well as from a combination of both long-term cultural experience and recent experience (see Casasanto and Bottini 2014; Bylund and Athanasopoulos 2017). In particular, it is shown that memory is a cognitive function that is closely connected to language, for example as participants may use language as aid memory during the task (Trueswell and Papafragou 2010). In that sense, memory tasks are more closely related to linguistic conceptualizations than initially thought. The relation between language and thought is summarized by Slobin (2003, 2006) who considers that language shapes our view of the world during the online process of speaking, but can also influence language-connected activities such as perception and memory.

Relevant to this debate are several recent studies that pay close attention to the variable weight that culture, environment, literacy, and language may have on spatial cognition by focusing on indigenous, rural communities. More specifically, Meakins, Jones, and Algy (2016) used the Max Planck Institute's "Animals in a row" memory task among the Gurindji people in Australia. Participants in this task are asked to memorize the placement of three animal figures positioned in a row in front of them, recall this placement and reconstruct it a few meters away after a 180° rotation. Meakins, Jones, and Algy (2016) report that the Gurindji participants provided a majority of what we refer to here as "geocentric" responses, that is, by memorizing the animal figures with respect to a cardinal point (e.g., the animal that was northernmost, for example, remained northernmost after the rotation). Crucially, participants provided geocentric responses whether they spoke Gurindji, a Pama-Nyungan language with an elaborate system of cardinal terms, or Gurindji Kriol, an admixture of an English-lexified creole and Gurindji, which has not taken over the Gurindji cardinal term system. Meakins, Jones, and Algy (2016) also note that the more educated participants relied strongly on "egocentric" responses, memorizing the animal figures based on their own body and viewpoint (e.g., the animal that was at the participant's right hand remained at the participant's right hand after the rotation). Le Guen (2011) also demonstrated that, independent of knowing and using geocentric linguistic terms, the Yucatec Mayas in Mexico strongly favour geocentric responses in the "Animals in a row" memory task. Similarly, Adamou and Shen (2017) showed that in an indigenous community of Mexico where the Otomanguean language Ixcatec has no longer been spoken for the last three generations, the monolingual Spanish speakers of the community predominantly provide geocentric responses in the same memory task. These results suggest that small-scale memorization of spatial relations, which may also rely on linguistic cues as aid, is independent of knowledge and use of corresponding geocentric linguistic terms and that geocentric memorization strategies persist even in languages that are otherwise shown to be predominantly egocentric.

Le Guen (2011) suggests that gestures are key in understanding how geocentric linguistic conceptualizations are maintained. Indeed, it is now admitted that gestures provide crucial information about linguistic conceptualizations, as speech and accompanying gestures are conceptually linked and form an integrated system (McNeill

1992, 2005; Kendon 2004; Goldin-Meadow 2004). Although co-speech gestures reflect the online conceptualization of a single event, they can express additional meaning that is not expressed in speech (see Gullberg 2011 for an overview of the literature on this topic). Based on the analysis of a large corpus of natural conversations, Meakins (2011), for example, showed that Gurindji Kriol speakers rely heavily on deictic terms (e.g., 'this one', 'there') and on accompanying pointing gestures in spatial descriptions. Le Guen (2011) reports a similar result for the Yucatec Mayas who combine deictic terms together with geocentric gestures in face-to-face communication. In sum, these studies suggest that deictic terms and geocentric or direct pointing gestures suffice to maintain geocentric linguistic conceptualizations even after the loss of the geocentric vocabulary. This in turn means that the geocentric conceptualizations in memory tasks that Meakins, Jones, and Algy (2016) and Le Guen (2011) observed in these communities align with geocentric linguistic conceptualizations. These results are therefore in accordance with the linguistic relativity hypothesis, only they enrich and update it to include co-speech gestures to lexical, morphological, and syntactic means (Whorf 1956: 158).

The maintenance of geocentric conceptualizations as observed in memory and in co-speech gesture reported in the above-mentioned studies is possible as there are no major disruptions in the community's habitat and way of life. The importance of the environment (both built and natural) on spatial cognition is captured in the Topographic Correspondence Hypothesis (Palmer 2015) and refined as the Sociotopographic Model to stress the importance of the socio-cultural interaction with the environment (Palmer et al. 2016). Indeed, early research on two Tamil-speaking communities revealed that rural communities favour geocentric thinking whereas urban communities favour egocentric thinking (Pederson 1993). Polian and Bohnemeyer (2011) and Marghetis, McComsey, and Cooperrider (2014) note that the degree of visibility of salient environmental cues better predicts the rise of an egocentric strategy in a given community than the mere rural vs. urban distinction. More recently, Lum (2017) reports findings that highlight the relation between the environment and socio-economic activities with a study showing that Dhivehi-speaking communities dedicated to fishing rely on geocentric representations whereas Dhivehi-speaking non-fishing communities rely on egocentric representations. In any case, for Whorf, linguistic changes are slower than cultural innovations (Whorf 1956: 156).

In the present study, we focus on a previously non-investigated indigenous community of Mexico, the Ngiguas, who have shifted to Spanish in their everyday life, but have kept their habitat and relation to the environment relatively stable. Our goal is to shed light on spatial linguistic conceptualizations, by examining speech and co-speech gesture as in Le Guen (2011) and Meakins (2011). The originality of our study is twofold: First, we investigate linguistic conceptualizations among the last Ngigua-Spanish bilingual speakers when they speak their native language, Ngigua, and the colonial, state language, Spanish, to see whether they have different linguistic conceptualizations of space or a single one. Indeed, a number of studies have shown that bilingualism affects non-linguistic conceptualizations in various ways and may lead to reconceptualization in one or both languages at the level of the individual (e.g., colour in Athanasopoulos 2009; Athanasopoulos et al. 2010; Athanasopoulos et al. 2011, and motion events in Brown and Gullberg 2011; Bylund and Jarvis 2011). Second, we compare the linguistic conceptualizations of the bilinguals, as expressed in speech and co-speech gesture, to those of the monolingual Spanish speakers from the community. To our knowledge, such comparison has never been conducted. Recent research has focused on how bilingualism affects spatial memory, with some studies showing that language affects preferred memorization strategies (Bohnemeyer et al. 2015; Meakins, Jones, and Algy 2016; Lin and Hsiao 2017), while others finding no effect of language dominance or language of task (Marghetis, McComsey, and Cooperrider 2014). Marghetis, McComsey, and Cooperrider (2014) discuss their data by moving from the level of language to that of linguistic expressions. In their study, they find a correlation between how well participants know egocentric terms and how often they adopt egocentric strategies to respond to the memorization task. Interestingly, they do not find the same correlation between geocentric terms and geocentric non-verbal responses, the latter being used independently as also noted by Le Guen (2011).

In the remainder of this introduction we provide some background on Ngigua before presenting the methods, in Section 2, the results, in Section 3, and ending with some concluding remarks in Section 4.

1.2. Background on Ngigua

The present study investigates spatial language and cognition in Ngigua or Ngiba[1] (ISO-639 code: coz), a Popolocan language of the Otomanguean stock. According to estimates by the Instituto Nacional de Estadísticas y Geografía (INEGI) and the Instituto Nacional de Lenguas Indígenas (INALI), as well as by the Summer Institute of Linguistics (SIL), Ngigua is severely endangered, having roughly 500–1,000 speakers who live in five municipalities of the Mixteca Alta in the State of Oaxaca (see Map in Figure 1). We conducted our study in the community of San Pedro Buenavista. San Pedro Buenavista is located at an altitude of 2400 m above sea level. It has less than 200 inhabitants who practice small-scale farming and cattle breading. The community is governed by the so-called *usos y costumbres* 'traditions and customs', a number of indigenous customary law and legal practices that were formalized in 1990 by an amendment to the Constitution of the State of Oaxaca and its Code of election procedures (1993).

Ngigua is an under-investigated language (see Belmar 1899; Mock 1982; Veerman-Leichsenring 2000). It has been in century-long contact with two unrelated languages, Nahuatl (Uto-Aztecan) and Spanish (Indo-European). A language shift to Spanish started upon the arrival of the Spaniards, but was accentuated during the twentieth century. Despite a centuries-long writing tradition in Mesoamerica based on hieroglyphs, Ngigua was written using the Latin script from the sixteenth century onwards. Ngigua has been introduced at schools only recently and the last native speakers of the language are not literate in it.

From a typological perspective Ngigua is of interest for its complex phonology, involving glottalized and aspirated clusters, as well as the relation between tones,

[1] In this paper we use the self-denomination Ngiba/Ngigua 'our language' and we provide the two pronunciations that are found in the various communities. However, the language is mostly referred to in the literature under the exonym Chocho (or Chocholtec). This name probably comes from the Spanish verb *chochear*, which literally means 'to become senile' and through extension to 'talk like a senile person.'

contrastive phonation, and stress. It is also particularly challenging for its complex verbal morphology, which combines several levels, such as tone, prefixes, and suffixes, and which also combines tense, mood, aspect and person marking morphology. From a syntactic viewpoint, it is a verb-initial language that shows related typological features, such as relative clauses following nouns, the existence of prepositions, and noun-adjective word order. Ngigua is also interesting for its use of noun classifiers and lexical derivation.

Figure 1. Map of the localities where Ngiba/Ngigua and the most-closely related languages of the Popolocan branch are spoken. The study took place in the community of San Pedro Buenavista (circled).

2. Methodology

Participants

We tested 17 Ngigua-Spanish bilinguals from the community of San Pedro Buenavista and a control group of 17 Spanish monolinguals from the same community. We note

that there are no monolingual speakers of Ngigua. All Ngigua participants were contacted through the Regional Committee for the language Ngiba/Ngigua. They were informed that this study was part of a research project on Ngigua, but they were not informed as to the specific research goals. Participants gave oral and written consent and received compensation for their participation in the study in accordance with local standards.

All participants were of similar socio-economic status, i.e., low income levels. They were all residents of the community of San Pedro Buenavista. Among the 17 Ngigua-Spanish bilinguals who participated in this study, only one had spent four years outside of the community. All bilingual participants had low education levels, i.e., they had at most six years of education (of which two have attended no schooling). 16 participants were female and one male. Age of participants ranges from 52 to 87 (M = 73.24, SD=9.18). Among the Spanish monolingual participants, six of them had lived in other Mexican cities for less than six years. Three Spanish monolingual participants had less than six years of education, and 14 had from 7 to 12 years of education. 10 participants were female and 7 male. Age of participants ranges from 24 to 46 (M = 33.12, SD = 6.98). In sum, the monolingual group had similar sociolectal background for Spanish with the bilingual group, but differed from the bilingual group in age and education levels.

Sociolinguistic interview

Goals. A sociolinguistic interview was conducted in Spanish to establish the bilingual participants' language background (adapted from Gullberg and Indefrey 2003 and Li et al. 2014).

Results. Nine bilinguals declared having learnt Spanish and Ngigua simultaneously before the age of three. Four participants were early sequential bilinguals, i.e., three had learnt Spanish between ages 4 to 8, and one had learnt Ngigua at the age of 8 (when the grandmother moved in with the family). Moreover, four participants were late bilinguals, having learnt Spanish after the age of 12.

The estimated age of onset of shift to Spanish is complex. Careful examination of the sociolinguistic context and the interviews leads us to believe that the Ngigua bilinguals did not shift to Spanish before puberty, a major threshold of full language

acquisition (e.g., Ullman 2004). Indeed, although prescriptive monolingual ideology at school encouraged them to abandon Ngigua for the benefit of Spanish, we should keep in mind that school attendance was low and none of the bilinguals in our study attended school after the age of 12. Rather, participants reported that the most dramatic moment of shift was when they got married and became parents, that is, in (early) adulthood.

Finally, only one bilingual declared Ngigua to be the language of daily communication whereas 16 declared using Spanish daily and not using Ngigua in any context, in private or in public. We therefore expect Spanish to be the dominant language of the bilinguals.

Verbal fluency test

Goals. To determine language dominance we adapted the verbal fluency task in Johns, Valdés Kroff, and Dussias (2018). This task more broadly draws on the "Weaker Links Hypothesis" (described among others in Gollan et al. 2008) according to which infrequent use of a language weakens the associations between word forms and meanings and these lower levels of activation translate into slower access times as evidenced by slower response times. The prediction is therefore that the language for which participants will provide the greatest number of lexical items is the language for which the associations are activated most easily and can be considered as their dominant language.

Procedure. In this task participants were asked to produce in one minute as many words as possible belonging to three semantic categories: body parts, animals, and fruits and vegetables. Only twelve out of 17 bilingual participants completed the verbal fluency task, in Ngigua and in Spanish, because of availability. One participant did not understand the task and was therefore not included.

Analysis. We coded 1 point per word. Spanish words in the Ngigua version were not accepted when they were not morphologically and phonetically integrated into Ngigua. We fitted a Poisson regression on the count data.

Results. Analysis of the results reveals significant effects of both language of the experiment (L.R. $\chi^2 = 6.1122$, df= 1, $p < 0.05$) and class of the words (L.R. $\chi^2 = 21.3465$, df= 2, $p < 0.001$). More importantly, there is a significant interaction between those two predictors (L.R. $\chi^2 = 15.5478$, df= 2, $p < 0.001$). From the effects plot in Figure 2, one

can see that in Spanish number of words does not differ across semantic categories (*M* = 11.47), whereas in Ngigua there is a sharp difference between, on the one hand, words for Animals (*M* = 8.54) and Body parts (*M* = 7.90) and, on the other hand, words for Fruits and Vegetables (*M* = 4.00) for which participants used mainly Spanish lexical items.

In accordance with the results of the sociolinguistic interview, the verbal fluency task confirms that Ngigua is the attrited language and Spanish the dominant language. However, it is not entirely clear whether this result is due to dominance or proficiency. To address this question we conducted a comprehension test.

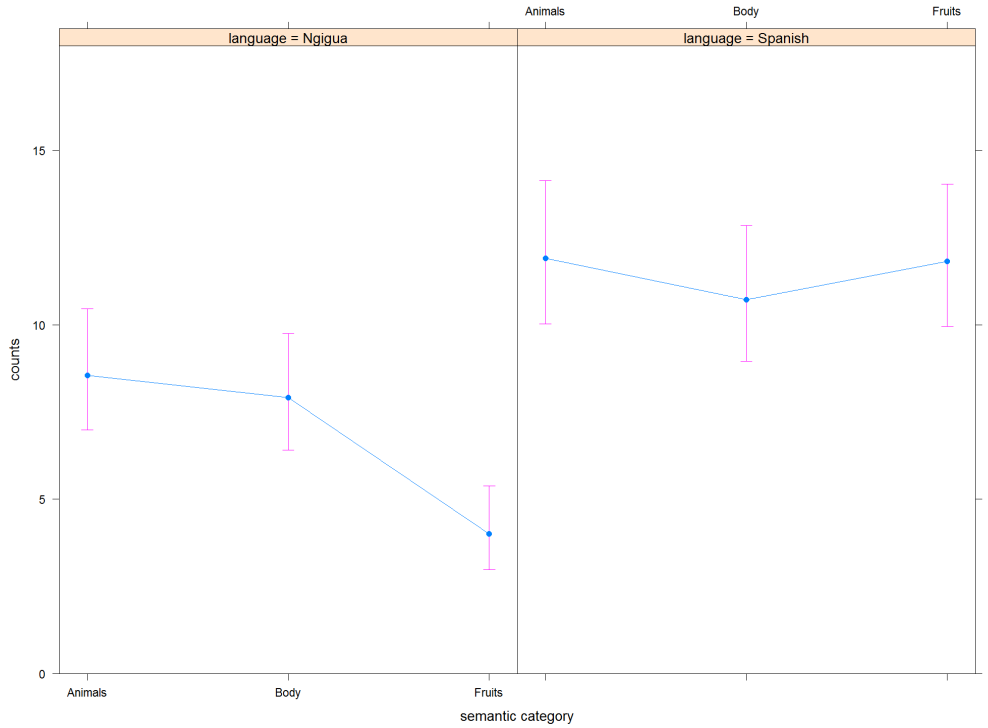

Figure 2. Effect of interaction between language of the task and semantic category based on the number of words/minute

Comprehension test (picture-matching experiment)

Goals. It has been argued that difficulties in performance among attriters, as those encountered in the verbal fluency task, are due to problems with online processing (i.e., accessibility, retrieval, and inhibition) and cognitive mechanisms associated to the task (e.g., decision making), rather than with grammatical knowledge *per se* (Schmid and Köpke 2017). In addition, Ullman (2004) and Paradis (2009) suggest that syntactic

processing mainly relies on procedural brain memory, which is to a large extent an automatic procedure that handles rule-based procedures, and that lexical processing mainly relies on declarative memory, which stocks memorized words and morphology. As a result, although lexicon may be affected by attrition, syntactic knowledge is predicted to remain intact. In accordance with this literature, we explored a novel method to test syntactic comprehension in the two languages by adapting an online, bimodal picture-sentence matching task with auditory stimuli that has been used to test subject preference in relative clauses (Adamou 2017b). This task is adapted to unschooled populations and also has the advantage of testing comprehension while not mobilizing other cognitive strategies.

Materials. Seventy two audio stimuli consisting of relative clauses were created in Ngigua and 72 in Mexican Spanish. Moreover, fifty four auditory stimuli with simple interrogative clauses were created for each language, Ngigua and Spanish, as fillers; e.g., 'Where are the bananas?'. To evaluate the grammaticality of the Ngigua relative clauses, we conducted a small norming study with five Ngigua-Spanish bilinguals who did not participate in the experiment. These participants listened to all 126 sentences in Ngigua and were asked to provide their ratings on a Likert 5-point scale, from 1 (this sentence is not very natural in Ngigua) to 5 (this sentence is very natural in Ngigua). All the sentences received a score above the threshold (3), with a mean rating $M = 4.45$, and all were kept for the picture matching experiment.

The Ngigua sentences were recorded with a native, elderly male speaker of Ngigua who has training as a translator (Ngigua-Spanish). The Spanish sentences were recorded with a female, native Mexican Spanish speaker from Mexico City. The recordings were made with a Marantz solid-state recorder via an external microphone. We used Audacity to edit the audio files. The resulting sentences for relative clauses in each language were similar in length although we were only interested in accuracy, not on speed.

For the visual stimuli, we used coloured photographs knowing that low-educated participants have difficulties recognizing black and white line drawings (Reis et al. 2006). We created 126 pairs of photographs which were culturally-adapted, that is, people depicted were of Mexican origin and the objects were everyday objects that can be found in Mexico. For the relative clauses, a pair of photographs depicted reversible

actions between participants equal in animacy. For the lexical targets, a pair of photographs depicted the same person realizing different actions in each photograph, e.g., sleeping vs. jumping, or two different objects, e.g., bananas vs. strawberries, or different aspects of the same object, e.g., clean vs. dirty.

Procedure. Participants were seated in front of a computer screen and listened to the audio stimuli from external audio speakers. The experiment was conducted on a computer via Open Sesame (Mathôt, Schreij, and Theeuwes 2012). The stimuli were fully randomized. The task started with two warm-up trials. The instructions were pre-recorded and were provided either in Spanish or in Ngigua depending on the version. Participants were invited to watch the photographs and listen to the synchronized auditory stimuli which appeared 500 ms later. They were instructed to select the picture that seemed to be more related to the meaning of the audio stimuli by pressing a button on the keyboard. Participants could press the left control button, which had a blue sticker on, to select the picture on the left of the screen, and the right control button, which had a yellow sticker on, for the picture on the right. They were told that they should press the button as soon as they recognized the related picture. Inter-trial intervals were not controlled.

One bilingual did not complete this task for reasons of availability. For the bilingual group, 8 participants responded to the Spanish version first and 8 responded first to the Ngigua version. Four versions of the experiment were created in each language and distributed equally among the two groups (bilingual and monolingual from the community). To reduce fatigue-related errors but secure statistical power, each bilingual participant responded to 45 trials in two versions, Ngigua and Spanish (total N = 90 trials). For each version, participants responded to 18 relative clauses (9 SRCs and 9 ORCs) and 27 lexical targets. The monolingual control group responded to 45 trials in the Spanish version. Accuracy was measured. Participants declared that they did not experience any difficulties with the questions, the sound files or the photographs.

Analysis. Statistical analyses were performed using the open source statistical software R (R Core Team 2017), and, in particular, the package lme4 (Bates et al. 2015) for the glmer function.

Results. First, we examined whether the bilinguals were more accurate in their responses in Ngigua or in Spanish. In a mixed-effect logistic regression, with pairwise

two-way interactions between the predictors "language of the experiment" (Spanish vs. Ngigua), "type of relative clause" (subject relative clause vs. object relative clause) and "level of education" (less than 6 years vs. 7 to 12 years), none of these interactions were retained after a stepwise model selection procedure. The only main predictor that was kept in the model was type of relative clause ($\chi^2 = 13.95$, df = 1, $p < 0.001$). Specifically, bilinguals recognize subject relative clauses correctly in 68%, while their accuracy for object relative clauses is below chance, i.e., 48%, across both languages. Regarding the random effects structure of the regression, we report that only "experimental item" was kept as a significant random effect, while "participant" was not retained. In other words, between-participant variability in accuracy scores is negligible, whereas some relative clauses appear to be harder to identify correctly than others.

We then compared the Spanish responses of the bilinguals to those of the Spanish monolingual control group. In a mixed-effect logistic regression, with "accuracy" as response variable, "language profile" (bilingual vs. monolingual) and "type of relative clause" (subject relative clause vs. object relative clause) as predictors and "participant" as random effect, we find that, on average, bilinguals are correct 60% of the time, whereas monolinguals are correct 89% of the time ($\chi^2 = 24.404$, df = 1, $p < 0.001$). In addition, across language profiles, subject relative clauses are recognized accurately in 85% of the time, while object relative clauses only 70% of the time ($\chi^2 = 20.023$, df = 1, $p < 0.001$). "Experimental item" was not retained as a random effect.

Discussion. In sum, analysis of the results shows that there is no significant difference between accuracy scores in the two languages among the bilinguals. These results indicate that syntactic complexity is understood as accurately in Spanish as in Ngigua, in accordance with the importance of the puberty threshold of full language acquisition. It also appears that subject relative clauses were identified correctly more often than object relative clauses, regardless of the language of these clauses, i.e., Ngigua or Spanish. This is most likely due to the relative clause subject preference that is well documented in the literature (see Adamou 2017b). Comparison of the Spanish responses of the two groups shows that bilinguals are less accurate than monolinguals. This result may be due to the higher education levels of the monolinguals (more than 6

years of schooling), and to a decline in performance related to the age of the bilingual group (*M* = 73.24 years old).

The localization task

Goals and predictions. To study linguistic conceptualizations of space we investigate speech and co-speech gestures. Based on the results in Le Guen (2011), we expect speakers responding in Ngigua to preferably rely on geocentric gestures or direct pointing combined with deictic and/or geocentric terms. We expect egocentric gestures to prevail in Spanish responses together with the terms 'right/left', among both bilinguals and monolinguals.

Design. We adapted the localization task based on Le Guen (2011) and Adamou (2017a). The advantage of this task is that it allows for comparability between the various members of the community as they respond to the same questions with the same interlocutors. We note that recording of natural conversations in Ngigua is not possible as Ngigua is no longer spoken in everyday interactions. The questions were adapted to the Ngigua population and we made sure the locations were likely to be known by all the participants. We construed four questions for locations in the community of San Pedro Buenavista, where participants live and where the tasks were conducted, and four questions for locations in the neighbouring city of Coixtlahuaca, which is 11 km away from San Pedro Buenavista. We aimed to test both north/south and east/west axes and participants' position was controlled for in order to provide unambiguous responses between right/left responses and cardinal directions; see Table 1. These questions were presented in Spanish, in the Spanish version of the task, and in Ngigua, in the Ngigua version.

Table 1. Questions for the localization task

Question	Speaker's position	Egocentric axis	Geocentric axis
Where is the primary school in relation to the clinic?	Facing east	Right/Left	North/South
	Facing north	In front of/ behind	North/South
Where is the primary	Facing north	Right/Left	East/West

school in relation to the church?	Facing east	Front/Back	East/West
Where is the middle school in relation to the church?	Facing east	Right/Left	North/South
	Facing north	Front/Back	North/South
Where is J's house in relation to the clinic?	Facing north	Front/Back	East/West
	Facing east	Right/Left	East/West
Where is Calvario's church in relation to the municipality?	Facing east	Right/Left	North/South
	Facing north	Front/Back	North/South
Where is the auditorium in relation to the municipality?	Facing east	Front/Back	East/West
	Facing north	Right/Left	East/West
Where is the presidency in relation to the old convent?	Facing east	Right/Left	North/South
	Facing north	Front/Back	North/South
Where is the Cecyte (school) in relation to the bus station?	Facing east	Front/Back	East/West
	Facing north	Right/Left	East/West

Procedure. For the localization task, participants were asked to sit outside in an open space where their upper body part could move freely. Arguing aesthetical reasons, a chair was previously set in a given direction (north or east) controlled by a compass iOS app. The interviews were video-recorded on a Nikon D5200 digital camera with 1920x1080 resolution and a 25p frame rate. Audio was recorded with a Marantz solid-state recorder via an external microphone.

The instructions were provided in Spanish or Ngigua depending on the version: "We are going to discuss places here in San Pedro and in Coixtlahuaca. Could you please tell me where the first location is in relation to the other location?" Instructions were followed by questions in the following format: "Where is X in relation to Y?"; see Table 1 for the list of questions. The task lasted approximately five minutes. Some speakers declared that the task was difficult to understand.

Coding. For the annotation we used the ELAN format from the Max Planck Institute for Psycholinguistics (Nijmegen, Netherlands). The video files were

synchronized with a number of tiers. We had to exclude the data from two bilinguals and one monolingual participant because they did not understand the task.

For speech, one tier was created for the broad phonetic transcription, another one for words, and a third tier was added for broad translation. Spanish was transcribed by a native speaker of Mexican Spanish (first author) and Ngigua in collaboration with a Ngigua-Spanish translator. We further created a tier to code frame of reference in speech. A frame of reference codes the way people use coordinate systems to think and talk about spatial relations between two objects (Levinson 2003). We use the term "egocentric" frame of reference when objects are located in relation to an observer's viewpoint and bodily coordinates, e.g., 'left' and 'right'. In the "geocentric" frame of reference, objects are located with reference to some environmental entity or cardinal direction, e.g., 'east' or 'west'. The "intrinsic" frame of reference is one in which the properties of one of the objects are mobilized to locate another object, e.g., its 'front', 'back', and 'sides'. We further coded three locative expressions of coincidence, namely deixis, topology, and toponymy (i.e., place names) (Levinson 2003).

Coding of the co-speech gestures was conducted following McNeill (1992: 89) by dividing the gestural space into extreme periphery, periphery, and central gestural space. We also coded the gestures that included the use of body, namely the head. In total, we coded 247 gesture strokes for the bilinguals in Spanish, 216 for the bilinguals in Ngigua, and 198 for the monolingual Spanish speakers. We created a tier to code frame of reference in gesture. For this tier, we followed Le Guen (2011) and coded "direct pointing", "geocentric", and "egocentric" frames of reference. We added a new category, dubbed "mixed gesture" comprising gestures that are accurate in a geocentric and egocentric way. We also coded gestures that were "unclear" and excluded them from the analysis. Finally, another tier provides the results of the merging of the two tiers that code frames of reference in language and gesture and allows to observe matches and mismatches between speech and co-speech gesture.

Analysis

Two mixed-effects Poisson regression models were built in order to determine how bilinguals speaking Spanish, those same bilinguals speaking Ngigua and the monolingual Spanish control group differ from each other with respect to, on the one

hand, several co-speech gesture types and on the other hand distinct linguistic expressions during the localization task. The model investigating co-speech gesture types includes the count of those gestures as dependent variable and an interaction effect between the predictor "co-speech gesture type" (four levels: "direct pointing", "egocentric", "geocentric" and "mixed") and the predictor "linguistic profile" (three levels: "bilingual in Spanish", "bilingual in Ngigua" and "monolingual"). The model investigating linguistic expressions has the count of those expressions as dependent variable and an interaction effect between the predictor "linguistic expression type" ("deixis", "egocentric", "geocentric", "intrinsic", "noun" and "topology") and again the "linguistic profile" of the participants. While the above predictors are the fixed effects of the study, "participant" was included as random effect and its inclusion in both models improves the fit compared to regression analyses without this random effect (χ^2 = 20.195, df= 1, $p < 0.001$ concerning the model with "number of co-speech gesture" as dependent count variable; χ^2 = 6.6525, df= 1, $p < 0.01$ concerning the model with "number of linguistic expressions" as dependent count variable). Statistical analyses were performed using the open source statistical software R (R Core Team 2015), and in particular the package lme4 (Bates et al. 2015) for the glmer function.

Procedure of the sessions

Participants were tested in their homes in San Pedro Buenavista. The testing was conducted by a Mexican Spanish-speaking researcher (first author) and a local bilingual assistant. Bilinguals responded in the tasks both in Spanish and in Ngigua; the order was counterbalanced across participants. After giving their consent, participants took part in the comprehension test (picture-matching experiment). Once the picture-matching experiment was completed, participants responded to the localization task, and then to the sociolinguistic interview (in Spanish). Finally, bilingual participants responded to the localization task in the language in which they had not yet been tested (Spanish or Ngigua) before completing the other version of the picture-matching task (again in Spanish or in Ngigua). The whole procedure lasted approximately an hour. The verbal fluency test was carried out during a different session with another battery of tasks that are not presented in this paper.

3. Results of the localization task

We start by exemplifying each type of gesture separately for the bilingual group, in Section 3.1., and for the monolingual group, in Section 3.2. We then present an overall quantitative view of the results for both groups, in Section 3.3, and a discussion in Section 3.4.

3.1. Results from the bilinguals in Ngigua and Spanish

Let us now illustrate the dominant types of gesture and linguistic expressions in detail. First, we will look at the results for the Ngigua-Spanish bilinguals with respect to the two versions of the experiment, the Spanish and the Ngigua versions.

Ngigua responses. Bilinguals responding in Ngigua frequently make geocentric gestures together with topological expressions, such as 'above/up' and 'below/down' (9% of responses; see Table A1 in Appendix). This is illustrated in Figure 3 and in Example 1 where square brackets code the duration of the gesture and bold letters code the gesture's stroke. A superscripted capital letter (e.g., ^{A}) indicates the video capture in the corresponding figure. In this example, the speaker faces north. In Figure 3a it can be seen that she first places the church of Coixtlahuaca to the south by gesturing with her arm on her left side and her palm behind her. In Figure 3b she gestures in front of her to locate the municipality further north. As can be seen in the map, which is also provided in Figure 3, the gestures locate the two buildings in a way that they match the location of the buildings in the south and north respectively. In terms of linguistic expressions, the location of building A, the church, is achieved through the word *kadia* 'above/up'. The location of building B, the municipality, is described by the word *jangi* 'below/down'. Interestingly, the terms 'above/up' and 'below/down' correspond to the location of the two buildings with respect to the topography of the city of Coixtlahuaca, where building B is located lower on a slope as compared to building A. Contrary to the

Ixcatec findings in Adamou (2017a) for the Ixcatec community, we did not find any evidence that the terms ‘above/up’ and ‘below/down’ are associated with cardinal directions.

Figure 3. Bilingual speaker facing north using geocentric gesture and topological expressions[2]

1. mm sua ningu [jie me gïï **isa** **kadia**[A] nunga sua centro]
   INTJ ART church big so LOC.3SG more above for ART center
   ‘Hmm, the big church, so it is farther above in the center,[3]

   [me **ti** **i**sa[B] jangi sua] ta-detua
   so until more below ART CLF-municipality
   so the municipality is below.’

Another frequent strategy in Ngigua is to point directly to the location of the building in real space and use topological linguistic terms (7% of responses are direct pointing with the head and 6% with the arms; see Appendix). This is illustrated in Figure 4 and corresponding Example 2. In this example, the speaker locates building A, the church, by pointing directly with her head to the location, and building B, the

[2] All the videos will be made available online.

[3] Transcriptions using Ngigua practical orthography that does not include the lexical tones. Nasals are noted with ¨.

middle school, by pointing with her index finger to the middle school's location. She locates the middle school with respect to topography, 'in the plain'.

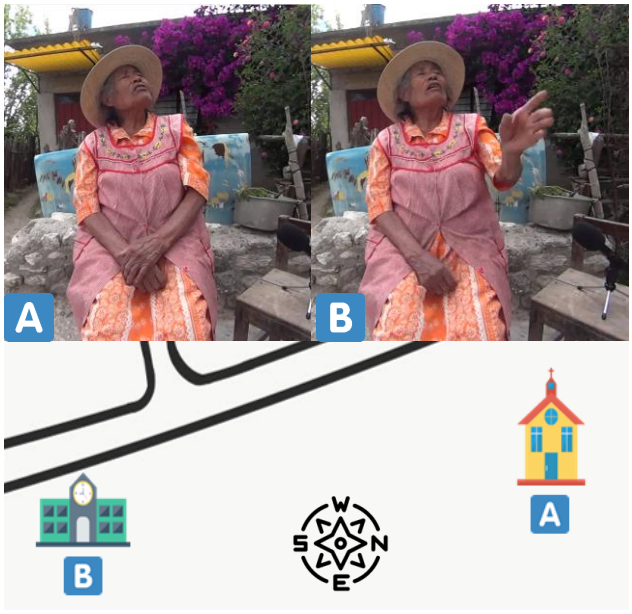

Figure 4. Bilingual speaker facing east using direct pointing in gesture and topological and deictic expressions

2.	ningu	[**gïï**	**ti**^{A}]	centro
	church	LOC.3SG	until	centre

'The church is in the center,

nu	sua	secundaria	[**gïï**	**nki**	**ndia**^{B}]
and	ART	middle_school	LOC.3SG	plain	there

and the middle school is in the plain, there,

ti	nki	gïï
until	plain	LOC.3SG

it is in the plain.'

Spanish responses. When responding in Spanish, bilinguals opt for a combination of geocentric gestures with deictic terms (20% of responses; see Appendix). It can be seen in Figure 5 that the speaker, who faces east, places building A

to the north using her left hand and building B to the south using her right hand, matching the actual location of the buildings in real space (A to the north and B to the south). The corresponding Example 3 shows that the speaker uses deictic terms, 'this', 'there', to accompany the gestures.

Figure 5. Bilingual speaker facing east using geocentric gesture and deictic terms

3.	al	[este	**lado^{A}**]	y	la	secun[daria
	at	DEM.PROX	side	and	DEF.SG.F	middle_school.SG.F

'On this side, and the middle school

queda	**pa**	**allá^{B}**]
be_located.3SG	toward	there

is located over there.'

Geocentric gestures combining with topological expressions are also present in the Spanish responses of the bilinguals (11% of responses; see Appendix). This type of response is illustrated in Figure 6 and corresponding Example 4. First, without making any gestures, the speaker mentions that building A, the auditorium of Coixtlahuaca, is 'above/up'. Then she makes a gesture with her arm in front of her from east to west,

palm open, while saying that building B, the municipality, is ‘below/down’. As she faces north we note that the gesture is accurate with respect to the orientation of the buildings in space, building B being indeed located to the north. In addition, the topological expressions ‘above/up’ and ‘below/down’ correspond to the topography of the city of Coixtlahuaca where building A is indeed higher than building B.

Figure 6. Bilingual speaker facing north using geocentric gesture and topological expressions

4. a pues ahí está para arriba auditorio y
INTJ so there be.3SG toward above/up auditorium and
‘Ah, so there it is above, the auditorium,

[y **abajo**$^{A-B}$ está] el / [el corredor **es**#] ahí#
and below/down be.3SG DEF.SG.M DEF.SG.M corridor.SG.M be.3SG there
and below is the corridor, there,

por ahí creo que sí está
from there believe.1SG that yes be.3SG
over there, I believe, yes, is…

este la presidencia
DEM.PROX DEF.SG.F municipality.SG.F
the municipality.’

In the Spanish responses of the bilingual speakers we note a type of so-called mixed gestures, i.e., gestures that are accurate in a geocentric and egocentric way, often

combining with egocentric expressions. Figure 7a and the corresponding Example 5 show that the speaker makes a gesture using her right arm and an open palm in the gestural space in front of her to locate building A, the church, while she uses the corresponding egocentric term *derecha* 'right'. This gesture is accurate in a geocentric sense as her gesture is to the east and building A is located to the east, and egocentric, in that she uses her right arm although she does not place it at her right side. Then, as can be seen in Figure 7b, the speaker locates building B, the primary school, using her left arm and her palm open at her left side while simultaneously using the egocentric term *izquierda* 'left', the arm indicating the north (the building is located more accurately to the north-west of building A). As a result, we consider that the responses are informative both from a geocentric and egocentric point of view.

Figure 7. Bilingual speaker facing east using mixed gestures and egocentric expressions

5.	pues	ahí	donde	está	la	carretera	
	so	there	where	be.3SG	DEF.SG.F	road	

'So there, where there is the road,'

[**a**	**la**	derecha]	pues	ahí	está	la	iglesia
at	DEF.SG.F	right	so	there	be.3SG	DEF.SG.F	church

'on the right, so there is the church,'

y	la	[primaria	**pues**	**está**	**a**	**la**]	izquierda
and	DEF.SG.F	primary_school	so	be.3SG	at	DEF.SG.F	left

'and (as for) the primary school, so there it is on the left.'

We now turn to examine the responses of the monolingual Spanish speakers.

3.2. Results from the Spanish monolinguals

We observe that monolinguals use geocentric gestures accompanied by geocentric frames of reference in language, namely the terms for cardinal directions (16% of responses; see Appendix). This is shown in Figure 8 and Example 6. The speaker faces east and makes a gesture using his arm that departs from the space in front of him and goes toward the back of his body or, in geocentric terms, from east to west. The westerly direction is also in accordance with the word *poniente* 'west' in his speech. In addition, the speaker adds a topographical term, *abajo* 'down', to render the inclination of the land. We note that the cardinal terms do not seem to copy Ngigua vocabulary since none of our Ngigua speakers used any cardinal terms in Ngigua.

Figure 8. Monolingual speaker facing east using geocentric gestures and cardinal terms

6.	sobre	la	misma	calle	más	al	[más	al	**poniente**$^{A\text{-}B}$]
	on	DEF.SG.F	same.SG.F	street.SG.F	more	at	more	at	west

'On the same street, more to the west,

más	abajo
more	below/down

more downwards.'

The second most frequent strategy among the Spanish monolinguals is the use of geocentric gestures with deictic terms. This type of answer represents 12% of responses

(see Appendix) and we can see them exemplified in Figure 9 and Example 7. It can be seen that the speaker gestures with his right arm in the center of his gestural space, palm towards his own body, to locate building A and then gestures with his left arm a little further in front of him, palm equally facing his body, to locate the second building; see Figure 9a. He then moves his left arm in the extreme periphery of his gestural space towards the southwest to locate the second building while looking at the interviewer. It can be seen in the map provided in Figure 9 that building B is indeed to the southwest of building A. In his speech he only uses deictic terms, 'here' and 'there', and therefore gesture plays a key role.

Figure 9. Monolingual speaker facing north using geocentric gesture and deictic terms

7.	[haga	de	cuenta	**aquí**^{A}	está	la	terminal]
	do.2SG.IMP	of	count	here	be.3SG	DEF.SG.F	terminal.SG.F

'Suppose the terminal station were here,

[y	el	Cecyte	está	tantito	**por**	**acá**^{A}	así
and	DEF.SG.F	NP	be.3SG	as_much.DIM	from	here	this_way

and the Cecyte over here, like this.

pero	sí	está	**más**	**pa**	**allá**^{B}]
but	yes	be.3SG	more	toward	there

But, yes, it's more over there.'

Finally, a third strategy combines the use of geocentric gestures and topological expressions (in 8% of responses; see Appendix), as we have already seen among the bilingual speakers. Figure 10a shows that the speaker first locates the building A using

his right arm in front of him, palm open, and in Figure 10b he extends his left arm in the extreme periphery of his gestural space towards the west, palm open, to locate the building B. These gestures are in accordance with the locations of the two buildings, building A being to the east of building B. In speech, the speaker indicates that the building A, the terminal bus station, is 'up' and building B, the Cecyte, is 'down'. Interestingly, this renders the location of the two buildings in an accurate manner with respect to of the city's topography and the slope of the ground.

Figure 10. Monolingual speaker facing north using geocentric gesture and topographical expressions

8.	al	Cecyte	igual	[porque	la	**terminal**^{A}	está	acá	arriba]
	at	NP	same	because	DEF.SG.F	terminal.SG.F	be.3SG	here	above/up

'Regarding the Cecyte, it's the same because the terminal is here, above,

[y	la	el	Cecyte	queda	**más**	**abajo**^{B}]
and	DEF.SG.F	DEF.SG.M	NP	be_located.3SG	more	below/down

and the Cecyte is located further down,

por	la	parte	de	abajo
from	DEF.SG.F	part	of	below/down

on the lower side.'

3.3. Overall results for the bilingual and the monolingual groups

Figure 11 presents the fitted average number of co-speech gestures. The y-scale reports the predicted average number of co-speech gestures per participant, in which the count response variable was modelled with Poisson regression. The confidence bars indicate

95%-confidence intervals for those predicted frequencies. Post-hoc Tukey tests for the differences across language groups indicate that:

- Geocentric co-speech gestures are used on average most often by the bilinguals when speaking Spanish (7.21), followed by the monolingual Spanish speakers (5.68) and finally the bilinguals when speaking Ngigua (3.83). Bilinguals responding in Ngigua differ significantly from themselves when responding in Spanish ($p < 0.001$), but not compared to the monolingual group ($p > 0.05$). Furthermore, being bilingual or monolingual in Spanish does not influence the frequency with which geocentric co-gestures are employed ($p = 0.38$).
- Egocentric co-speech gestures are used on average most often by the bilinguals when speaking Spanish (1.98), followed by the monolingual Spanish speakers (1.24) and finally the bilinguals when speaking Ngigua (0.77). Bilinguals responding in Ngigua differ significantly from themselves when responding in Spanish ($p < 0.05$), but not compared to the monolingual group ($p > 0.05$). In addition, being bilingual or monolingual in Spanish does not influence the frequency with which egocentric co-speech gestures are employed ($p = 0.27$).
- Direct pointing co-speech gestures are used on average most often by the bilinguals when speaking Ngigua (5.94), followed by themselves when responding in Spanish (4.02) and finally by the monolingual control group (2.01). The pairwise differences between these three groups turns out each time to be significant (at least $p < 0.05$).

While we relied on veracity of the overall map to code geocentric gestures, we should add that these gestures also exhibit the following characteristics, which are typical of geocentric gestures (based on Levinson 2003: 265–266): geocentric gestures are large (55% of the bilinguals' gestures in Ngigua and in Spanish are effected in the extreme periphery, and 37% of the Spanish monolinguals' gestures), they may be directed toward the back of the body with an accompanying rotation of the body while being dissociated from their gaze, they combine arm movement and hand shape, and they may involve both hands (8% of the gestures of the Spanish monolinguals vs. 4% among the bilinguals in Spanish and 1% in Ngigua).

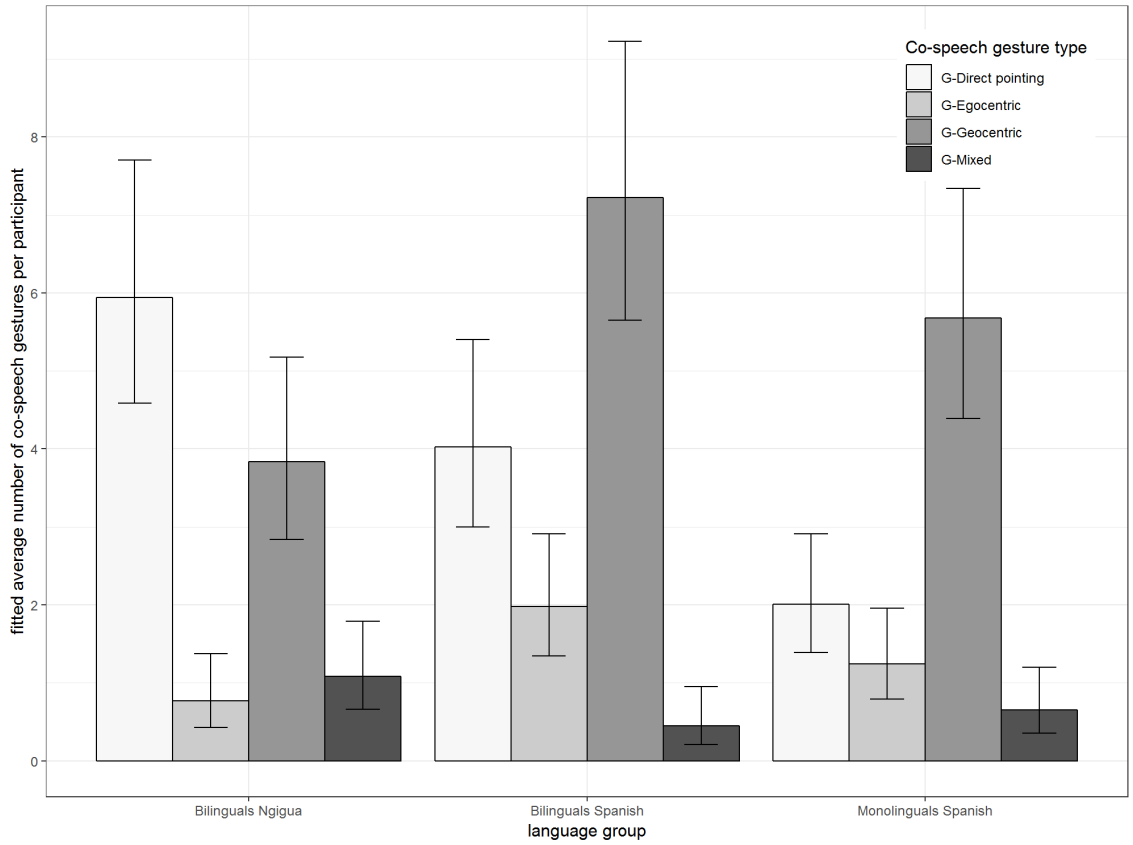

Figure 11. Fitted average number of co-speech gestures per participant as a function of the types of co-speech gesture (color-coding) and of linguistic profile of the participant (x-axis: bilinguals in Ngigua, bilinguals in Spanish and monolingual Spanish control group)

Figure 12 shows fitted average number of linguistic expressions per participant. Post-hoc Tukey tests for the differences across language groups indicate that:

- Geocentric linguistic expressions are used on average most often by monolingual speakers (4.06), followed by the bilingual participants speaking Spanish (0.79) and finally by the bilingual participants speaking Ngigua (0.26). Bilinguals responding in Ngigua differ significantly from the monolingual group ($p < 0.001$), but not from themselves when responding in Spanish ($p = 0.14$). Moreover, the monolingual participants differ significantly from the bilingual participants when speaking Ngigua ($p < 0.001$).
- Egocentric linguistic expressions are used on average most often by monolingual speakers (2.83), followed by the bilingual participants speaking

Spanish (2.30) and finally by the bilingual participants speaking Ngigua (2.10). The pairwise differences between those three groups turns out each time to be nonsignificant (lowest p-value = 0.42).

- Deictic linguistic expressions are used on average most often by the bilinguals when speaking Spanish (8.09), followed by themselves when doing the experiment in Ngigua (5.59) and finally the monolingual control group (2.34). The pairwise differences between those three groups turns out each time to be significant (at least $p < 0.05$).
- Topological linguistic expressions are used on average most often by the bilinguals when speaking Ngigua (6.31), followed by themselves when doing the experiment in Spanish (4.67) and finally the monolingual control group (2.40). Bilinguals responding in Ngigua differ significantly from the monolingual group ($p < 0.01$), but not from themselves when responding in Spanish ($p = 0.13$). Moreover, the monolingual participants differ significantly from the bilingual participants when speaking Ngigua ($p < 0.001$).

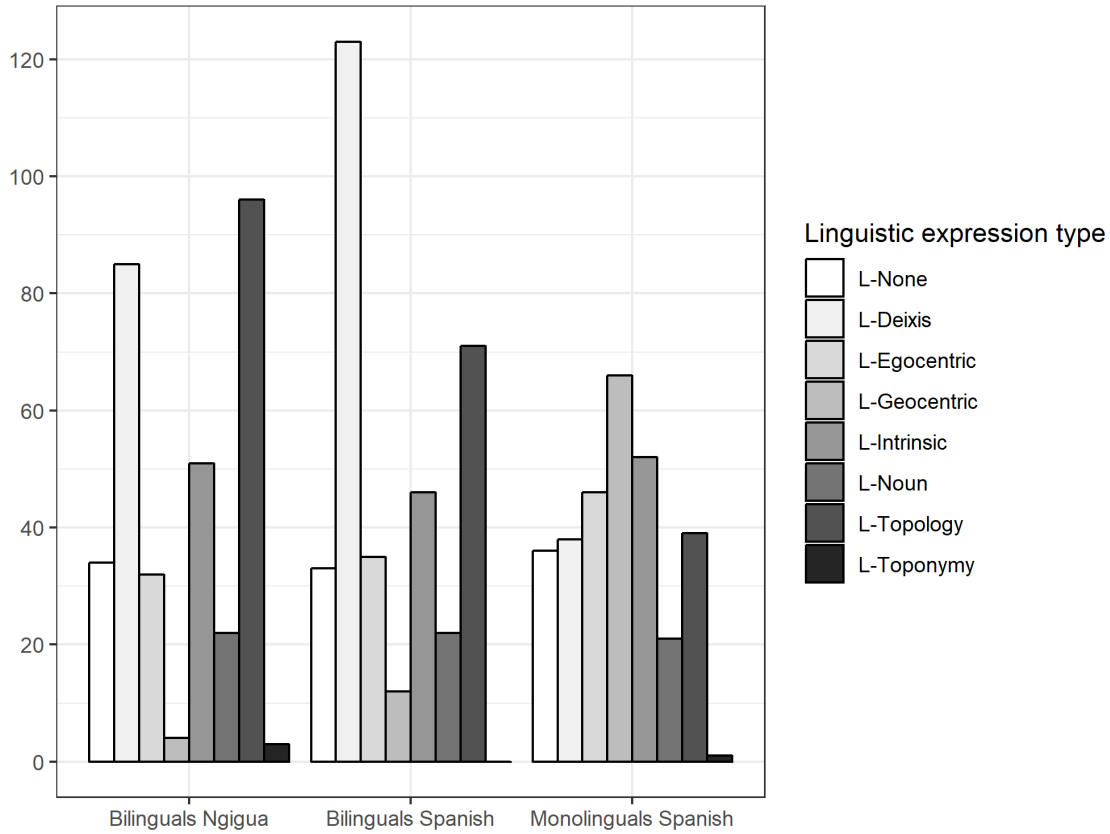

Figure 12. Fitted average number of linguistic expressions per participant as a function of the types of linguistic expression (color-coding) and of linguistic profile of the participant (x-axis: bilinguals in Ngigua, bilinguals in Spanish and monolingual Spanish control group)

We now examine how the above mentioned types of gestures align with linguistic expressions. The focus on the co-occurrence of linguistic expressions with specific/individual co-speech gestures forces us to look at subsets of the dataset that become too small to perform reliable and robust inferential statistics (the problem is especially evident with the egocentric and the mixed gestures). The following analyses will therefore be carried out on the observed rather than the fitted average per-participant counts, and are meant to be descriptive/exploratory in nature. Figure 13 shows the average results per participant for geocentric co-speech gestures. It can be seen that when bilinguals speak Spanish they use deictic terms the most, followed by topological terms. When speaking Ngigua, bilinguals rely on the same two types of linguistic expressions without any clear preference for one or the other. Spanish monolinguals also use these linguistic means, but additionally make use of geocentric linguistic expressions, in particular Spanish cardinal terms, e.g., *poniente* 'west'. Cardinal terms are used peripherally by the bilinguals in Spanish and they are absent from the repertoire in Ngigua. We cannot conclude whether Ngigua cardinal terms have been forgotten or whether the language never used any specialized lexical terms in these descriptions.

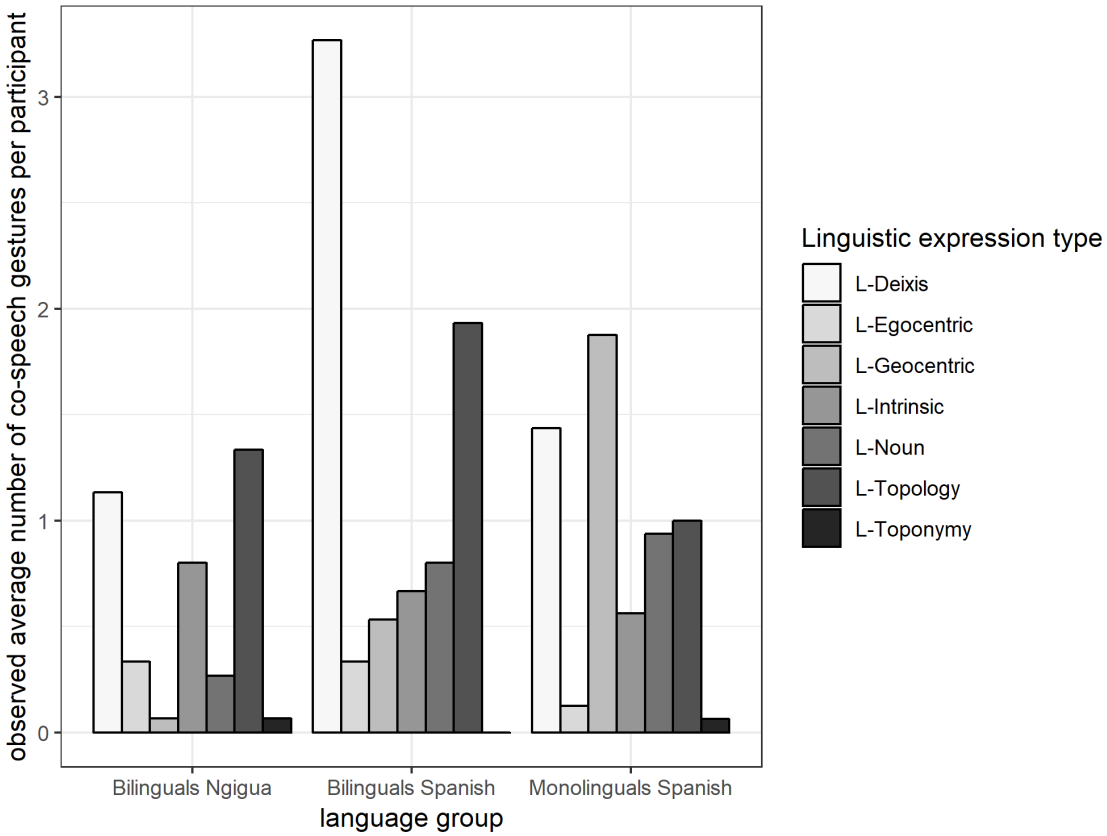

Figure 13. Observed average number of linguistic expressions per participant for the geocentric co-speech gestures as a function of the types of linguistic expression (color-coding) and of linguistic profile of the participant (x-axis: bilinguals in Ngigua, bilinguals in Spanish and monolingual Spanish control group)

In Figure 14 we focus on direct pointing (with the hands or the head). While Spanish monolinguals use all kinds of linguistic means to accompany direct pointing, bilinguals favor deictic terms, such as ‘here’ and ‘there’, and topological terms, such as ‘above/up’ and ‘below/down’, in both languages.

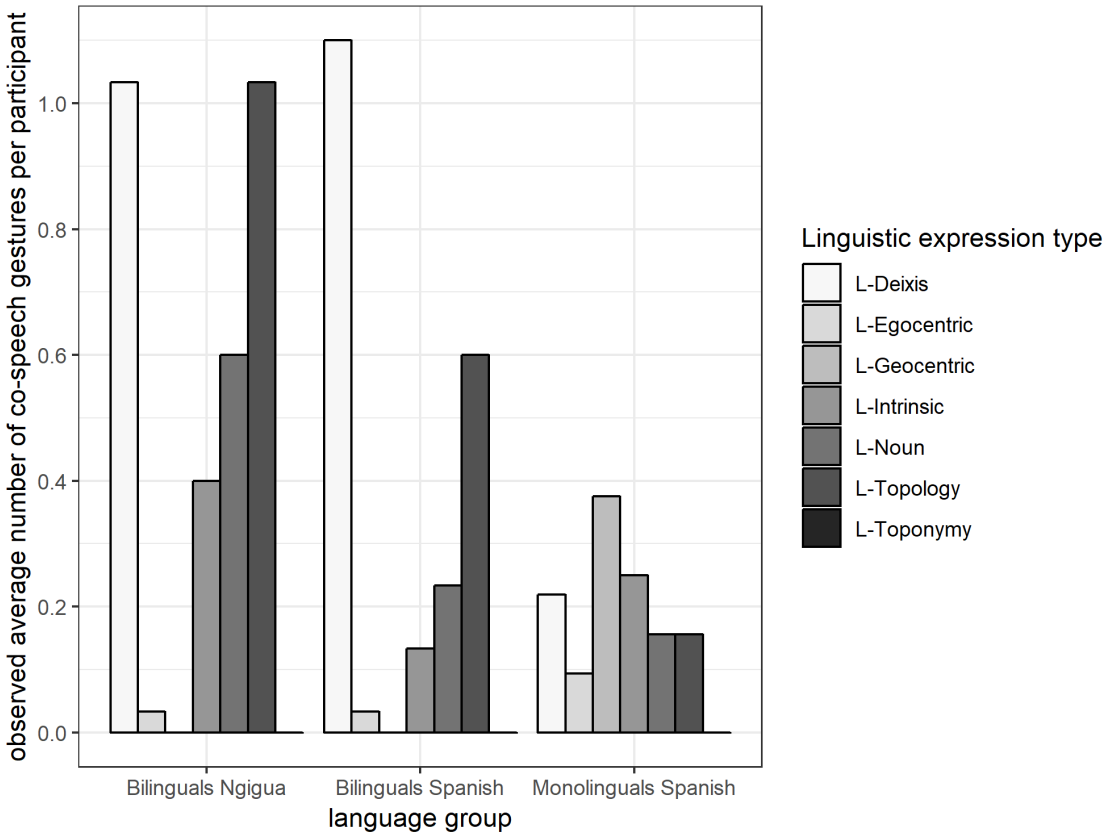

Figure 14. Observed average number of linguistic expressions per participant for the direct pointing co-speech gestures as a function of the types of linguistic expression (color-coding) and of linguistic profile of the participant (x-axis: bilinguals in Ngigua, bilinguals in Spanish and monolingual Spanish control group)

Figure 15 graphs the types of linguistic expressions that accompany egocentric gestures. Predictably these are used with egocentric terms such as ‘right’ and ‘left’ for all the respondents. No geocentric linguistic expressions are noted. We also note that the terms for ‘left hand’, *raju*, and ‘right hand’, *raxä*, are used in Ngigua to indicate more generally ‘left’ and ‘right’, possibly under the influence of Spanish as widely reported for other Mesoamerican languages.

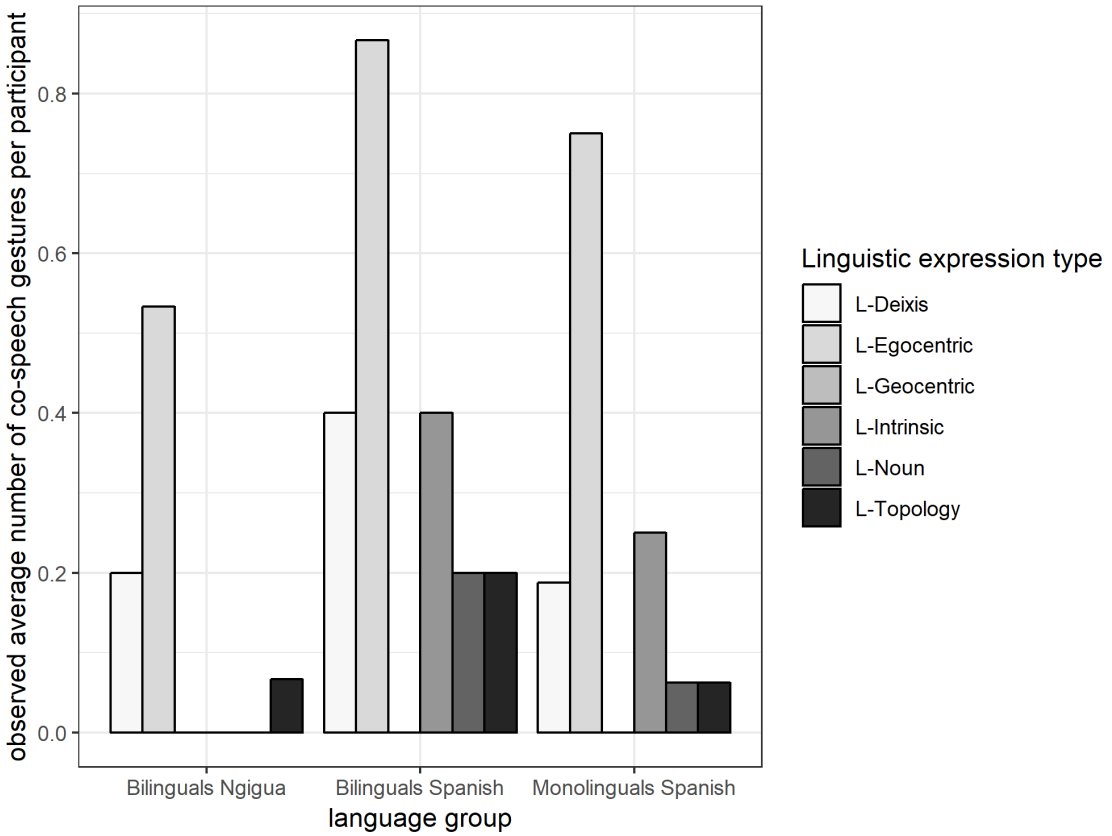

Figure 15. Observed average number of linguistic expressions per participant for the egocentric co-speech gestures as a function of the types of linguistic expression (color-coding) and of linguistic profile of the participant (x-axis: bilinguals in Ngigua, bilinguals in Spanish and monolingual Spanish control group)

Finally, Figure 16 presents the so-called mixed gestures, which are adequate from an egocentric and a geocentric view. It is important to note that these gestures frequently combine with egocentric linguistic expressions. It is possible that, in these cases, mixed gestures are triggered by the use of the egocentric lexicon, which temporarily clashes with the dominant geocentric representations. More generally, however, the emergence of these gestures can be motivated by the shift to Spanish, a language with egocentric terms, and the need to align with these terms and at the same time maintain the existing geocentric system of cognitive representations.

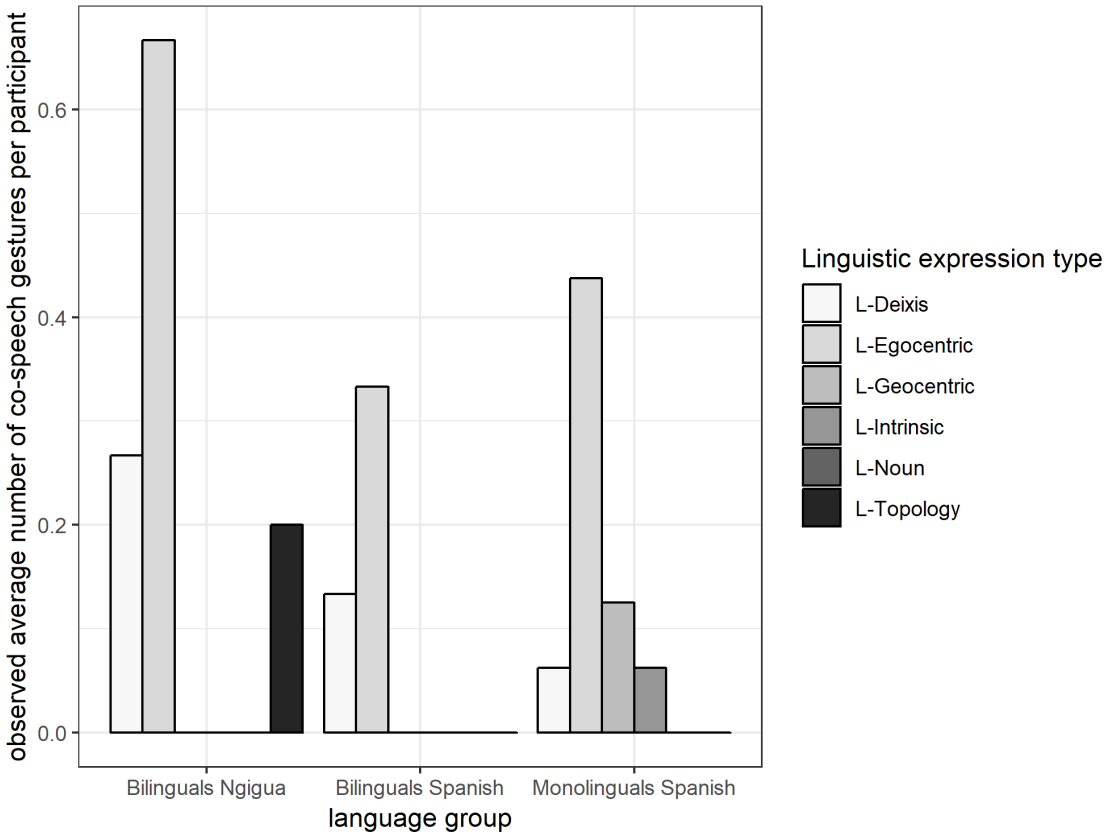

Figure 16. Observed average number of linguistic expressions per participant for the mixed co-speech gestures (accurate in an egocentric and geocentric way) as a function of the types of linguistic expression (color-coding) and of linguistic profile of the participant (x-axis: bilinguals in Ngigua, bilinguals in Spanish and monolingual Spanish control group)

3.4. Discussion

In the present study we investigated speech and co-speech gesture in a localization task. In accordance with results in Le Guen (2011), Ngigua respondents relied primarily on direct pointing and geocentric gestures that they combined with topology and deictic terms. In addition, bilingual respondents in our study relied on direct pointing and deictic terms, whether in Ngigua or in Spanish, more than Spanish monolinguals did. Against our prediction, egocentric gestures did not prevail in Spanish, either among bilinguals or monolinguals, nor did the egocentric terms ‘right/left’. And yet, bilinguals responding in Spanish used the most egocentric gestures, followed by Spanish monolinguals, and finally by bilinguals when responding in Ngigua. Similarly, Spanish monolinguals used more egocentric terms than bilinguals did, who in turn used more

egocentric terms when responding in Spanish than in Ngigua, a language that like other Mesoamerican languages did not rely on egocentric linguistic terms. These results suggest that egocentric linguistic conceptualizations stem from the dominant language, Spanish.

Analysis of the results further reveals that the majority of geocentric gestures and terms were used in Spanish, by bilinguals and monolinguals alike. To understand this result we need to consider the role of the language of education, in this case Spanish. It seems that the more educated speakers relied on Spanish cardinal terms to strengthen the existing geocentric representations that were most likely in use in the community, as can be seen among the lesser-educated group of bilinguals. The latter, in contrast, do not use these terms in either language, something that allows us to hypothesize that Spanish cardinal terms became available mainly through schooling. We can therefore conclude that, in the case of the Ngigua people, education in Spanish provided them with lexical means to strengthen pre-existing geocentric cognitive representations. These novel findings illustrate that education and literacy do not automatically lead to the adoption of an egocentric perspective, for example through reading and writing from left to right. Rather, speakers can draw on the language of education to consolidate locally-relevant conceptualizations of space. Interviews with the younger speakers show that they are perfectly conscious of the fact that the elders do not use the Spanish cardinal terms and clearly associate their own use of cardinal terms to schooling.

Our data also show that there is rarely a mismatch between linguistic expressions and cognitive linguistic representations as expressed in co-speech gestures. We therefore argue that both "egocentric" and "geocentric" languages have a variety of lexical means that can be mobilized to complement a variety of cognitive representations. We saw for example that deictic terms, topological terms, cardinal terms, or mere nouns, can combine successfully with geocentric gestures (as in Le Guen 2011; Meakins 2011). In addition, we note that egocentric terms combine with egocentric gestures, but also with mixed gestures, which are accurate in a geocentric and egocentric way.

Finally, we turn to discuss the predominance of geocentric conceptualizations in this rural community of Mexico in relation to the environment. We note that the Ngigua people construct a mental map of the various buildings in their own community and in

nearby communities based not only on cardinal directions but also on topography. They are then able to reconstruct these relations by considering their own position with respect to cardinal directions at the moment of speech. Attention to both cardinal directions and topography could be interpreted as evidence that the Ngigua people's relation to the built and natural environment shapes their spatial linguistic conceptualizations. This approach would support the Sociotopographic Model, which stresses the importance of environment and people's interactions with it in their everyday lives (Palmer et al. 2016). Indeed, we suggest that the fact that geocentric conceptualizations survive language shift is strongly related to the fact that we are dealing with a rural community that has not significantly altered its habitat or its way of life, which still relies on agricultural activities and small-scale cattle breading (also see Adamou and Shen 2017 for a similar result among another community of the same mountainous area, the Mixteca Alta). In addition, the community is very small (fewer than 200 inhabitants), its members maintain face-to-face interactions in everyday life where they can rely on gesture while they have limited interactions with outsiders who might use different gestures and spatial linguistic expressions. In addition, there is overall social and cultural cohesion, for example through the system of *usos y costumbres* that structures the community's social life around collective actions and tasks.

4. Conclusion

The present study offers insight on linguistic conceptualizations of space among the last bilingual speakers of an indigenous Mexican language. On the one hand, research on endangered languages generally focuses on linguistic change driven by influence from the dominant language, sometimes over generations of speakers, but does not examine the effects of loss at the level of the individual bilingual speaker. On the other hand, research on these populations of bilinguals is extremely sparse as it involves elderly individuals with little or no schooling who must be tested outside the lab and requires additional anthropological research.

Summarizing the results, we can conclude that bilinguals use the native (geocentric) linguistic conceptualizations in both languages, but restrict the egocentric ones to the new, dominant language, Spanish. Crucially, the Ngigua data confirm that geocentric conceptualizations can be transmitted to monolingual generations, including in a language where egocentric means prevail in other settings. It also shows that this process of transmission relies on conceptual convergence between the two languages that takes place at the level of the bilingual generation of speakers. The present study therefore offers new evidence about how rural, indigenous populations preserve geocentric linguistic conceptualizations despite a shift to a language which tends to use egocentric vocabulary. In particular, it was shown that the monolingual Spanish-speaking Ngiguas draw on Spanish cardinal terms, which they acquired through schooling, in order to strengthen geocentric representations. In addition, all the respondents in our study use a variety of linguistic expressions that can match and complement the geocentric representations, such as deictics, which draw attention to the gesture, and topological terms.

For future research, although it would be interesting to observe how the acquisition of geocentric conceptualizations is taking place by investigating child-directed speech, we note that this is not possible in the Ngigua community under study where there are practically no families with children remaining in the community due to economically driven migration. Such research might therefore need to be conducted in other indigenous communities that show similar characteristics.

Abbreviations

1, 2, 3	first, second, third person
ART	article
CLF	classifier
DEF	definite article
DEM	demonstrative
DIM	diminutive
F	feminine
IMP	imperative
INTJ	interjection
LOC	locative

M	masculine
NP	proper noun
PL	plural
PROX	proximate
SG	singular

References

Adamou, E., 2017a. Spatial language and cognition among the Ixcatec-Spanish bilinguals (Mexico). In K. Bellamy, M. Child, A. Muntendam and M. C. Parafita Couto (Eds), Multidisciplinary Approaches to Bilingualism in the Hispanic and Lusophone World. John Benjamins, Amsterdam and Philadelphia, pp. 175–209.

Adamou, E., 2017b. Subject preference in Ixcatec relative clauses. Studies in Language 41 (4), 872–913.

Adamou, E., Shen, R. X., 2017. Beyond language shift: Spatial cognition among the Ixcatecs in Mexico. Journal of Cognition and Culture 17 (1-2), 94–115.

Athanasopoulos, P., 2009. Cognitive representation of colour in bilinguals: the case of Greek blues. Bilingualism: Language and Cognition 12 (1), 83–95.

Athanasopoulos, P., Dering, B., Wiggett, A., Kuipers, J.R., Thierry, G., 2010. Perceptual shift in bilingualism: Brain potentials reveal plasticity in pre-attentive colour perception. Cognition 116 (3), 437–443.

Athanasopoulos, P., Damjanovic, L., Krajciova, A., Sasaki, M., 2011. Representation of colour concepts in bilingual cognition: The case of Japanese blues. Bilingualism: Language and Cognition 14 (1), 9–17.

Bates, D., Maechler, M., Bolker, B., Walker, S., 2015. Fitting Linear Mixed-Effects Models Using lme4. Journal of Statistical Software 67, 1–48.

Belmar, F., 1899. Idiomas indígenas del estado de Oaxaca. El Chocho. Oaxaca.

Bohnemeyer, J., Donelson, K. T., Moore, R. E., Benedicto, E., Capistrán Garza, A., Eggleston, A., Hernández Green, N., Hernández Gómez, M. S., Herrera Castro, S., O'Meara, C. K., Pérez Báez, G., Palancar, E., Polian, G., Romero Méndez, R., 2015. The contact diffusion of linguistic practices: Reference frames in Mesoamerica. Language Dynamics and Change 5 (2), 169–201.

Bowerman, M., Levinson, S. C. (Eds), 2001. Language acquisition and conceptual development. Cambridge University Press, Cambridge.

Brown, A., Gullberg, M., 2011. Bidirectional cross-linguistic influence in event conceptualization? Expressions of path among Japanese learners of English. Bilingualism: Language and Cognition 14 (1), 79–94.

Brown, P., Levinson, S. C., 1993. Linguistic and nonlinguistic coding of spatial arrays: Explorations in Mayan cognition (Working Paper No. 24). Cognitive Anthropology Research Group, Max Plank Institute, Nijmegen.

Bueti, D., Walsh, V., 2009. The parietal cortex and the representation of time, space, number, and other magnitudes. Philosophical Transactions of the Royal Society of London B: Biological Sciences 364, 1831–1840.

Bylund, E., Jarvis, S., 2011. L2 effects on L1 event conceptualization. Bilingualism: Language and Cognition 14 (1), 47–59.

Bylund, E., Athanasopoulos, P., 2017. The Whorfian time warp: Representing duration through the language hourglass. Journal of Experimental Psychology: General 146, 911–916.

Casasanto, D., Bottini, R., 2014. Mirror reading can reverse the flow of time. Journal of Experimental Psychology: General 143, 473–479.

Gallistel, C. R., 2002. Language and spatial frames of reference in mind and brain. Trends Cognitive Sciences 6, 321–322.

Goldin-Meadow, S., 2004. Hearing gesture: How our hands help us think. Harvard University Press, Cambridge MA.

Gollan, T., Montoya, R., Cera, C., Sandoval, T., 2008. More use almost always means a smaller frequency effect: Aging, bilingualism, and the Weaker Links Hypothesis. Journal of Memory and Language 58, 787–814.

Gullberg, M., 2011. Thinking, speaking and gesturing about motion in more than one language. In A. Pavlenko (Ed.), Thinking and speaking in two languages. Multilingual matters, Bristol, pp. 143–169.

Gullberg, M., Indefrey, P., 2003. Language Background Questionnaire. Developed in The Dynamics of Multilingual Processing 3. Max Planck Institute for Psycholinguistics, Nijmegen. Accessed at http://www.mpi.nl/departments/other-research/research-projects/the-dynamics-of-multilingual-processing/tools

Haun, D. B. M., Rapold, C., Janzen, G., Levinson, S. C., 2011. Plasticity of human spatial cognition: Spatial language and cognition covary across cultures. Cognition 119, 70–80.

Jarvis, S., Pavlenko, A., 2008. Cross-linguistic influence in language and cognition. Routledge, New York and London.

Johns, M. A., Valdés Kroff, J. R., Dussias, P. E., 2018. Mixing things up: How blocking and mixing affect the processing of codemixed sentences. International Journal of Bilingualism. First published on February 5, 2018. doi/10.1177/1367006917752570

Kendon, A., 2004. Gesture. Visible action as utterance. Cambridge University Press, Cambridge.

Kroll, J., Dussias, P., Bice, K., Perroti, L., 2015. Bilingualism, mind, and brain. Annual Review of Linguistics 1, 377–394.

Le Guen, O., 2011. Speech and gesture in spatial cognition among the Yucatec Mayas. Cognitive Science 35, 905–938.

Levinson, S. C., 2003. Space in language and cognition. Cambridge University Press, Cambridge.

Li, P., Gleitman, L., 2002. Turning the tables: Language and spatial reasoning. Cognition 83, 265–294.

Li, P., Abarbanell, L., Gleitman, L., Papafragou, A., 2011. Spatial reasoning in Tenejapan Mayans. Cognition 120, 33–53.

Li, P., Zhang, F., Tsai, E., Puls, B., 2014. Language history questionnaire (LHQ 2.0): A new dynamic web-based research tool. Bilingualism: Language and Cognition 17(3), 673–680.

Lin, Y.-T., Hsiao, H.-C., 2017. Cultural mediation between language and landscape in spatial referencing in a multilingual context: a test case in Taiwan. Paper presented at the International Conference of the Association for Linguistic Typology 12. Australian National University, Canberra.

Lum, J., 2017. Frames of spatial reference in Dhivehi language and cognition. PhD thesis at Monash University, Melbourne.

Marghetis, T., McComsey, M., and Cooperrider, K., 2014. Spatial reasoning in bilingual Mexico: Delimiting the influence of language. Proceedings of the 36th Annual

Conference of the Cognitive Science Society. Cognitive Science Society, Austin, TX.

Mathôt, S., Schreij, D., Theeuwes, J., 2012. OpenSesame: An open-source, graphical experiment builder for the social sciences. Behavior Research Methods 44, 314–324.

McNeill, D., 1992. Hand and mind: What gestures reveal about thought. University of Chicago Press, Chicago IL.

McNeill, D., 2005. Gesture and thought. University of Chicago Press, Chicago IL.

Meakins, F., 2011. Spaced out: inter-generational changes in the expression of spatial relations by Gurindji people. Australian Journal of Linguistics 31 (1), 43–78.

Meakins, F., Jones, C., Algy, C., 2016. Bilingualism, language shift and the corresponding expansion of spatial cognitive systems. Language Sciences 54, 1–13.

Mock, C., 1982. Los Casos Morfosintácticos del Chocho. Anales de Antropología 19, 345–378.

O'Meara, C., Pérez Báez, G., 2011. Spatial frames of reference in Mesoamerican languages. Language Sciences 33, 837–852.

Palmer, B., 2015. Topography in language. Absolute Frame of Reference and the Topographic Correspondence Hypothesis. In de Busser, R., LaPolla, R. (Eds), Language structure and environment. John Benjamins, London. 177–226.

Palmer, B., Gaby, A., Lum, J., Schlossberg J., 2016. Topography and frame of reference in the threatened ecological niche of the atoll. Conference paper presented at Geographic grounding. Place, direction and landscape in the grammars of the world. Copenhagen, May 2016.

Paradis, M., 2009. Declarative and procedural determinants of second languages. John Benjamins, Amsterdam.

Pederson, E., 1993. Geographic and manipulable space in two Tamil linguistic systems. In Frank, A.U., Campari, I. (Eds.) Spatial information theory: a theoretical basis for GIS. Springer, Berlin, pp. 294–311.

Pederson, E., Danziger, E., Wilkins, D. P., Levinson, S. C., Kita, S., Senft, G., 1998. Semantic typology and spatial conceptualization. Language 74, 557–589.

Polian, G., Bohnemeyer, J., 2011. Uniformity and variation in Tseltal reference frame use. Language Sciences 33(6), 868–891.

R Core Team, 2017. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/

Reis, A., Faisca, L., Ingvar, M., Petersson, K. M., 2006. Color makes a difference: two-dimensional object naming in literate and illiterate subjects. Brain and Cognition 60, 49–54.

Schmid, M. S., Köpke, B., 2017. The relevance of first language attrition to theories of bilingual development. Epistemological keynote paper with commentaries. Linguistic Approaches to Bilingualism 7(6), 637–667.

Slobin, D., 2003. Language and thought online: Cognitive consequences of linguistic relativity. In Gentner, D., Goldin-Meadow, S. (Eds.), Language in mind: Advances in the study of language and thought. MIT Press, Cambridge, MA, pp. 157–191.

Slobin, D., 2006. What makes manner of motion salient? Explorations in linguistic typology, discourse, and cognition. In Hickmann, M., Robert, S. (Eds), Space in languages: Linguistic systems and cognitive categories. John Benjamins, Amsterdam, pp. 59–81.

Trueswell, J., Papafragou, A., 2010. Perceiving and remembering events cross-linguistically: Evidence from dual-task paradigms. Journal of Memory and Language 64, 64–82.

Ullman, M., 2004. Contributions of memory circuits to language: the declarative/procedural model. Cognition 92, 231–270.

Veerman-Leichsenring, A., 2000. Gramática del chocho de Santa Catarina Ocotlán (Vol. 86). Research School CNWS, School of Asian, African and American Studies, Univeriteit Leiden, Instituto de investigaciones Antropológicas, Universidad Nacional Autónoma de México, Leiden, The Netherlands.

Whorf, B. L., 1956. Language, thought, and reality. [4th edition, 1959]. John Wiley and Sons, The Technology Press of MIT, New York NY.

Appendix

Table A1. Types of linguistic terms and gestures (occurrences and percentages). We indicate in bold the percentages corresponding to the types that are discussed in detail in the paper.

Speech	Gesture	Bilinguals in Ngigua		Bilinguals in Spanish		Monolinguals in Spanish	
All locative information is on the gesture		35	*16%*	35	*14%*	32	*16%*
Deixis	Direct pointing	12	*6%*	17	*7%*	6	*3%*
Deixis	Direct pointing-Head	17	*8%*	12	*5%*	2	*1%*
Deixis	Egocentric	3	*1%*	5	*2%*	3	*2%*
Deixis	Geocentric	16	*7%*	50	***20%***	23	***12%***
Deixis	Mixed	4	*2%*	2	*1%*	1	*1%*
Egocentric	Direct pointing	0	*0%*	0	*0%*	2	*1%*
Egocentric	Direct pointing-Head	1	*0%*	1	*0%*	1	*1%*
Egocentric	Egocentric	8	*4%*	13	*5%*	13	*7%*
Egocentric	Geocentric	6	*3%*	4	*2%*	2	*1%*
Egocentric	Mixed	10	*5%*	5	*2%*	7	*4%*
Geocentric	Direct pointing-Head	0	*0%*	0	*0%*	5	*3%*
Geocentric	Egocentric	0	*0%*	1	*0%*	0	*0%*
Geocentric	Geocentric	1	*0%*	8	*3%*	31	***16%***
Geocentric	Mixed	0	*0%*	0	*0%*	2	*1%*
Intrinsic	Direct pointing	2	*1%*	1	*0%*	2	*1%*
Intrinsic	Direct pointing-Head	9	*4%*	4	*2%*	5	*3%*
Intrinsic	Egocentric	0	*0%*	6	*2%*	3	*2%*
Intrinsic	Geocentric	12	*6%*	10	*4%*	10	*5%*
Intrinsic	Mixed	0	*0%*	0	*0%*	2	*1%*
Noun	Direct pointing	10	*5%*	4	*2%*	3	*2%*
Noun	Direct pointing-Head	11	*5%*	3	*1%*	3	*2%*
Noun	Egocentric	0	*0%*	3	*1%*	1	*1%*
Noun	Geocentric	4	*2%*	12	*5%*	18	*9%*
Topology	Direct pointing	13	***6%***	6	*2%*	1	*1%*
Topology	Direct pointing-Head	15	***7%***	13	*5%*	3	*2%*
Topology	Egocentric	1	*0%*	4	*2%*	1	*1%*
Topology	Geocentric	19	***9%***	28	***11%***	15	***8%***
Topology	Mixed	3	*1%*	0	*0%*	0	*0%*
Toponymy	Direct pointing-Head	2	*1%*	0	*0%*	0	*0%*
Toponymy	Geocentric	2	*1%*	0	*0%*	1	*1%*

Totals	216	*100%*	247	*100%*	198	*100%*