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Spatial Cognition, Modality and Language Emergence: Cognitive Representation of Space in Yucatec Maya Sign Language (Mexico)

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Abstract: This paper analyzes spatial gestures and cognition in a new, or so-called "emerging", visual language, the Yucatec Maya Sign Language (YSML). This sign language was created by deaf and hearing signers in various Yucatec Maya villages on the Yucatec Peninsula (Mexico). Although the sign language is not a signed version of spoken Yucatec Maya, both languages evolve in a similar cultural setting. Studies have shown that cultures around the world seem to rely on one preferred spatial Frame of Reference (FoR), shaping in many ways how people orient themselves and think about the world around them. Prior research indicated that Yucatec Maya speakers rely on the use of the geocentric FoR. However, contrary to other cultures, it is mainly observable through the production of gestures and not speech only. In the case of space, gestures in spoken Yucatec Maya exhibit linguistic features, having the status of a lexicon. Our research question is the following: if the preferred spatial FoR among the Yucatec Mayas is based on co-expressivity and spatial linguistic content visually transmitted via multimodal interactions, will deaf signers of an emerging language created in the same cultural setting share the same cognitive preference? In order to answer this question, we conducted three experimental tasks in three different villages where YMSL is in use: a non-verbal rotation task, a Director-Matcher task and a localization task. Results indicate that YMSL signers share the same preference for the geocentric FoR.

Keywords: frames of references; emerging sign language; Yucatec Maya sign language; cognition; language; spatial thinking

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1. Introduction

Spatial cognition is crucial for humans to think about the world. It helps not only in remembering and thinking about real and imaginary places, but it also constrains other domains, such as time (Majid et al. 2013). Interestingly, although spatial cognition, in terms of cognitive ability, is shared among individuals and cultural groups, it is to some extent malleable. These premises have two consequences. First, humans can think about space in different ways according to context (Li and Abarbanell 2018). Second, languages and cultures will come to determine one specific (or preferred) manner in which individuals of the same group will communicate about space (Levinson 2003).

The issue of spatial cognition and its variation across languages has been the subject of great debates since the mid-nineties, especially revolving around the question of cross-linguistic variation in the preferred frames of reference. A spatial Frame of Reference (FoR), simply put, is a way to encode spatial relationships between entities (a Figure and a Ground) in terms of the relevant angular information necessary to establish location in space (Levinson 2003, p. 2). Crucially, a FoR is used to locate entities that are different from the body of the speaker or signer, making FoRs theoretically distinct (although not unrelated) from deixis (see Le Guen 2011a for a discussion on such a relation). Three main

FoRs are usually considered in the literature. The first is the intrinsic FoR in which a Figure is located relative to a Ground's intrinsic division (e.g., front, back or sides). For instance, "the tree is in front of the house". The relation in this FoR is a binary one with two objects located in relation to each other. This FoR is probably the most widespread in the languages of the world (if not universal). It usually coexists with the other FoRs, as its functionality is ultimately limited (especially in terms of angular information). The second FoR is the egocentric FoR in which a Figure is located in relation to the Ground based on the viewpoint of the speaker or signer (usually helping to create the Ground's internal division). For instance, "from the road, the tree is to the right of the house". Importantly, this FoR involves a triadic relationship where coordinates are specified in relation to the speaker/signer's viewpoint. In cases of remote locations, it becomes necessary to project a virtual viewpoint on the scene, usually asking the interlocutor to imagine from where the scene is being described. This strategy typically involves a linguistic preface that states something like "if you're standing at x/looking at x, the Figure is y relative to the Ground". Finally, the third FoR is the geocentric FoR in which coordinates between entities are defined by external features of the environment (e.g., mountains, direction of the sun, wind, rivers, etc.). We consider the absolute FoR, based on the use of cardinal directions, to be a sub-system of the geocentric FoR, as cardinal directions cannot be passed (i.e., nothing is beyond North, but once you pass a mountain the whole system has to be updated; see Wassmann and Dasen (1998)). The geocentric FoR is also a triadic system where coordinates are specified not by the viewpoint of the individual but by (contextually) stable features of the environment. For instance, "The tree is North-East of the house" or "the tree is on the riverside of the house". Such a system implies a constant reckoning of the environment.

While the intrinsic FoR is common, it is also limited, especially when the Ground has no obvious internal division. Just imagine you arrive at a Y junction with a tree separating two roads, and someone gave you the following instruction: "at the junction take the road on the side of the tree". This instruction is clearly not very helpful! This is why the egocentric and the geocentric FoRs are more advantageous in terms of orientation and communicative power. Imagining again the same situation, relying on the egocentric FoR (e.g., "at the junction you take the road to the left") or the geocentric FoR (e.g., "you take the road that goes East") is far more convenient. However, the two are not interchangeable and entail specific constraints. Imagine now that the same instructions were given to two different people coming from different directions. While instructions based on the geocentric FoR can remain the same for both individuals, instructions based on the egocentric FoR will have to be specifically designed, implying a specific viewpoint for each case (e.g., "if you are coming from the city you take the left road, but if you are coming from the mountain you have to take the right"). The use of each FoR conveys specific cognitive processes, especially when it comes to the memorization of space and spatial arrangements (Tversky 1998).

Probably because of the specific constraints implied by the use of the egocentric or the geocentric FoR, cultures around the world usually rely either on one or the other, stating this preference as a communicative norm among individuals of the same group. While both FoRs can coexist, they are not interchangeable, and even people living in cities with streets aligned on cardinal directions can think they are going North or South (instead of left or right), but they usually do not extend this mapping to different contexts or scales, as for items in their kitchen, for instance (e.g., "I left the pot South-West of the coffee maker"). Some cultures, however, do apply such mapping to other contexts, especially the ones who lack terms for left and right (Palmer et al. 2021). Preferences for frames of reference have enabled researchers to argue about how much culture, and more specifically language, can influence or even determine cognitive processes related to space, an issue we will come back to in the discussion.

The preference for the egocentric of the geocentric FoR is, however, not straightforward. While researchers have claimed that the rural setting should always trigger the use of the geocentric FoR (Tkachman 2022), studies have shown that this is not the case and that various factors can influence this choice, such as the level of formal education, language

change, modes of transportation, etc., and that the distribution of the FoR is not limited to the physical environment (urban vs. rural) (Dasen and Mishra 2010; Ross et al. 2015; Polian and Bohnemeyer 2011; Calderón et al. 2019; Bohnemeyer et al. 2014). Regarding emerging sign languages specifically, there are, to date, no psycholinguistics studies that have tackled the issue of FoRs. While several authors have pointed to the possibility that signers in these settings may rely on the geocentric FoR, the evidence proposed is anecdotical or a description of pointing strategies (which can be correlated but not causally related) (de Vos 2012; Mesh 2017).

There have been debates regarding which is the preferred Frame of Reference among the Yucatec Mayas. Ultimately, the discussion turned out to be more a methodological issue and involved the way language is approached. On the one hand, Bohnemeyer et al. (Polian and Bohnemeyer 2011; Bohnemeyer and Stolz 2006) considered language to be only oral, and so they designed tasks that would only consider verbal production, finding that all three possible frames of reference were in use among the Yucatec Mayas, with no strict preference. Although their results are undeniable, it seems strange that a culture would indiscriminately use the geocentric and the egocentric FoR, as they are, in many instances, contradictory. On the other hand, Le Guen (2011b) took a multimodal approach on language, seriously considering gesture production in spatial descriptions. Based on extensive ethnography, he designed an experiment in which participants had the option to spontaneously use both verbal and gestural semiotic channels to locate real-world entities among each other. Results show that, as reported in Bohnemeyer et al.'s studies, participants used all three frames of reference in their speech, as well as manner deictics in great proportion. Speech did not encompass the relevant spatial information, which was instead provided through gestural production. Basically, for Yucatec Mayas, spatial gestures act as spatial words, and more precisely as linguistic symbols. That is, a gesture to the north means "North" and can be introduced in speech as "like this, this way". Such use of multimodality is important, since our study deals with the representation of space in an emerging sign language in a Yucatec Maya cultural setting and because sign languages are also based on visual linguistic symbols, namely signs.

In order to better explain why the egocentric and the geocentric FoRs are not compatible, especially when it comes to gesture production and decoding, let us consider their use in a wayfinding situation. Imagine you are facing a Yucatec Maya speaker explaining to you how to get from his house to the church of his village (see Figure 1). A typical description would be something like "*Tinnaayle', ka ya'ax bin beya'* [gesture 1], *ken ts'o'ojke' kabin beya'* [gesture 2], *despweese' kak'eechle' bey baandaa'* [gesture 3]. *K'uchkech te seentroo',* bey yanik le iiglesya te' ya'axche'o' [gesture 4]". "From my house, you go first like this [gesture 1], then, you go like this [gesture 2], after that, you turn this way [gesture 3]. When you get to the main plaza, the church stands like this with respect to the Ceiba tree [gesture 4]". As is clear from the instructions in Maya or English, one must pay attention to the gestures, as the speech does not contain any angular information. Attention to gesture becomes crucial to distinguish the egocentric from the geocentric FoR. If you consider the gestures to be oriented according to real-world orientation (i.e., using a geocentric FoR), you might find the church easily (following the green path on Figure 1). However, interpreting the gestures using one's point of view at each segment (i.e., an egocentric FoR), you might get to a very different place (following the red path on Figure 1). Gesture 1 is actually similar in both FoRs and can be read as going East as well as going to the left. However, from gesture 2, the two paths diverge; while gesture 2 is oriented towards the South, an egocentric coder might think one must still go forward as the gesture is pointing in front of the speaker during the explanation. In the case of gesture 3, it is similar to gesture 1, indicating East. However, from an egocentric perspective it looks like one must take a left turn, since the speaker is lifting their left arm. The same goes for the last gesture. Also noticeable from this example is why the intrinsic FoR is limited in terms of angular information. According to this FoR, the church would be "in front of" or "to the side of" the tree, and although a

true statement, it does not give specific information as to which side of the tree the church is located (this, because the tree as a Ground has no intrinsic orientation).

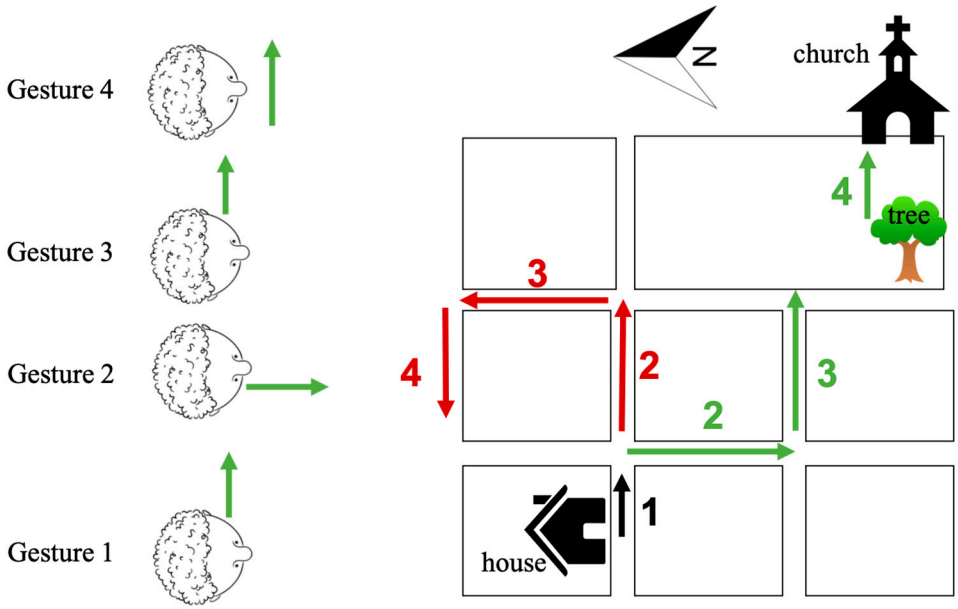

Figure 1. Wayfinding according to gestures produced based on geocentric FoR (in green) and its understanding according to the egocentric FoR (in red).

Now, imagine you are a deaf child in a Yucatec Maya context (or any culture using the geocentric FoR for spatial locations), and you can only rely on gestures to get where you were told to go. You will quickly figure out that gestures have to be understood and remembered according to their real-world orientation (otherwise, you will not get to any place and will surely be scolded by your mother!). Of course, the inverse is also true: if the speaker gives instructions according the egocentric FoR, the gestures will have to be understood using this FoR.

Yucatec Maya Sign Language (YMSL) is an "emerging language" (Meir et al. 2010), an indigenous sign language used by deaf and hearing signers in Yucatec Mayan communities with a high incidence of deafness in the peninsula of Yucatán, Mexico. Data for this paper were collected in three communities: Chicán, Nohkop and Trascorral. The communities of study are all located within the state of Yucatán but at one to several hours drive from each other. Members of the three communities have not been in contact in the past; their sign languages emerged within recent decades and are historically unrelated. Despite the lack of a historical link, YMSLs from different communities exhibit an important degree of overlap in their lexicon and can be considered similar languages, a proposition that has been argued in previous works, at least for Chicán and Nohkop (Le Guen 2012; Le Guen et al. 2020; Le Guen and Uicab Martín 2021; Safar 2017, 2020a, 2020b; Safar et al. 2018). The villages differ from each other in their overall population size as well as the number and distribution of deaf people. Chicán is a village of 720 inhabitants, including 16 deaf people who are between 19 and 69 years old. The oldest signer was in his early eighties when he passed away in 2020. In Nohkop, signers are all from a family of five siblings between the ages of 20 and 28 who grew up together and among whom four are deaf. Trascorral is home to a family of 13 siblings, six of whom are deaf and are between 11 and 33 years old.

The three tasks presented in this paper were all designed to leave participants with the choice of reproducing an array by using either the egocentric or the geocentric FoR. Although forced, both choices are equally valid and aim at displaying the preferred FoR for individual participants and/or the community. Based on what we have explained above, we have three possible predictions. The first is that signers (deaf and Bilingual-Bimodal) follow the general pattern of the Yucatec Maya community and use the geocentric FoR. This

prediction would imply a transmission of spatial FoR via the visual channel from Yucatec Maya speakers to signers. Our second prediction is that modality would shift the preference for signers, especially deaf signers, towards the use of the egocentric FoR. The fact that signers have to be face to face for communicating could increase their reliance on their own viewpoint and, as a consequence, make the egocentric FoR a preferred strategy for thinking about spatial arrangements (Secora and Emmorey 2020; Gumperz and Levinson 1996). This prediction is based on previous studies in institutionalized SLs as well as some emerging SLs, especially Nicaraguan SL (A. Senghas 2003). One crucial use of space is the signing space among signers that requires a symbolization of spatial relations; as Emmorey et al. point out, "when space operates in the service of grammatical functions, the spatial relation between the loci themselves is irrelevant" (Emmorey et al. 1995, p. 43). It would seem that such use of space as well as the perspective of the signers would trigger a preference for the egocentric FoR (Perniss 2012). Senghas' proposal for the evolution of a home sign system towards a full-fledged sign language is that signers would shift from an "unrotated perspective" (i.e., the geocentric FoR) to a "rotated perspective" (i.e., the egocentric FoR), coincidently, the one also used in ASL (A. Senghas 2003). The third possible prediction is that results would display mixed strategies (Bohnemeyer et al. 2014). This would imply either a shift in the preferred FoR in the community (if individuals show consistent results), which could be based on modality and/or level of education, or that the task was not properly understood (if individuals display inconsistent results). The three tasks were performed by signers of YMSL, both Bilingual-Bimodal hearing (speakers of Yucatec Maya, sometimes Spanish and users of YMSL) and deaf.

Section 2 discusses the results of a non-verbal rotation task, widely conducted over the world, called the "animals in a row". Section 3 deals with a communication task, run in YMSL, that consists of having one participant describing to another how to place an array of items on a table. Section 4 examines the results of a localization task, the same used in Le Guen (2011b) but adapted for the YMSL. Finally, after a quick summary of the results (Section 5) we present a discussion (Section 6) on the implications of the results, followed by the conclusion (Section 6).

2. Non-Verbal Rotation Task

In order to test non-verbal preference for FoR among YMSL signers, we relied on a commonly used task, the so-called "animals in a row", first developed by Brown and Levinson and their colleagues from the Max Planck Institute for Psycholinguistics (Brown and Levinson 1993; Pederson et al. 1998). This non-verbal task is based on the "rotation paradigm" that forces subjects to make an implicit choice between two distinct types of conceptual representation of a spatial scene. In order for them to make this choice, they have to reconstruct an array of oriented objects first presented on a table, then turn 180 degrees and reproduce "the same array" on a second table. Participants then have to memorize and internally decide (i.e., think using internal speech, following Levinson (2003)'s prediction) what counts as the correct reproduction of the array as similar. They have two choices at their disposal. Either they consider the array to be oriented according to their own viewpoint (relying on the egocentric FoR) or they consider the array to be oriented according to external landmarks or cardinal directions (relying then on the geocentric FoR).

Le Guen (2011b) ran this experiment with speakers of Yucatec Maya and showed that they display a clear preference towards the geocentric FoR (see also Bohnemeyer et al. 2022). According to the author, this preference towards a geocentric FoR is due to the fact that people rely on local landmarks and cardinal directions, especially for agricultural purposes, orientation in space, weather predictions and telling time (considering the rotation of the sun and moon), that is, based on their local cultural habits and forms of exploitation of the environment. Of course, this prediction relies on habitus from a traditional way of life among speakers, and in the case of YMSL, various factors might influence this preference, which raises some different issues.

The first factor is the degree of literacy and formal education in school. As pointed out by previous authors, literacy (in Spanish in this case) tends to promote the use of the egocentric FoR among participants (Polian and Bohnemeyer 2011; Li and Gleitman 2002; Li et al. 2011). Since our sample of signers encompasses a variety of signers, hearing and deaf, with various degrees of education, we are able to analyze this feature.

The second factor is modality. Yucatec Maya speakers can manage their access to the world without being face to face (Hanks 1990), using, for instance, oral back-channels (Brown et al. 2021). This is, however, not the case among YMSL signers. Because of the visual nature of sign language, signers have to see each other and each other's hands constantly to maintain communication. This means that they have to share a common signing space between individuals while they are interacting. One possibility is that sharing a common signing space visually available to both (or more) signers encourages the use of an egocentric FoR, itself based on viewpoint. Once again, our sample combines deaf and hearing signers; thus, if modality plays a significant role in the preference of FoR, it should emerge in the results.

2.1. Method

2.1.1. Participants

A total of 29 participants from 3 villages agreed to engage in the task. In total, 20 females and 9 males participated. Ages ranged from 10 to 68 years old (average 32.5). It should be pointed out that our sample was limited, especially in the case of deaf participants. Deaf people who were willing to participate or were present were always limited in number and our sample was thus restricted to the available people.

In Chicán, 18 people (10 females) agreed to participate, including 13 deaf signers (5 females) and 6 close kin related Bilingual-Bimodal signers (5 females). Ages ranged from 10 to 68 years old (average 39.8). In Nohkop, 6 people (5 females) agreed to participate, including 3 deaf signers and 3 close kin related Bilingual-Bimodal signers (2 females). Ages ranged from 12 to 27 years old (average 22.5). In Trascorral, 5 people, all female, agreed to participate, including 2 deaf signers and 3 close kin related Bilingual-Bimodal signers. Ages ranged from 12 to 31 years old (average 18). More details can be found in Table 1.

2.1.2. Setting

Two tables were placed 4–5 m apart, oriented according to cardinal axes (either North–South or, more commonly, East–West). For this task, called "animals in a row", researchers have used little toy animals (hence the name), usually a pig, a horse and a cow (Brown and Levinson 1993; Le Guen 2011b; Levinson 2003). However, for practical reasons, we decided to change the animals to toy cars (1/64 scale). Like toy animals, these stimuli also have an intrinsic orientation (i.e., a clear front and back), are all symmetric along their left/right axis and are familiar objects to the participants. We used different models and shapes, and each car had a specific color: red, white or blue. See Figure 2.

Figure 2. Toy cars used as stimuli for the rotation task.

Table 1. List of participants for the rotation task.

Village	Participant	Deaf/Hearing	Gender	Age	Handedness	Education Level[1]
Chicán	1	deaf	M	55	RH	Primary
	2	deaf	M	58	RH	No formal study
	3	deaf	M	68	RH	No formal study
	4	deaf	M	58	RH	No formal study
	5	deaf	M	17	RH	Secondary
	6	deaf	M	32	RH	Secondary
	7	deaf	M	58	RH	Secondary
	8	deaf	F	48	RH	No formal study
	9	deaf	F	48	RH	No formal study
	10	deaf	F	59	RH	No formal study
	11	deaf	F	48	RH	Primary
	12	deaf	F	22	RH	Secondary
	13	hearing	F	18	RH	Secondary
	14	hearing	F	10	RH	Primary
	15	hearing	F	16	RH	Secondary
	16	hearing	F	41	RH	No formal study
	17	hearing	F	50	RH	No formal study
	18	hearing	M	12	LH	Secondary
Nohkop	19	deaf	F	27	RH	No formal study
	20	deaf	F	19	RH	No formal study
	21	deaf	F	25	RH	No formal study
	22	hearing	M	27	RH	Secondary
	23	hearing	F	12	RH	Primary
	24	hearing	F	25	RH	Secondary
Trascorral	25	deaf	F	31	RH	Primary
	26	deaf	F	12	RH	Primary
	27	hearing	F	18	RH	Secondary
	28	hearing	F	12	RH	Secondary
	29	hearing	F	17	RH	Secondary

In Chicán, some experimental sessions were conducted at the YMSL project house, based on the traditional model of Maya thatched roof houses, while the rest were conducted in the participants' homes (in Chicán and in the other communities).

2.1.3. Procedure, Materials and Coding

The experiment was presented as a memorization task. We displayed the 3 stimuli according to 8 predetermined (but random) configurations (see Figure 3). This was done in order to avoid possible confusion and for comparative purposes. We also varied the orientation of each stimulus. This contrasts with previous studies where all stimuli were facing the same way. This, we think, adds to the difficulty of the task, but also prevents

participants guessing the real purpose of the experiment. The stimuli were always placed along the width of the table.

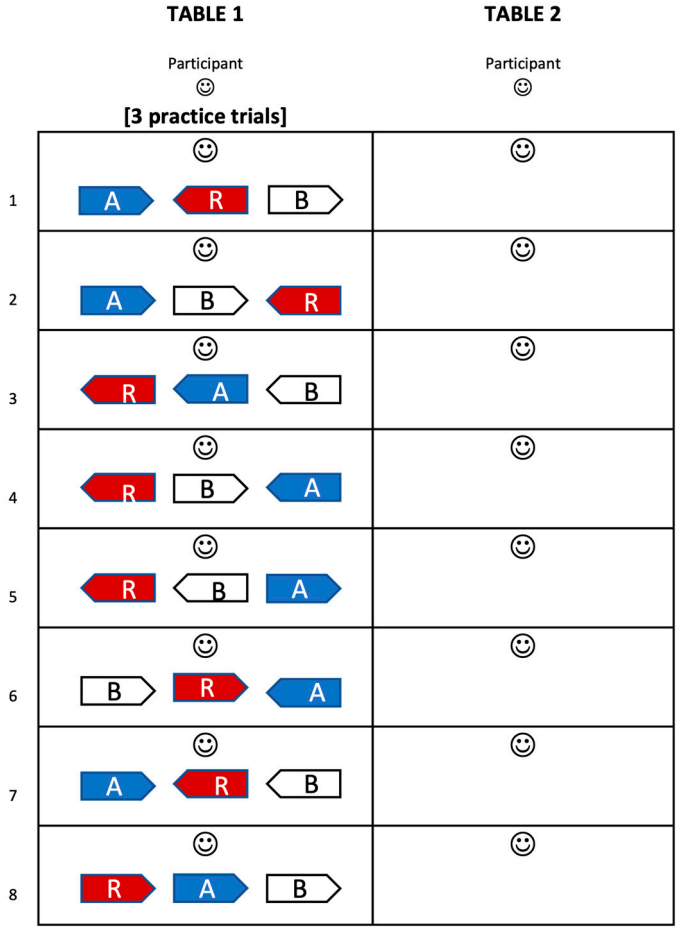

Figure 3. Predetermined configuration of the stimuli (A = blue; R = red; B = white).

Before starting the task, each participant's information was collected: community, first and last name, gender, age, right/left-handedness, school level, and whether the participant is hearing or deaf.

The dynamic was as follows: The procedure was explained to the participants in detail, either in Maya by the researcher or in YMSL by an interpreter. If the participant did not understand the instructions of the experiment, the explanation was repeated again. The task was conducted in the Yucatec Maya language for hearing signers by A. Tuz Baas and in YMSL for deaf signers. For this, the help of a YMSL interpreter was necessary to clearly explain the procedure and to avoid misunderstandings. Instructions in YMSL are presented in Figures 4 and 5.

First, during the training procedure, the participant was introduced to the stimuli, ensuring that he or she could recognize all of them. Then, three practice trials on the first table were completed. The three toy cars were put in random order on the table, and the participant could observe the order as long as needed. Once the participant felt comfortable, the researcher took the stimuli and placed them in the participant's hands for him or her to reproduce as they were. Once this training procedure was successfully completed, the first test trial was conducted with the two tables.

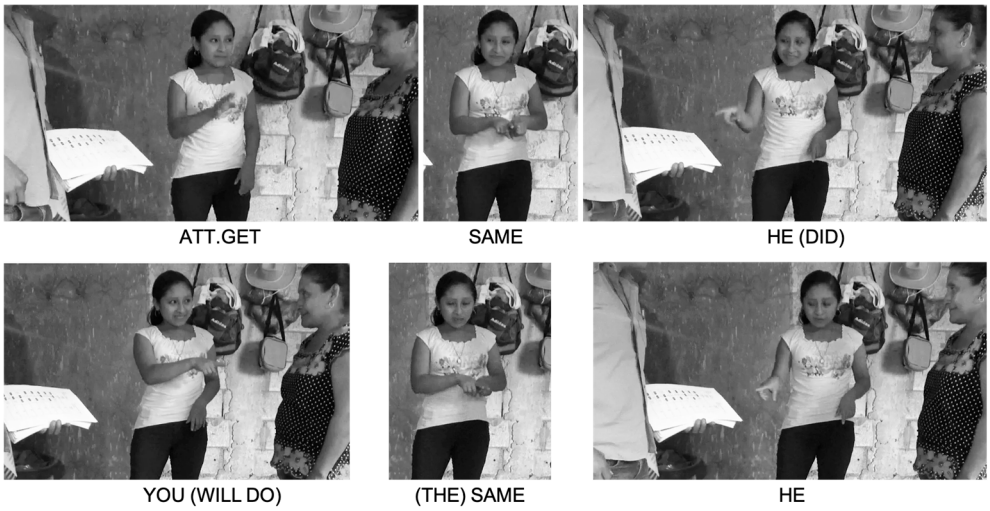

Figure 4. YMSL instructions: "Hey, the same as he did (you have to do), he. . .".

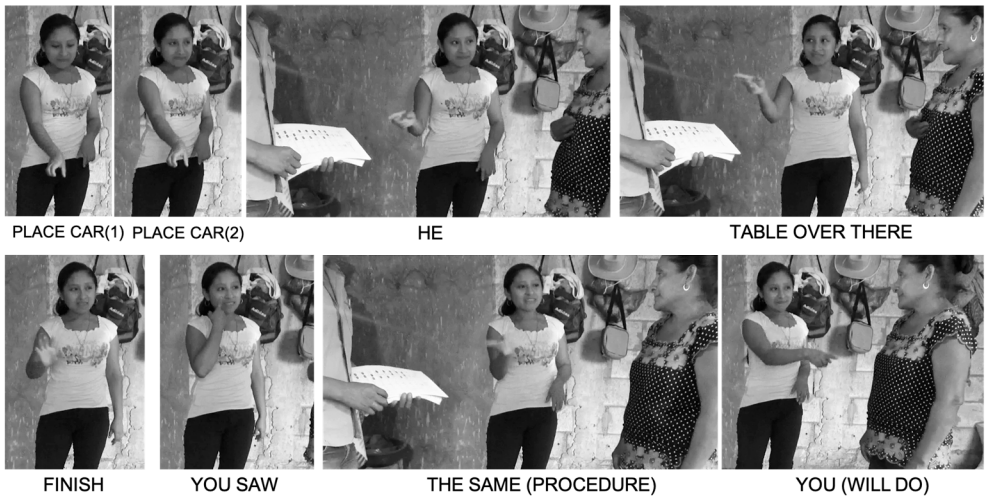

Figure 5. YMSL instructions: ". . .he is going to place the cars. When he finishes as you saw, you have to reproduce the same thing on the other table (there)".

After the three practice trials, the recorded test started with the 8 configurations. For each configuration, the researcher displayed the cars on the table, left them for the participants to observe as long as needed, then took the animals from the table. Then, both the researcher and the participant walked towards the second table. Making a 180° turn, the researcher gave the participant the animals and asked the participant to reproduce the configuration on the second table. If the participant correctly placed the stimuli (using one or the other FoR), both moved back to Table 1 for the next configuration, and so forth, until the 8 trials were completed.

The crucial parameter in this task is that the participant performs a 180° rotation, leaving him or her with two possible choices. The first is to reproduce the configuration based on viewpoint and thus arrange the stimuli along the left/right axis. Such a strategy makes use of the egocentric frame of reference. In this case, the stimuli in Table 2 are placed so as to mirror those of Table 1. Alternatively, the participant might reproduce the configuration based on the use of the geocentric frame of reference. In this case, the stimuli face the same direction for Tables 1 and 2. The participant would not use his or her viewpoint in reproducing the configuration but rather would rely on geographical space. These two possibilities are exemplified in Figure 6. For each trial, the participant's response was noted on the sheet presented in Figure 3. All sessions were video-recorded and then

transcribed and coded in ELAN (Brugman and Russel 2004). Coding was performed by two coders (O. Le Guen and A. Tuz Baas) and compared to the responses noted on the paper sheet during the experimentation. In almost all cases, both coders were in agreement, and differences were resolved by checking the video-recorded sessions.

Table 2. Participant data from the Director-Matcher task by community.

Community	Participants		Age Range	Gender		Total
	BB	Deaf		Male	Female	
Chicán	4	11	10–68	7	8	15
Nohkop	2	3	17–27	2	3	5
Trascorral	2	2	12–31	0	4	4

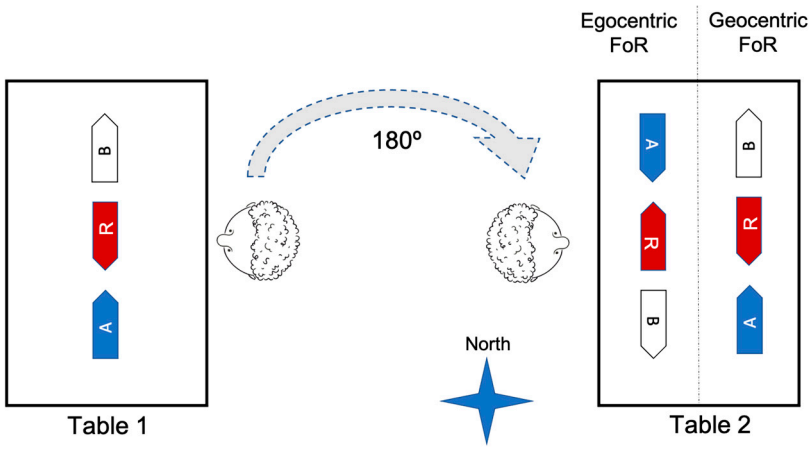

Figure 6. Predictions for the rotation task.

There was no time limit for completing the task. Participants usually took between 10 and 17 min to complete the task, with younger participants typically completing the task faster than older participants, regardless of their education level.

2.2. Results

Overall, the results show a clear preference for the use of the geocentric FoR. We will first look at results by community and then discuss the influence of modality. Tuz Baas (Forthcoming) analyzed different variables in more detail, such as age, gender and level of education. Contrary to what might have been expected, neither level of education nor age significantly influenced the preferred FoR.

Results by community show an overall preference for the geocentric FoR; see Figure 7. In Chicán, 65% of all the participants' results indicated that the task was resolved using the geocentric FoR, while Nohkop and Trascorral showed higher percentages (86% and 90%, respectively). However, looking at the combined results is not enough to estimate individual preferences. In Brown and Levinson (1993), the percentage per individual is considered significant when it is higher than 75%, meaning a clear preference for the geocentric FoR, and less than 25% implies a preference for the egocentric FoR. In the present case, considering results for all communities, only 2 participants show less than 25%, that is, they reliably used the egocentric FoR, while 10 participants display results between 28.5% and 62.5%, meaning they were not consistent in the task. Finally, 17 participants scored 75% or more, showing a reliable use of the geocentric FoR.

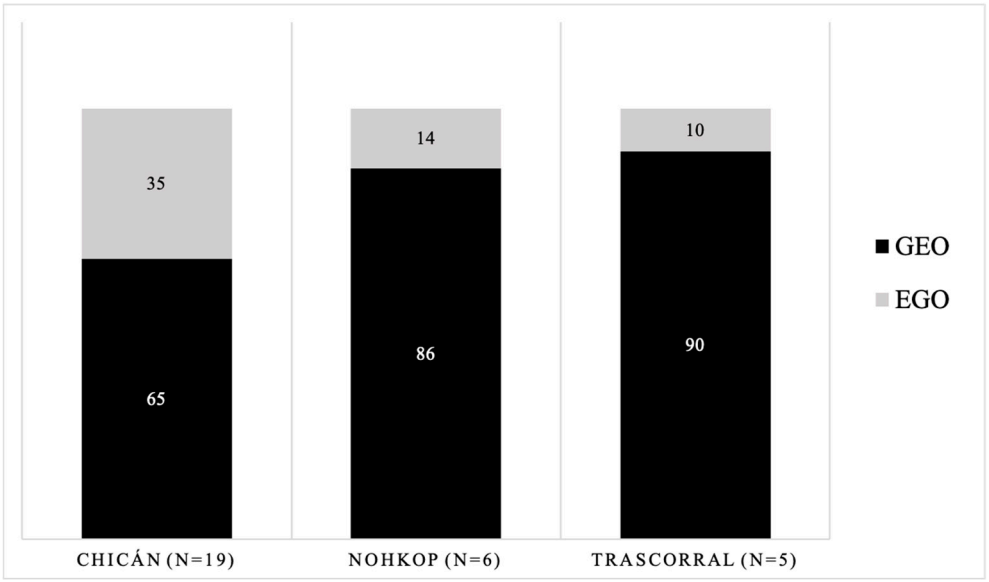

Figure 7. Results in percentage by community for the preference towards FoRs.

Results by community confirm the preference for the use of the geocentric FoR in the non-verbal task, but the question remains as to what extent modality has an influence. We divided the responses of participants by community but also by modality, that is, considering two groups: hearing (Bilingual-Bimodal or BB) and deaf signers. The results are presented in Figure 8.

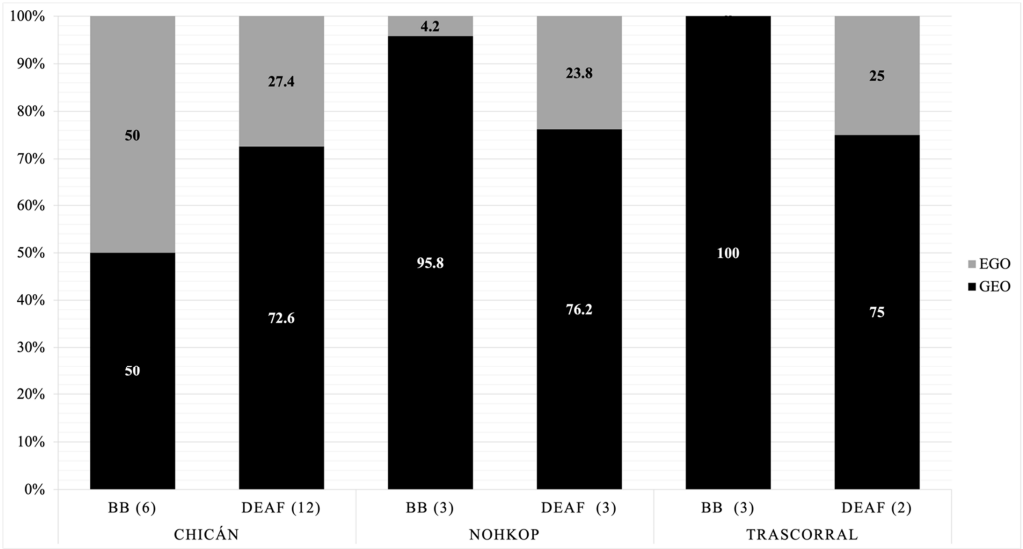

Figure 8. Results in percentage by community and hearing status for the preference towards FoRs (100% indicates a preference for the geocentric FoR, while 0% means a preference for the egocentric FoR). BB = hearing Bilingual-Bimodal signers; Deaf = deaf signers.

Overall, deaf signers show a consistent use of the geocentric FoR, with results in each community at around 75%. In Nohkop and Trascorral, Bilingual-Bimodal signers display almost exclusively a preference for the geocentric FoR when resolving this task. When looking at individual results, in Chicán, among the 6 hearing participants, 2 used the geocentric FoR 100% of the time, 3 consistently used the egocentric FoR and only one used both 50% of the time.

In Le Guen (2011b, p. 918), Yucatec Maya participants who performed the same task chose, overall, the geocentric FoR 95% of the time. However, unlike the participants of the

current study, the majority of participants from Le Guen (2011b)'s study were monolingual Yucatec Maya speakers. Although the observed preference for the egocentric FoR could be due to bilingualism with Spanish, which increases the preference for egocentric FoR, as Chi Pech (2021)'s study indicates, an analysis of the results in this task do not show a consistent correlation. Of the 12 BB participants, only 5 show egocentric results, and they are not the most fluent in Spanish. Future research should be conducted to detect what could be a relevant factor for this choice.

3. Director-Matcher

While the rotation task is an individual problem to resolve, our next task, the so-called "Director-Matcher" paradigm involves negotiation between two participants regarding what should be considered a "correct" configuration of items according to one or the other Frame of Reference. In this task, an array of stimuli is arranged on the Director's table and he or she has to explain to the Matcher, who holds the same stimuli but in his or her hands, how to display them similarly as they are for the Director. Crucially, the Matcher does not have visual access to the Director's stimuli. One central aspect of this task, as in the rotation task, is that both strategies (egocentric or geocentric) are correct. But, contrary to the individual rotation task, here two levels of measures are considered: first, whether the Matcher correctly understood the instructions of the Director and, second, whether the two participants rated the configurations as the "same".

3.1. Method

3.1.1. Participants

A total of 24 participants took part in the study, many of whom also took part in the rotation task. As in the previous task, we had a sample of deaf and Bilingual-Bimodal signers from three communities (Chicán, Nohkop and Trascorral). In Chicán, 15 people participated (8 women), among whom 11 were deaf and 4 were hearing, with ages ranging from 10 to 68 years (average of 42 years old). In Nohkop, five people participated, including three women (all deaf) and two men (both hearing). The age range of the participants was 17 to 27 (with an average age of 24.5 years). Finally, in Trascorral, four individuals participated in the task; all were women, with two hearing and two deaf, with an age ranging from 12 to 31 years (the average age was 17.8 years). See Table 2 for details.

3.1.2. Setting

For this experiment, due to the modality, we could not use a curtain to completely visually separate participants (as in the similar experiment of Ball and Chair (Bohnemeyer et al. 2014), for instance). Because participants needed to see each other to communicate but could not watch each other in item configuration, we opted for a table separated by a cardboard barrier that was tall enough to block the sight of the other person's items while leaving the upper chest visible for communication in sign language. The two participants were facing each other, standing up or seated; see Figure 9.

3.1.3. Material

We used the same items as in the rotation task participants were familiar with: small toy cars with distinctive features. In order to avoid participants simply using colors, and to increase communicative effort, we decided to use two white toys, one being a car and the other a truck. Two identical sets of four cars were used, as presented in Figure 10.

Figure 9. Example of the task conducted between two participants from Chicán (a Bilingual-Bimodal hearing woman on the left and a deaf man (her husband) on the right).

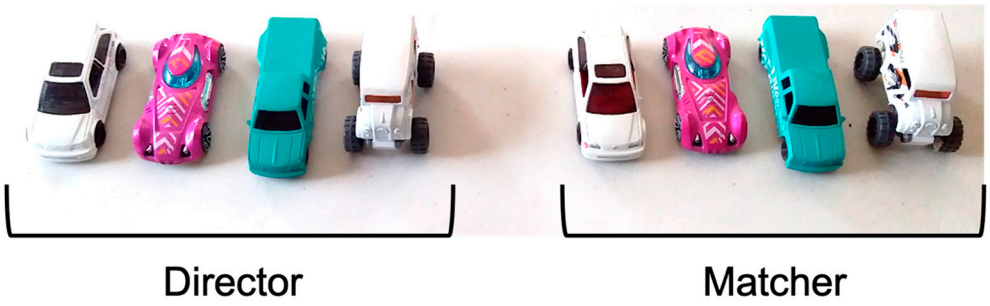

Figure 10. The two identical sets of car toys used as stimuli in the Director-Matcher task.

3.1.4. Procedure

The researcher gave instructions in Maya for hearing people and in YMSL for deaf participants, with the help of the interpreter. If instructions were not clear, they were repeated as many times as necessary. All participants, however, had to carry out the task using only YMSL.

The explanation was as follows:

> "Now we are going to play a game. There is a table here, as you will see it is divided by cardboard; you are going to sit/stand up facing each other face to face. As you can see, I have 8 different car toys of different models and colors; as you will notice, there are four colors, which are pink, green and two white, one big and the other smaller. These four are for you (Director), and these four are for you (Matcher); as you can also notice, they are all the same. I am going to take the car toys, and I am going to configure them in a specific way; then, you (Director) are going to explain to him/her (Matcher) how they are arranged so that she/he (Matcher) can reproduce it in his/her corresponding part of the table. When your partner tells you that (s)he is done solving it, we will lift the carboard, and you both can check if they (the stimuli) are the same. If you (Director) think or believe that the Matcher has not done it the right way, go to your place and explain it to him/her again. This game consists of 4 trials in two rounds: in the first round, the person who guides the game (Director) will be the Matcher in the second half of the game. The dynamics will be the same in both rounds. If there is any doubt, let me know so I can explain it again".

The game consisted of two rounds that corresponded to the eight pre-established configurations (only known by the experimenter). In each round, the Director indicated the configuration he or she had for the Matcher to reproduce. As we mentioned, the first person running as the Director had to indicate the first four configurations, and to avoid any guesses, when the Matcher and Director changed roles, four new different configurations were employed. Importantly, the negotiation was to be limited to the Director and the Matcher only, and neither the experimenter nor any people present were to intervene. The task was completed when both the Director and the Matcher were satisfied with the configurations and considered them to be "the same".

3.1.5. Predictions and Coding

As with the rotation task, there were two possible options for reproducing the configuration, both considered "identical" or "correct". The first involves the use of the egocentric FoR, in which case, the Matcher will have a similar configuration to the Director, but each one will be arranged from their viewpoint, that is, the Matcher's configuration will be the mirror image of the Director's (see Figure 11). The second strategy available relies on the geocentric FoR. In this case, the car toys will be arranged identically but based on real-world orientation (like cardinal directions, for instance) (see Figure 11).

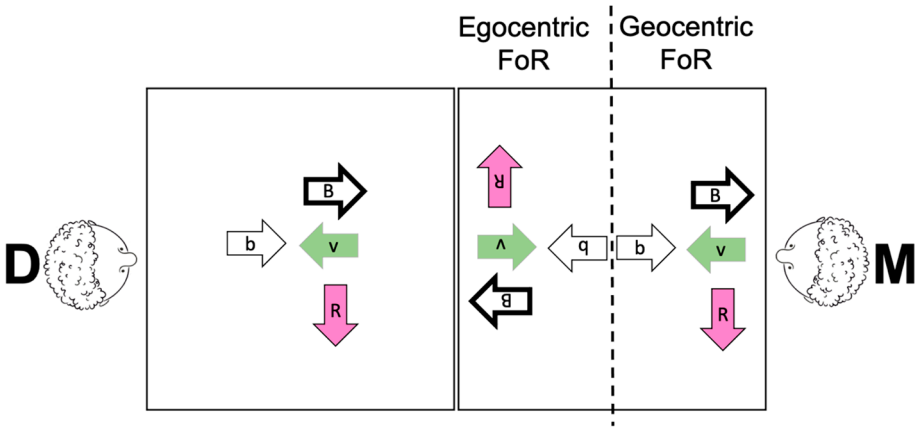

Figure 11. Predictions for the Matcher arrangement according to the egocentric and geocentric FoR.

We coded the response from the Matcher as either egocentric or geocentric. The possibility of a non-codable response was also considered, in the case participants could not agree.

3.2. Results

Overall, participants were in agreement in the task and did complete it successfully with only a few mistakes (such as switching cars, for instance). Results by community are shown in Figure 12. Clearly, the vast majority of participants relied on the geocentric FoR, with few results based on the egocentric FoR. It is to be noted that none of the participants fully relied on the egocentric FoR, and we might attribute these results to their unfamiliarity with the task. Due to the reduced number of participants, results from Trascorral seem to present more variation, but this is due to only one participant who chose each FoR half of the time.

An analysis by modality, separating deaf from Bilingual-Bimodal speakers' results, indicates that Bilingual-Bimodal hearing participants consistently chose the geocentric FoR; see Figure 13. This is not surprising, given what Le Guen (2011b) showed in his study of hearing Yucatec Mayas. Variation among deaf participants is more difficult to explain. The few participants who chose the egocentric solution do not seem to share specific features. That is, no correlation could be found, including level of study, gender, age, etc. Such choices might be the results of inattention.

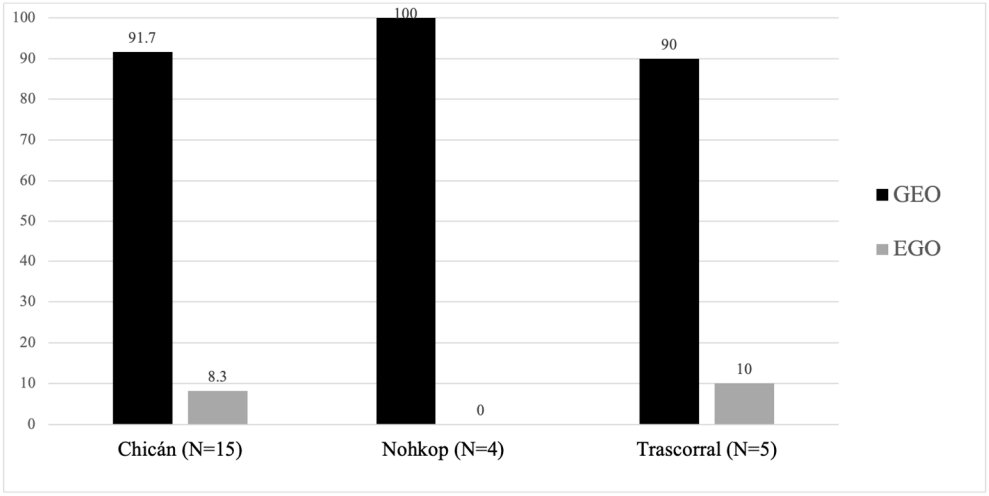

Figure 12. Director-Matcher results by community in percentages.

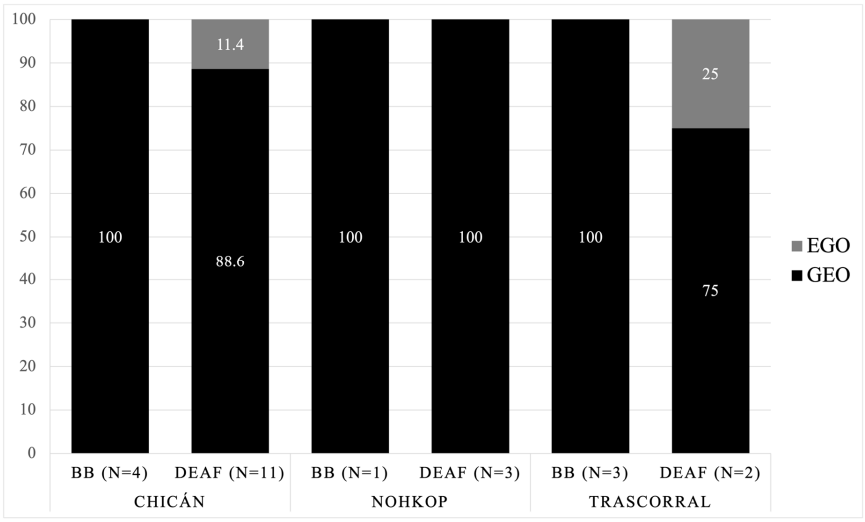

Figure 13. Director-Matcher results by community and modality in percentages.

Overall, the results from the Director-Matcher task are consistent with the rotation task, indicating a clear preference for the geocentric FoR in the community, among Bilingual-Bimodal hearing participants as well as deaf participants.

4. Localization Task

The localization task is a replication of a task also run in Le Guen (2011b). In this experiment, the participant is presented with two entities to be located with respect to each other; one serves as the Ground, and the other as the Figure. As in the previous tasks, two possible solutions are available to the participants, both equally valid. One option is to use the egocentric FoR, in which case the entities are located with respect to each other based on a projected viewpoint (for instance, "if the city hall is to your back, the water tower is to the right of the basketball court"). The second option relies on the use of the geocentric FoR, which should respect the real-world orientation of the Ground and Figure respective to each other (for instance, "the tower is South with respect to the basketball court").

If, indeed, as proposed by Le Guen (2011b), the preference for the geocentric FoR is transmitted and learned through the visual channel (gestures), we should expect Yucatec Maya Bilingual-Bimodals and deaf signers to show a similar preference. As mentioned earlier, however, another prediction could be made that would favor the use of the egocentric FoR among deaf (and possibly BB) signers. This prediction relies on the postulate

that because deaf signers have to communicate face to face (that is, being in front of each other), they would use a symbolic signing space between each other that would favor each signers' viewpoint. Such use of a signing space would cancel the reliance on real-world locations (which could be located behind one signer, for instance) and promote the use of the egocentric FoR, as is the case among Western signers. A third prediction would be that signers use a bird's-eye view perspective (Perniss 2012), i.e., the intrinsic FoR, with no specific orientation (point of view or extrinsic landmarks), keeping only the intrinsic orientation between the two entities. However, no participants used this strategy.

Unlike the previous experiments, this task is more naturalistic, since it deals with real entities (located in the town or nearby areas) that participants are familiar with. In addition, it is comprised of questions similar to those that might be asked in everyday life.

4.1. Method

4.1.1. Participants

In this experiment, only the results for participants from Chicán are presented. A total of 18 participants (11 women) from Chicán took part, among whom 13 were deaf and 5 were BB hearing. Ages ranged between 10 and 68 years old (average 41.5). Details are provided in Table 3.

Table 3. Participants' data from the localization task.

Community	Participants		Age	Gender		Total
	BB	Deaf		Men	Women	
Chicán	5	13	10 to 68	7	11	18

4.1.2. Material

All explanations were given in YMSL. However, due to the visual nature of the language and in order to avoid people simply pointing at the entities to locate them, participants were shown images of the Figure and Ground to make sure they located them among each other in the signing space. The entities were buildings known to the participants and located in their village. It is worth mentioning that, for this experiment, the entities that had to be located could vary depending on the participants' locations at the time of the study. Entities had to be situated to some distance from the participant's location, again, to avoid people just pointing at them.

4.1.3. Setting and Procedure

In this experiment, participants were divided into two groups, with a specific orientation. The first group faced eastward, while the second group faced southward. The reason for this arrangement lies in that it has several advantages to compare participants' responses in terms of FoRs. First, it allows the two FoRs to be contrastively distinguished. Even if participants in sitting 1 locate the Figure, say, to the left of the Ground, and it happens to correspond to the real-world orientation, this will not be the case in sitting 2. Secondly, the question asked is close to real, everyday communication, and signers commonly refer to places, houses, trees or locations among each other, even within the village.

The basic question asked was: "Where is the FIGURE in relation to the GROUND?". Participants were free to respond however they liked, as long as they explicitly mentioned both the Figure and the Ground. All interviews were audio–video recorded, with the camera always facing the participant; see Figure 14. All videos were transcribed in ELAN.

Figure 14. Example of the interpreter (on the **left**) explaining the task in YMSL to a deaf participant (on the **right**).

Participants were asked to locate three pairs of buildings, all located in Chicán. The three pairs were the following: (a) Will's house (Figure) with respect to City hall *(comisaria)* (Ground); (b) the Protestant temple (Figure) with respect to the Catholic church (Ground); and (c) City hall *(comisaria)* (Figure) with respect to the Water tower (Ground). All these buildings are represented in the schematized map in Figure 15.

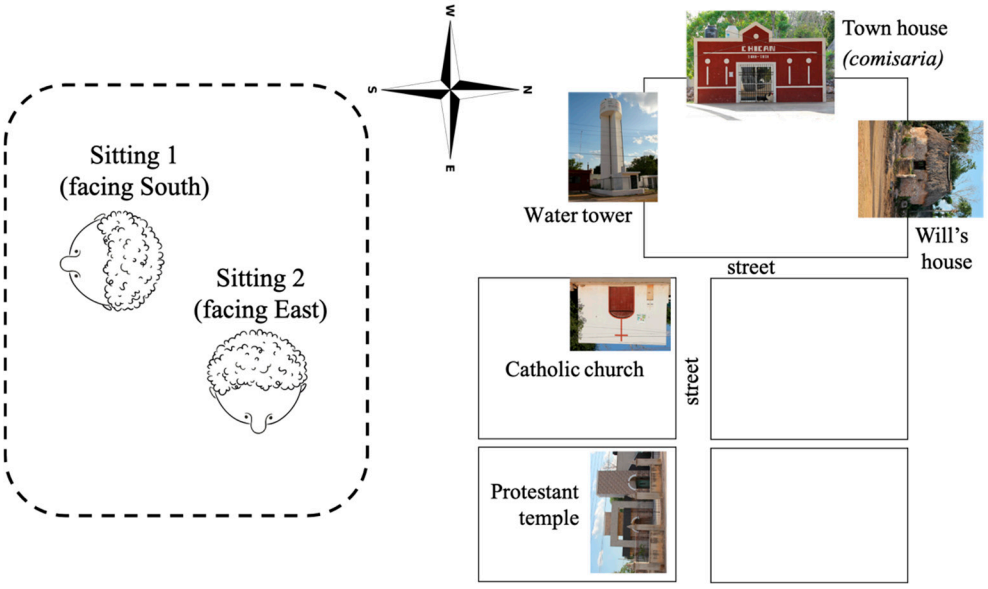

Figure 15. Location of all pairs of buildings in Chicán used as stimuli in the localization task and the two groups of participants in sitting 1 and 2.

As can be appreciated from Figure 15, not all the buildings were oriented the same way, and this allowed for various possibilities in terms of orientation of the configurations: South–North, East–West or West–South. Another advantage of using these particular pairs was that because they were all in or near the central square, it was easy to have participants sit a few blocks away. Also, most of the time, one or the other configuration was to the left or right and, more interestingly, to the back of the participants. For instance, if a participant in sitting 1 was located South of the main square, all the buildings happened to be behind

him or her. Such a disposition is, in principle, more likely to trigger a shift towards the egocentric FoR, unless the preference for the geocentric FoR is robust (see Le Guen 2011a).

4.1.4. Predictions and Coding

As in previous tasks, two predictions could be made: participants could use either the egocentric or the geocentric FoR, both correct responses in their own right. In Le Guen (2011b), Yucatec Maya speakers could use speech only or a multimodal strategy. As it turned out, they relied on gesture to provide the relevant angular information, and their speech was mostly deictic, referring to the gesture production (e.g., "the FIGURE is like this [GESTURE] and the GROUND like this [GESTURE]"). This is also what they do in everyday life, hence the importance of ethnographic data.

In the case of YMSL signers, who all completed the task in sign language, we expected only visual information to be produced. In order to exemplify more clearly how the spatial gestures look, let us consider the example of how Will's house (Figure) is located with respect to City hall (Ground). Both strategies are schematized in Figure 16. In sitting 1, a gesture production using the egocentric FoR will look quite different from gestures produced based on the geocentric FoR. The use of the egocentric FoR will rely on a projected viewpoint, for example, in the main square with Will's house to the right. In this case, the gesture will reflect this virtual viewpoint, and Will's house will be located to the right of City hall (see Figure 16, transposed viewpoint). That is, the participant will consider that from this transposed viewpoint, Will's house is to the right, making a right-handed gesture, and the City hall is to the left, making a left-handed gesture (see the red gesture from sitting 1 in Figure 16). A participant in sitting 2 will be expected to produce "the same" gestures, that is, from a similar transposed viewpoint, locating Will's house to the right of City hall (see the red gesture from sitting 2 in Figure 16). In both cases, the gestures will be similar based on the participant's (projected) viewpoint.

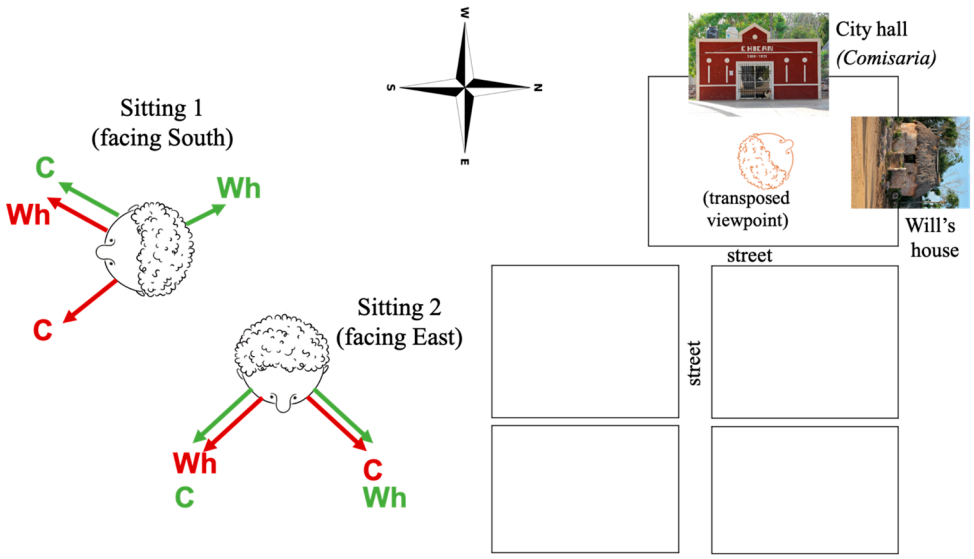

Figure 16. Predictions regarding spatial gesture production for both FoR (in red, the egocentric strategy, and in green, the geocentric strategy). Wh stands for the visual representation of Will's house, and C stands for City hall.

Gestures produced to refer to the locations of the Figure and Ground based on geocentric FoR will always respect real-world orientation, that is, they will systematically place Will's house north of City hall. This independently of the viewpoint or current orientation of the participant. Hence, as presented in Figure 16, the gestures from sitting 1 and 2 (in green) will look different relative to the body of the participant but be correctly oriented according to the real-world positions of Will's house and City hall.

From our prediction in Figure 16, in sitting 2, geocentric and egocentric gestures could appear, at first glance, similar in terms of gesture production. Both FoRs involve a gesture to the left and to the right of the signer. However, each hand would indicate a different entity according to a specific FoR. According to the egocentric FoR, as in sitting 1, from a projected viewpoint, the participant would place Will's house to the right of City hall and use his/her right hand to represent or place Will's house and his/her left hand to represent or place City hall in the signing space. In contrast, the use of the geocentric FoR will still place both entities according to their actual spatial relation as in real space, that is, Will's house will be located north of City hall, even in the signing space.

Coding was based on gesture production according to the egocentric and geocentric FoR. It is important to note that the intrinsic FoR, although theoretically available, was not used by the participants. All data were video recorded and transcribed in ELAN.

4.2. Results

Results were compared at various levels. In order to determine which FoR was used, spatial gestures of the participants were compared with the real-world orientation of the Figure respective to the Ground. Gesture production was also compared contrastively between sitting 1 and 2 (i.e., between groups).

As shown in Figure 17, participants facing South put Will's house North of City hall (sometimes using the football court, i.e., the main square, as a proxy) in the signing space. Because of their position, this resulted in participants putting Will's house to their back and City hall in front of them. Participants facing East, on the other hand, tended to put Will's house to the left of their body and City hall to their right. Although, again, this is not how they thought about it, they placed Will's house North of City hall in the signing space. Importantly, the signing space for geocentric coders (i.e., signers or speakers who rely on the geocentric FoR for spatial location) extends all around the body and is not limited to the space in front of the body that corresponds to their viewpoint (a strategy more favored by egocentric coders).

Figure 17. Examples of results from sitting 1 where participants faced South and sitting 2 where participants faced East. Wh stands for the visual representation of Will's house and C stands for City hall.

A total of 54 responses were collected from the 18 participants from Chicán (three responses per participant). Two answers were not considered in the calculation as they did not respond to the criteria established (i.e., explicitly mention the Figure and the Ground in the response). Hence, two responses were discarded, leaving a total 52 analyzed. In total, 50 responses were based on the geocentric FoR, while only two used the egocentric FoR. Results are shown in Figure 18.

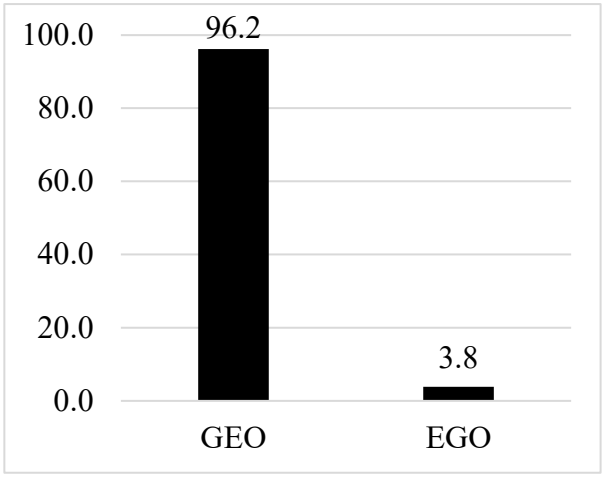

Figure 18. Results of the localization task from Chicán in percentage.

Once again, results from a more naturalistic task confirm that the preferred FoR among YMSL signers is the geocentric FoR. These results are particularly revealing for deaf signers, as they display a similar preference to Yucatec Maya speakers but also a similar use of the gestural/signing space that extends all round their body and does not consider viewpoint (see Le Guen 2011b).

5. Summary of the Results and Some Implications for Spatial Cognition

Results from the three tasks indicate a clear preference for the geocentric FoR. This preference was made clear in three different settings and conditions: an individual non-verbal task, a director-matcher task and a localization task based on real-world locations. The complementary results are important as they allow us to determine which FoR is preferred individually as well as within the speech community overall. Comparative results between modalities reveal that no significant difference was observed between Bilingual-Bimodal signers and deaf signers.

Results confirm our first prediction that because geocentric FoR is in use in the surrounding community and is mainly transmitted visually, signers adapted this FoR. Our third prediction that results would be mixed was not supported since, overall, participants did understand all tasks and display coherent results. Finally, our second prediction that modality might promote the use of the egocentric FoR is not supported either. It is a puzzling result based on what the literature on space in sign language predicts. We will come back to this issue in the discussion.

The results suggest that, though cognitive flexibility can exist in individuals' responses, this is not the case in an interactive task, such as the Director-Matcher task. While individuals can opt for one FoR or the other in the non-verbal task (maybe not always on purpose; see results in Figure 7), there is a clear constraint when it comes to a joint task (see results in Figure 12). In this latter case, the preferred FoR used in the community determines which configuration is rated as "correct". As discussed previously, there is an inherent contradiction between the egocentric and the geocentric FoR. Not only does each one imply a very specific cognitive representation of space, but the comprehension of gestures made according to one or the other differs greatly in how they should be interpreted (as explained earlier). It is important to recall that, embedded within every interaction between speakers or signers of the same language, a truth condition exists. In the Director-Matcher task, participants have to agree that only one solution is the correct one. Even if, theoretically, participants understand that another solution could be acceptable, it is clear that it does not correspond to their community ethics. As an example, in a Director-Matcher pilot study run a few years back, one deaf woman from Chicán was trying to make the point that placing the items according to the egocentric FoR was also legitimate. She was, however, facing several other deaf signers in the room (among them, her brother and her sister)

who strongly disagreed with her. Ultimately, the debate got so heated that the researcher had to interrupt the task and put everyone at ease again. Although anecdotal, this case goes to show that there is a clear consensus among members of one community on the preferred FoR; there is a strict condition of truth, and steering away from it can imply serious communicative consequences.

The final task involved a more natural request, namely how to locate two real-world entities that are different from the signers' body (or current position). Again, all participants employed the geocentric FoR to locate both entities with respect to each other. Although this is a systematic task in a controlled environment (specifically, the direction each participant is facing), it replicates nonetheless what signers usually perform in real life (see Le Guen et al. 2020 for examples).

6. Discussion

This paper addresses several issues. The first regards the Whorfian issue of how language influences spatial thoughts and the preferred Frame of Reference. The second, and perhaps more fundamental, deals with how spatial preference can be transmitted from a spoken language to a sign language. The final issue, which we will only mention in this paper (see Le Guen (2022) for a discussion), concerns how the use of the geocentric FoR influences the use of the signing space and its possible consequence on sign language grammar. Let us consider each one separately.

6.1. The Influence of Language on Spatial Thinking

This issue of how language can influence speakers' thoughts has been debated since the mid-1990s, and many convincing arguments have shown that, indeed, there is a clear effect of language on thought (Majid et al. 2013, 2004, 2018; Gumperz and Levinson 1996; Lucy 1992). Nonetheless, several researchers have invested a lot of effort into "debunking" the so-called Sapir–Whorf hypothesis, claiming that, according to this hypothesis, language would define thinking processes of individuals, considering it a *linguistic determinism* in which language would come to limit and govern thought (Li and Gleitman 2002; Li et al. 2011). In response, researchers in favor of considering the effect of language on thought have considered a "weaker" version of such a hypothesis, seeing it as *linguistic relativity* (Lucy 1996; Wassmann and Dasen 1998). However, it is doubtful if anyone ever seriously claimed that linguistic determinism does exist.[2] If linguistic determinism were real, multilingualism would either be impossible or people speaking several languages would only display mental categories of one language, which would be imposed over the others. Obviously, we know that this is not the case, and speakers as well as signers can use various languages, think in each of them separately and understand their own subtleties and specificities. Actually, a recent study among bilingual Yucatec Maya-Spanish speakers indicates that "modes" of languages (Grosjean 1998) have an influence on speakers' spatial representation, i.e., one tends to think differently about space if the task is run in Spanish or in Yucatec Maya (Chi Pech 2021).

A more interesting question asked by Le Guen (2011b) is whether language is limited to words in speech or if linguistic content can be distributed across various semiotic channels, namely between speech and gesture. Various proposals by Kendon (2004), Okrent (2002), and Enfield (2009), among others, have already considered that spoken languages are in fact multimodal by nature. However, the distribution of linguistic content in each modality is not homogenous across cultures and languages. While speakers (and signers) do produce gesture while they communicate in everyday interactions, the amount of propositional content that is conveyed by gesture can be almost absent in some cultures (gestures are mostly pragmatic (Kendon 2017)), whereas in others, gestures provide the most relevant information in the utterance (at least within specific domains). Recent studies have shown how gestures can allow speakers to avoid some parts of verbal utterances, as in the case of taboos for instance (Brookes 2014). More critically though, in some cultures, gestures seem to be the preferred or even the only way to convey relevant information. We mention that

this is the case for space among Yucatec Mayas speakers (Le Guen 2011b), but Floyd shows a similar phenomenon with time reference among the Nheengatú, where gestures function as time adverbs in natural discourse (Floyd 2016).

Coming back to the issue of linguistic relativity, it is clear that not only spoken languages (i.e., spoken words) can help in creating mental categories or orienting cognitive processes, but so can gesture, pretty much in the same way. The Yucatec Maya case is exemplary in this matter, and women (at least in Quintana Roo), because they usually lack the spoken vocabulary for the geocentric FoR, acquire spatial lexicon via the visual channel. However, the issue of the influence of mental categories by a sign language has not been explored as much as in spoken language. Nevertheless, a few studies show that, irrespective of modality, a linguistic system does indeed have an impact on the formation of mental categories while modality has only an impact on processing (Grote 2013).

The results of our three tasks show that there is a clear preference for a cognitive representation of space based on the geocentric FoR among YMSL signers, both deaf and hearing. The fact that non-signing speakers of Yucatec Maya also display a similar preference leads us to ask if and how this preference has been adopted from the surrounding culture.

6.2. From Multimodality (Co-Expressivity) to Sign Language

The second issue that this study raises is the influence that either the surrounding cultural habits and/or the multimodal language used by the hearing signers have on a sign language, specifically in our case, an emerging sign language. This issue has been central in our collective work, and we have shown that it does have an influence in several domains, such as iconicity (Le Guen et al. 2020), sign creation (Safar 2020a, 2020b; Safar and Petatillo Chan 2020; Le Guen and Uicab Martín 2021), sign names (Le Guen et al. 2023), and even grammar (Le Guen 2022).

In many sign languages, the cultural setting that surrounds deaf signers clearly has an influence on specific linguistic domains, specifically conceptual domains such as time (Brennan 1983; Meir and Sandler 2008; Le Guen 2012) and metaphor (Taub 2001; Wilcox 2001). Regarding specifically the preference for spatial FoRs, we were only able to find one study on sign language, indicating that ASL deaf signers in non-verbal rotation tasks tend to rely, unsurprisingly, on the egocentric FoR, the preferred FoR of most urban and educated US English speakers (Calton 2005).

As we previously mentioned, we know that among Yucatec Maya speakers, the use and the transmission of the preferred FoR (the geocentric FoR) is achieved via gestures, a feature also pointed out by other authors in Mayan languages (Brown and Levinson 2009; Haviland 2000; Levinson 2003, p. 269). It is then not surprising to find that YMSL signers also rely on this FoR. However, it does contradict our prediction that shared sign space would favor the egocentric FoR, leaving us with the question of how signers deal with spatial arrangements in symbolic signing space.

6.3. Implications of the Use of the Geocentric Frame of Reference for an Emerging Sign Language

What the results of the localization task show is that YMSL signers use a similar strategy as Yucatec Maya speakers, namely putting entities in the symbolic space around their body, respecting their real-world location. Because of this use of symbolic space and the habit of allocentric localization, signers do not rely on their own viewpoint to describe a scene, especially if it is a real-world scene. As results of the localization task also indicate, signers tend to put entities sometimes behind their back. However, while pointing and sometimes placing spatial gestures can be larger, in most natural interactions, signers restrict their signs and gestures to the shared signing space created between signers. For spatial content, they usually do not rely on their viewpoint (i.e., the egocentric FoR) but on a bird's-eye view, respecting real-world locations when relevant (i.e., the geocentric FoR). YMSL signers use then what Senghas referred to as an "unrotated perspective" (A. Senghas 2003, p. 518).

Interestingly, such use of a symbolic signing space, Le Guen (2022) argues, promotes a non-body-centered use of space, which is especially useful for grammar. In fact, YMSL signers, even from the first generation, are able to produce double agreement constructions, a feat usually considered by other authors as arising only a few generations deep for emerging sign languages (Meier 2002; R. J. Senghas et al. 2005).

Research on preferred Frames of References have been conducted on spoken languages, focusing on only one modality, verbal production. This has led researchers to puzzle over the results of verbal tasks in which speakers display the use of various FoRs but have a consistent tendency to resolve non-verbal tasks using the geocentric FoR (Bohnemeyer et al. 2022; Haun et al. 2006). Additionally, many works on space in sign languages have considered the use of space from a linguistic perspective (focusing on grammar and perspective taking in discourse) and have been conducted in "Western sign languages" (i.e., in settings where the geocentric FoR is preferred). The results provided in this paper raise the question of the importance of multimodality in the conception of space for speakers of languages around the world and how sign languages (especially emerging sign languages) that arise in communities where the geocentric FoR is preferred deal with grammar, localization and memorization of the environment.

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Notes

[1] US Preschool/Kindergarten is Mexican *Preescolar*/Preeschool; US Grades 1–6 correspond to *Primaria*/Primary in Mexico: US Grades 7–9 correspond to the *Secundaria*/Secondary in Mexico; and US Grades 10–12 correspond to the *Bachillerato*/High School.

[2] Maybe with the exception of people like Weisgerber, a German linguist later discredited in the 1960s. Linguists like Sapir or Whorf never did, only putting forward the idea of some effect of language of thought in certain domains.

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