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Reference frames in language and cognition: cross-population mismatches

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Abstract: Numerous studies have found evidence of a speech community's referential practices in discourse being predictive of its members' behavior in nonverbal tasks. In this article, we discuss a series of exceptions to this alignment pattern, drawing on data from eleven populations of Asia, Europe, the Middle East, North and Central America, and Oceania. These exceptions have not been discussed in conjunction with one another and the striking commonalities across the findings of these studies have gone unnoticed: (a) in discourses referring to small-scale space, either intrinsic frame use is dominant or both relative and geocentric frames are used frequently in addition to intrinsic frames; and (b) in recall/recognition memory, geocentric coding is more common than egocentric coding (in tasks that involve stationary stimulus configurations) in nine of the populations, while in the remaining two, there is evidence of extensive intrinsic coding even in nonverbal cognition. We discuss these findings in light of Haun's innate geocentrism hypothesis (Haun, D. B. M., C. Rapold, J. Call, G. Janzen & S. C. Levinson. 2006. Cognitive cladistics and cultural override in hominid spatial cognition. *Proceedings of the National Academy of Sciences* 103(46). 17568–17573). Our data offers partial support for this hypothesis, but simultaneously calls into question whether any extrinsic reference frames are available innately.

Keywords: language and cognition; linguistic relativity; semantic typology; sociotopography; spatial frames of reference

1 Introduction

In recent decades, numerous studies have found evidence that a speech community's referential practices in discourse are predictive of its members' behavior in nonverbal tasks, especially in recall and recognition memory studies (Bohnemeyer et al. 2014, 2015; Haun et al. 2011; Levinson 2003; Mishra et al. 2003; Pederson

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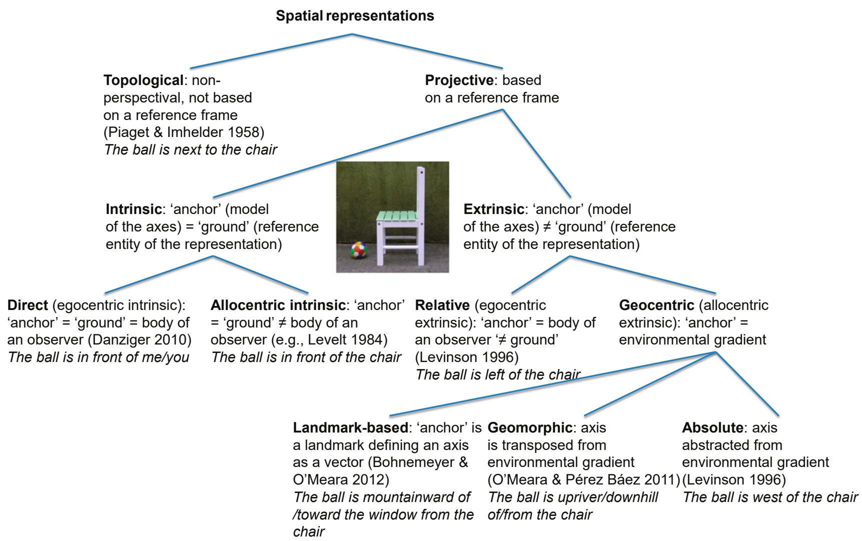

Figure 1: A fine-grained classification of spatial representations in terms of the underlying reference frame types (cf. O'Meara and Pérez Báez 2011; Bohnemeyer et al. 2015).

et al. 1998; Wassmann and Dasen 1998; inter alia). This research has focused on what are known as *spatial frames of reference*, cognitive axis systems used to project directions and regions in space. Figure 1 gives an overview of frame types which previous typological research has found it useful to distinguish.

In this article, we discuss a series of exceptions to the much-discussed alignment between verbal and nonverbal frame use preferences. Whereas studies showing alignment between verbal and nonverbal preferences have dealt with language varieties where *either* relative *or* geocentric frame use is dominant in discourse, in the communities of the present study, the linguistic pattern is different. In these communities, when discourses refer to small-scale space, either intrinsic frame use is dominant (very little extrinsic frame usage) or *both* relative and geocentric frames are used frequently in addition to intrinsic frames. In none of our study populations does an extrinsic frame type account for the largest percentage of uses in our linguistic data. In such cases, there is no clear prediction for either relative or geocentric frame use in solving cognitive tasks (Danziger 2001).

While these cases have been pointed out individually, they have not been discussed in conjunction with one another. Consequently, the striking commonality across the findings of these studies has gone unnoticed: in nine of the eleven documented cases across Asia, Central and North America, Europe, and Oceania that lack an overall community-level linguistic bias toward either geocentric or relative frame use in discourse, geocentric nonverbal coding is more common than relative nonverbal coding in tasks that involve stationary stimulus configurations. In the remaining two populations, there is evidence suggesting only limited extrinsic coding in both verbal and nonverbal tasks.

We discuss to what extent this distribution can be accounted for by the hypothesis of a weak innate geocentrism bias in primates which is subject to "cultural override" in individual human populations (Haun et al. 2006). While this hypothesis offers a potential explanation for the prevalence of geocentric strategies in nonverbal cognition in most of our study populations, the absence of a parallel linguistic preference for geocentrism in these groups points to the desideratum of a model of the cultural transmission of cognitive practices. Moreover, the lack of evidence for robust geocentrism in both language and cognition in two of the groups in our sample calls into question to what extent any extrinsic reference frame use in humans can exist independently of cultural transmission.

2 Methods

This article presents a meta-study comparing findings of eleven individual studies carried out with distinct though overlapping instruments. In this section, we briefly introduce those instruments, discussing nonverbal cognition tasks before discourse tasks.

2.1 Recall/recognition tasks

The instruments which we summarize here were used in the studies of cultural and individual variation in reference frame use in nonverbal cognition. All rely on a combination of two elements: participants first commit a stimulus configuration to memory, and then, after having undergone rotation (by 180° in the studies reported here), they identify it from among a range of options or they reconstruct it from materials provided. The rationale is that if a participant memorizes the configuration geocentrically, with respect to the environment, then after the participant has been rotated, the "new" configuration's orientation will be the same as the original relative to the environment, but change relative to the participant's body. In contrast, if a participant memorizes the configuration egocentrically, with respect to their own body, then under rotation, the configuration's orientation will remain invariant with respect to their body, but change in orientation with respect to the environment.

Table 1 summarizes the task protocols used in the studies we compare here. Note that while we present all the available nonverbal task data from our eleven populations in Section 3 and in the Supplementary Materials, we limit our statistical tests in Section 4 to orientation data from the Animals in a Row (AIAR) task and the New Animals task for maximal comparability across the sample.

The instructions given to the participants are deliberately vague so as to avoid any bias toward a particular strategy; for example, in the case of AIAR and New Animals, the instruction is simply "Make it again!". Li and Gleitman (2002) argue that this vagueness invites fallback on subvocal verbal encoding; see Levinson et al. (2002) for a response. However, Li and Gleitman's alternative design type targets ability rather than preference, fundamentally altering the research question.

Table 1: Recall/recognition tasks used in the studies compared here.

Task	References	Stimuli	No. of test trials	Task type
Animals in a Row (AIAR)	Levinson and Schmitt (1993), Levinson (2003: 154–159), and Pederson et al. (1998)	Array of 3 toy animals (participants asked to memorize correct 3 out of a set of 4)	5 (chosen by the researcher from out of a set of options)	Recall and reconstruction
New Animals	Bohnemeyer (2008b) and Bohnemeyer et al. (2015)	6 (fixed)		
Chips Recognition	Levinson et al. (1993) and Levinson (2003: 159–160)	2 sets of 5 identical playing cards showing two circles or squares of distinct colors	4 or 8[a]	Recognition (4 test cards are rotated at 90° intervals from one another)
Steve's Maze	Levinson (1993)	Simple schematic maps (1 trial) with incomplete paths drawn on them; 3 test cards per map that show potential completions: 1 geocentric, 1 relative, 1 distractor	5	Inference and recognition

[a]The relevant instructions in Levinson et al. (1993: 111): "Number of trials: 4 per axis (Do left/right, front/back optional – do the same for all subjects)."

2.2 Referential communication tasks

All studies we compare here relied primarily on the same type of instrument for profiling populations in terms of their preferred strategies for spatial reference in discourse: so-called referential communication tasks, in which dyads of participants verbally coordinate on identical copies of nonverbal stimuli without sharing a visual field (Clark and Wilkes-Gibbs 1986). Typically, a screen is placed between the two participants, blocking the second

Table 2: Referential communication tasks used in the studies compared here.

Task	References	Stimuli	No. of test trials	Task type
Man and Tree (original version)	Levinson et al. (1992) and Pederson et al. (1998)	2 × 4 × 12 photographs featuring dyadic configurations of toys (men, trees, balls)[a]	4 (each involving 1 set of 12 photos)	Participants instruct one another to match the photos
Ball and Chair	Bohnemeyer (2008a: 29–32) and Bohnemeyer et al. (2015)	2 × 4 × 12 photographs featuring dyadic configurations of a ball and a chair		
Man and Tree (Senghas version)	Senghas (2000) and Terrill and Burenhult (2008)	2 × 16 photographs featuring dyadic configurations of a toy man and a toy tree	1 or 2 (each involving a set of 16 photos)	Participants instruct one another to match the photos
Talking Animals	Bohnemeyer (2012)	4 identical sets of toy animals; stimulus configurations built by researcher for 1 participant according to schematic drawings	4 (each with a unique configuration)	Participants instruct one another to rebuild the stimulus configuration

[a]Levinson et al. (1992: 7) comment as follows: "Note that 'Men and Tree' is a notation for the full set of 4 photo-photo matching games which explore these questions. There is one training game in the set (game 1) and there are distractor photos – intended to make the game more fun to play – within games 2, 3, and 4 of the set. This means that all photos in the "Men and Tree" set do not necessarily depict a man or a tree. It also means that there is one entire game (game 1) of the "Men and Tree" set in which not a single man or a single tree appears."

participant from viewing the stimulus configuration. It is generally acknowledged that this type of task is of low ecological validity. In particular, it suppresses discourse that relies on deictic demonstration (Danziger 2010). To compensate for this weakness, researchers rely on spontaneous observation and tasks such as local history narratives and procedural descriptions. The rationale for referential communication designs is that they force participants to be as explicit in their reference acts as is required to resolve whatever ambiguities are built into the stimulus configurations. Table 2 compares the referential communication tasks in the studies we draw on below.

3 The individual studies

Table 3 provides basic information about the eleven study populations in the studies.

Table 3: The language of the participants, the estimated number of speakers, the field site, and the researchers who carried out the studies under comparison.

Language	ISO 639-3	Family	Genus or proximal major sub-branch	No. of speakers	Field site	Studies
Aṣ-Ṣāniʕ Arabic	ajp	Afro-Asiatic	Arabic	20,000 (estimate from Cerqueglini)	Lakiya (Negev, Israel)	Cerqueglini (2015, 2019, this collection); unpublished work by Cerqueglini
Hijazi Arabic	acw	Afro-Asiatic	Arabic	14.5 million (in 2011)	Asir (Saudi Arabia)	Alshehri et al. (2018); unpublished work by Alshehri
Bashkir	bak	Turkic	Kipchak	1.2 million (in 2010)	Bashkortostan (Russia)	Nikitina (2018)
Dhivehi	div	Indo-European	Indo-Aryan	335,000–410,000 (Gnanadesikan 2017)	Laamu Atoll (Maldives)	Lum (2018) and Palmer et al. (2017)

Table 3: (continued)

Language	ISO 639-3	Family	Genus or proximal major sub-branch	No. of speakers	Field site	Studies
L2 Mandarin (L1 Min Nan)	cmn	Sino-Tibetan	Sinitic	13.8 million (2010 Population and Housing Census)	Keelung, Taichung, Tainan, and Taipei (Taiwan)	Lin (2017, this collection)
Mopan	mop	Mayan	Yucatecan	9,000–12,000 (in 2008; Hofling 2011)	San Antonio (Toledo district, Belize)	Danziger (1996, 1999, 2001, 2011)
Murrinhpatha	mwf	Southern Daly	N/A	3,000 (Mansfield 2019)	Wadeye (Australia)	Blythe et al. (2016) and Gaby et al. (2016)
Rural Mexican Spanish Rural Nicaraguan Spanish	spa	Indo-European	Romance	≥ 20 million[a] 2.4 million[b]	San Miguel Balderas (Mexico) Rosita (Nicaragua)	Bohnemeyer et al. (2014, 2015) and Eggleston (2012)
Sumu-Mayangna	yan	Misumalpan	N/A	≈ 10,000 (Benedicto et al. 2016)	Las Minas area (RAAN, Nicaragua)	Eggleston et al. (2011) and Eggleston (2012)
Yucatec	yua	Mayan	Yucatecan	774,755 (in 2020)[c]	Rural communities in central Quintana Roo (Mexico)	Bohnemeyer and Stolz (2006), Bohnemeyer (2011), Le Guen (2011), and Bohnemeyer et al. (2014, 2015)

[a]Mexican census data from 2020 shows a population of 126,014,024. Of these, 6.2% were identified as speakers of indigenous languages aged 3 or older (https://www.inegi.org.mx/temas/lengua/, accessed 16 June 2021). According to the CIA World Factbook, 80.7% of the Mexican population lives in urban communities. Based on these numbers, one can safely estimate the number of rural Spanish speakers to lie upward of 20 million.
[b]Nicaragua had a population of 6,200,000 in 2020. The CIA World Factbook reports that 95.3% of the population were Spanish speakers in 2005, and 59% lived in urban areas. On this basis, we can estimate upward of 2.4 million rural Spanish speakers.
[c]https://www.inegi.org.mx/temas/lengua/, accessed 16 June 2021.

The bar charts below (Figures 2–12) summarize the quantitative results of the studies on reference frame use in discourse and nonverbal cognition by population. Unless otherwise noted: (a) the unit of observation is propositions for the linguistic data (where a single description of a stimulus item may comprise multiple propositions, each

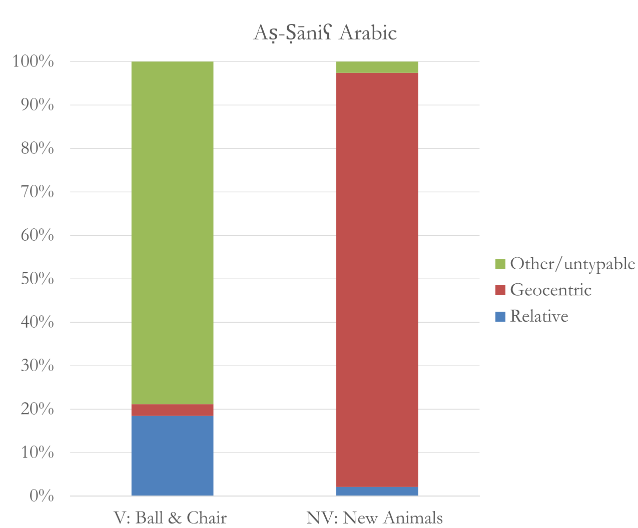

Figure 2: Quantitative results of the aṣ-Ṣāniʕ Arabic studies (V: verbal studies; NV: nonverbal studies).

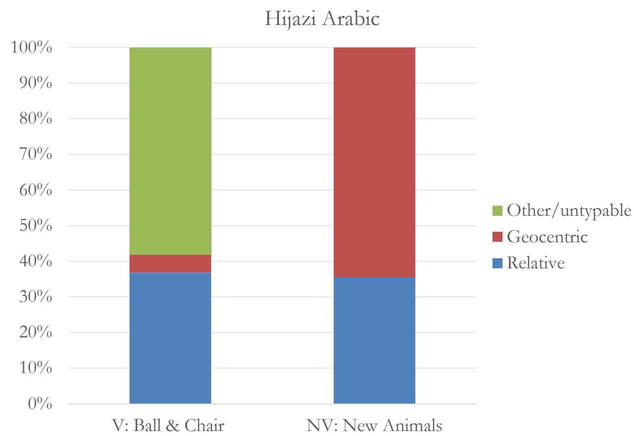

Figure 3: Quantitative results of the Hijazi Arabic studies (V: verbal studies; NV: nonverbal studies).

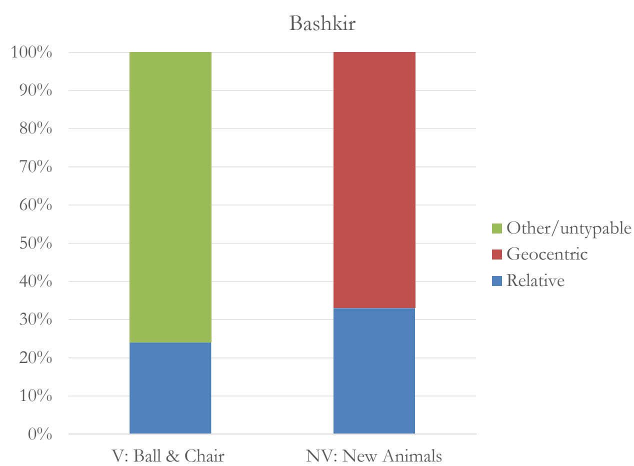

Figure 4: Quantitative results of the Bashkir studies (V: verbal studies; NV: nonverbal studies).

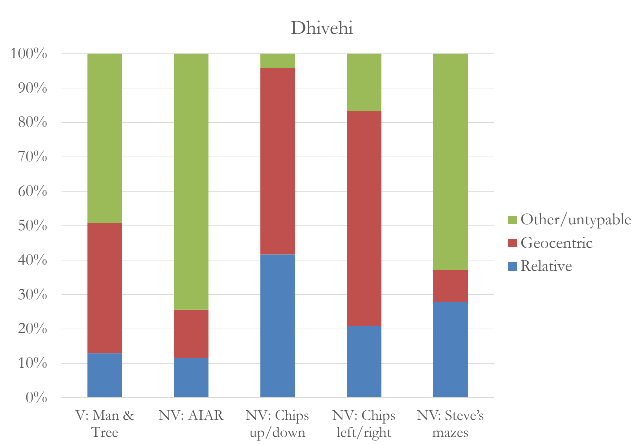

Figure 5: Quantitative results of the Dhivehi studies (V: verbal studies; NV: nonverbal studies; unit of observation for NV data: participants; AIAR data reflects both orientation and order of animals).

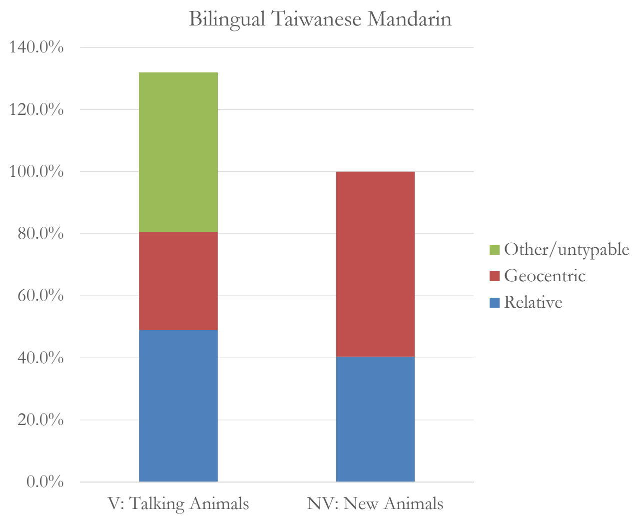

Figure 6: Quantitative results of the bilingual L2 Taiwanese Mandarin studies (V: verbal studies; NV: nonverbal studies; unit of observation for verbal data: participants × trials × items; reported percentages of verbal responses do not sum to 100 because observations may instantiate multiple frame types simultaneously).

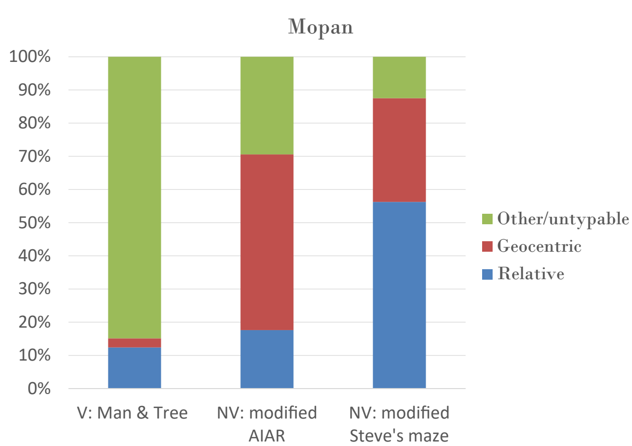

Figure 7: Quantitative results of the Mopan studies (V: verbal studies; NV: nonverbal studies; unit of observation for nonverbal data: participants).
After several attempts with the standard protocol yielded only untypable results, both the AIAR and Steve's Maze task instructions were modified for Mopan speakers. Mopan participants in AIAR were told to pay attention to the animals and "where they are looking". Mopan participants in the Steve's Maze task were told to draw the path that they would follow onto a laminated version of the maze on the stimulus table, before being rotated to consider options on the recognition table. Reported results are from these modified versions of the tasks. See Danziger (2001) for details.

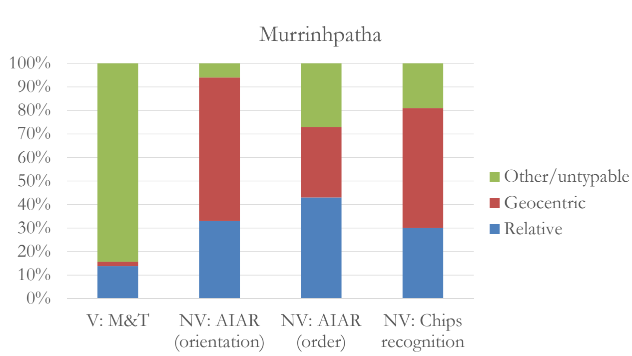

Figure 8: Quantitative results of the Murrinhpatha studies (V: verbal studies; NV: nonverbal studies).

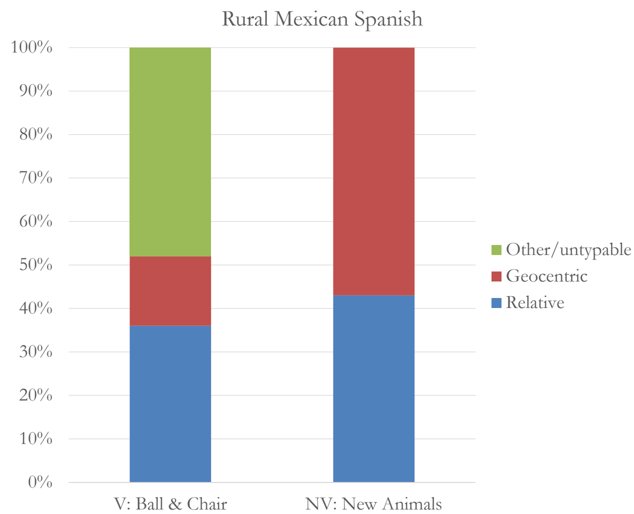

Figure 9: Quantitative results of the rural Mexican Spanish studies (V: verbal studies; NV: nonverbal studies).

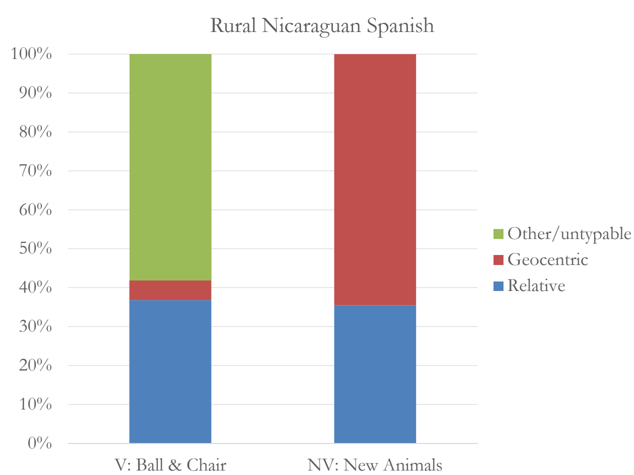

Figure 10: Quantitative results of the rural Nicaraguan Spanish studies (V: verbal studies; NV: nonverbal studies).

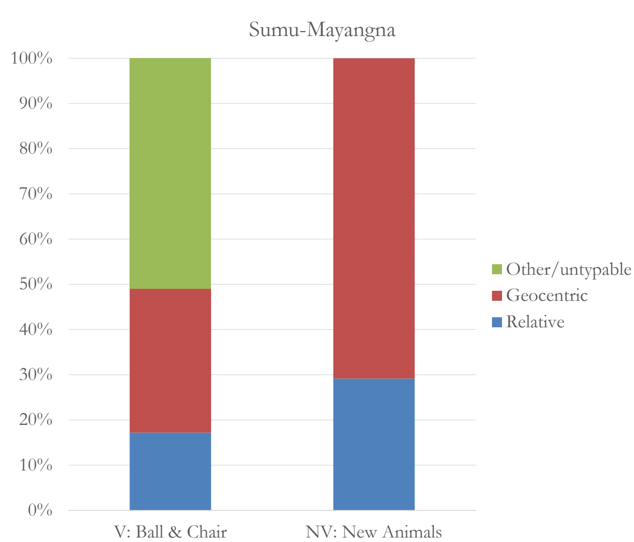

Figure 11: Quantitative results of the Sumu-Mayangna studies (V: verbal studies; NV: nonverbal studies).

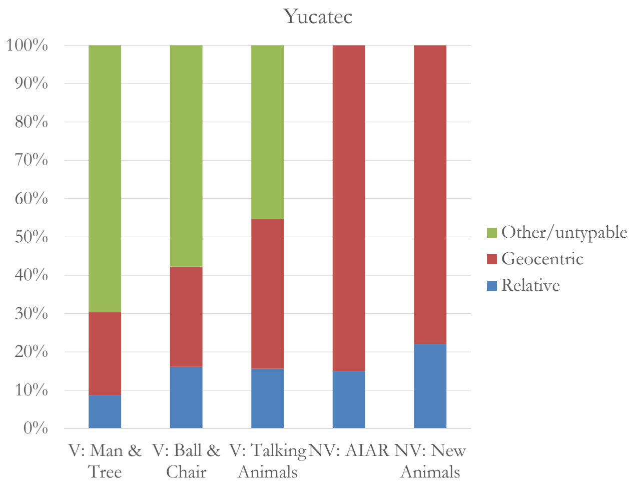

Figure 12: Quantitative results of the Yucatec studies (V: verbal studies; NV: nonverbal studies; AIAR data reflects both orientation and order of animals).

potentially relying on a distinct frame) and trials for the recall memory data; (b) data from array reconstruction tasks was coded for the orientation of the animals. More detailed information can be found in the Supplementary Materials.

Before we proceed to discuss these findings, a few comments are in order. Frequency counts are represented in terms of percentages with varying denominators depending on how the individual researchers coded the data. The denominators are made explicit in the Supplementary Materials. In some instances, verbal frequencies are based on units that can instantiate multiple frame types simultaneously (e.g., descriptions of a particular item), so that sums of percentages may exceed 100. Examples illustrating these generalizations can be found in the Supplementary Materials, along with examples of preferred strategies and ethnographic background on all eleven populations.

4 Summary of findings

Any statistical analysis of the data presented here is subject to all the usual caveats that apply to statistical tests of patterns emerging from meta-studies. In particular, the data was collected using similar, but not in all cases identical, tools. It was also originally analyzed and presented in somewhat divergent ways, although we have done our best to correct for such differences here.

In view of these limitations, a maximally coarse-grained analysis that compares basic outcomes across populations seems the only feasible option. Such a test, however, presupposes a decision on a question that to our knowledge has no off-the-shelf answer: the question of whether the data from the two Arabic varieties in our sample can be treated as distinct observations or should be grouped as one, and analogously for the data from the two Spanish populations. Both views are defensible. What argues in favor of grouping the varieties by language is that the speakers of the two dialects of each language behaved remarkably similarly to one another. In addition, for the purposes of statistical significance testing, grouping is the most conservative choice, as the odds of finding statistical significance increase with sample size.

Our sample is defined in terms of two criteria: (a) availability of quantitative population data on frame use in both discourse and nonverbal cognition; and (b) absence of clear linguistic extrinsic bias. In none of the populations does either of the extrinsic frame types account for 50% or more of the linguistic observations, and in none of them does either of the extrinsic frame types represent the largest share of the linguistic observations.

We performed a multinomial test over the population outcomes. We consider there to be three possible outcomes for any population – a relative bias, a geocentric bias, or no extrinsic bias – with a one-in-three chance of each of these outcomes occurring randomly. We classify a population as showing a relative bias if under the original experimental procedure at least 50% of responses to individual trials were relative and/or at least 50% of participants performed relatively overall across their set of trials, depending on how the data were coded by the author(s) of the original study. We classify a population as showing a geocentric bias in an analogous way. If a 50% threshold for either geocentric or relative responses was not reached (under the original experimental procedure), we classify the population as showing no extrinsic bias.

4.1 Across all nonverbal tasks: dispreference for relative solutions

In nonverbal tasks, we found an overall dispreference for relative solutions among the populations in our study, which is statistically highly significant ($p < 0.002$). We found three partial exceptions to the general dispreference for relative solutions:

(1) As noted in the footnote to Figure 7, Mopan speakers initially produced mostly untypable (i.e., neither relative nor geocentric) responses in pilot implementations of two cognitive tasks. In response, Danziger chose to modify the task protocols (Danziger 2011). In the AIAR task, Danziger instructed the participants to consider "where the animals are looking". Most participants responded with allocentric choices. In the Steve's Maze task, Danziger instructed participants to draw the inferred path onto the stimulus map prior to responding. Most participants in this case offered egocentric responses. Danziger (2001: 213) concludes that "no monolithic Mopan preference toward Absolute (i.e., geocentric) or Relative nonlinguistic strategies is identifiable".

(2) Dhivehi speakers produced mostly untypable responses in two nonverbal tasks. In AIAR, most participants produced a "monodirectional" pattern consistent with intrinsic coding, like the Mopan participants prior to the change in experimental procedure. In Steve's Maze, most participants selected a mixture of geocentric and relative[1] completion cards; however, of those that had a clear preference, there were more egocentric coders than geocentric coders. Note, however, that the Dhivehi participants did not display a preference for egocentric solutions in other nonverbal tasks (AIAR and Chips Recognition).

(3) In AIAR, Murrinhpatha speakers ordered the animals in a relative way more frequently than in a geocentric way (e.g., the leftmost animal in the response corresponded with the leftmost animal of the stimulus array). However, they mainly oriented the animals in a geocentric way (e.g., if animals were facing north in the stimulus array, they were arranged to face north in the response array). Although this finding might be partially explainable in terms of the different affordances of orientation versus location contexts (see the Supplementary Materials for further discussion), we observe that in Chips Recognition, a task involving coding of location only, Murrinhpatha speakers performed predominantly geocentrically. We also observe that Dhivehi speakers, the only other population in our sample for which we have AIAR order data, do not show a bias towards relative order (Lum 2018: 300–301).[2]

We note that two of the three exceptions involve a path completion (maze) task, the only maze task data in our sample. A possible explanation for nonverbal egocentric encoding in maze tasks is that participants assume the perspective of the moving figure in the maze, thereby representing the path as a sequence of turns, each of which is either a left turn or a right turn (cf. Dasen and Mishra 2010: 132–134; Taylor and Tversky 1996). Note that this particular egocentric strategy could be understood as an intrinsic one, therefore not necessarily involving the relative frame.

4.2 Preference for geocentric solutions to the array reconstruction tasks

In general, there was a significant preference across our populations for geocentric solutions to nonverbal tasks ($p < 0.002$). But a number of participants produced untypable responses, which may reflect the fact that

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1 Or, more broadly, egocentric, as for this task, the use of frames that treat the participant's own body as a landmark (as in "toward/away from me") seems relevant. Such frames are egocentric and extrinsic, but not relative, since they do not involve transposition of axes, representing a problem for the typology shown in Figure 1.

2 In most AIAR studies, including most of those in our sample, only orientation data is recorded, not order data, in line with the purpose of the original experiment design (Levinson and Schmitt 1993).

the nonverbal tasks were designed to distinguish between extrinsic frame encodings (geocentric vs. relative), rather than to provide a clear intrinsic frame response (Danziger 2011; Lum 2018). The one case for which strictly comparable data is not available is Mopan, where only a modified version of AIAR was implemented (experimenter instructed consultants to consider “where the animals are looking” following rotation). The exception is an important one, since the modification was introduced precisely because in initial trials, it proved impossible to induce Mopan to make strict choices between relative and geocentric solutions (Danziger 2001). Under these circumstances, we categorize Mopan as a community in which there was neither a relative nor a geocentric preference on the standard task.

4.3 Discussion

To our knowledge, our sample includes every single population-specific or cross-population study that has ever been conducted in which both verbal and nonverbal reference frame preferences in the small-scale domain were tested, and in which either an intrinsic bias or no bias was found on the linguistic side.[3] We can thus say with confidence that the general absence of evidence of a relative bias in all eleven populations represents an extremely strong finding. The evidence for cognitive geocentrism in nine of the eleven populations also represents a statistically improbable outcome. What can account for this significant distribution?

The prevalence of geocentrism in the AIAR and New Animals memory tasks in nine of the eleven sample populations, along with the absence of a preference for relative solutions in any of the sample languages, initially suggests support for the proposal of an innate weak geocentrism bias that may be “overridden” by a culturally transmitted preference for relative frames in the small-scale domain. This proposal resulted from a study (Haun et al. 2006) of spatial cognition in members of all five great ape species and in preverbal human infants in Germany. Haun and his colleagues found evidence of geocentric rather than relative encoding in all six study populations. They interpret this as evidence of a soft innate geocentrism bias that is overridden by cultural transmission of relative encoding in some modern human populations. Haun et al. (2006) do not discuss intrinsic frames.

Additional evidence in support of the hypothesis comes from observations (Nardini et al. 2006; Shusterman and Li 2016), of a preference for environmental over body-based cues in three-to-four-year-old children learning English. Bohnemeyer et al. (2014) discuss the evidence from the two Spanish-speaking populations presented here as additional support for the hypothesis.

However, attempting to explain our data with reference to a hypothetical biological preference for geocentric cues in spatial cognition immediately runs into two problems. First, how is the proposed geocentrism in nonverbal tasks to be reconciled with the absence of a similar linguistic bias in all our study populations (and in fact the near absence of geocentric frame use in discourse in five of them)? On the innate geocentrism hypothesis, the linguistically relative populations are cognitively relative due to cultural override. It is not obvious how such cultural override has affected our populations, or what kind of cultural override has affected them. If language is a mechanism of cultural override, then has there been no cultural override in our populations, since most of them appear to be cognitively geocentric on the evidence presented here? But if there has been no cultural override, then why are our populations not linguistically geocentric?

Second, how can the proposed geocentrism bias be reconciled with the absence of robust evidence of geocentrism (or indeed any extrinsic preference) in the Dhivehi and Mopan participants when solving nonverbal tasks? In discussion of the Mopan results in particular, Danziger (2001) concludes that there is no evidence for a preference of geocentric or of relative coding in nonverbal tasks, and proposes that both of these extrinsic frame types must be culturally acquired across all human populations and languages.

This article is not the place to attempt a resolution of these problems. However, any such resolution will have to answer a number of further questions, to be briefly considered in the remainder of this section.

3 In the Supplementary Materials, we briefly mention some studies that did not entirely meet the criteria for inclusion, but should be considered for future research.

First, what aspects of geocentrism, if any, could plausibly be innate? There are many different subtypes of geocentric frames, all of which are clearly culture-specific and learned (see, e.g., Brown and Levinson 2000; Cablitz 2002; de León 1994; Levinson 2003; Levinson and Wilkins 2006; Mishra et al. 2003; Palmer et al. 2017; Polian and Bohnemeyer 2011; Schlossberg 2018; Wassmann and Dasen 1998; inter alia). It seems likely, then, that it is not any fully formed geocentric frame type that could be innately available (at least not in humans). The hypothetical innate bias might not be more than a preference for allocentric over egocentric *anchoring*. Such anchoring may be compatible with intrinsic rather than extrinsic frame use. Indeed, most experiments show only that human children and nonhuman primates are more inclined to record object locations with respect to the environment than with respect to their own bodies (Haun et al. 2006; Nardini et al. 2006; Shusterman and Li 2016).[4]

Second, how would the proposed cultural override work? In the data of the present study, this question arises because many of our populations show some use of relative as well as of geocentric encoding in their speech, without showing substantial evidence of an override toward relative solutions in the nonverbal tasks. The question cannot be answered without a theory of the cultural transmission of cognitive practices, including referential practices. Bohnemeyer et al. (2015) argue that the transmission of cognitive practices must rely on observable behaviors including language, gesture, and other cultural practices.[5]

Finally, there is in fact evidence suggesting that the use of extrinsic reference frames – including of the geocentric variety – requires more support by cultural transmission than that of intrinsic reference frames (Danziger 2001). The use of extrinsic frame types in small-scale space is more constrained typologically than the use of intrinsic frames. It seems that all adult human populations make non-marginal use of intrinsic frames (where "marginal" could be defined with respect to an arbitrary threshold such as 5% of overall uses).[6]

Thus, although it appears that all reference frame types are subject to cultural transmission and learning, it seems that all human populations come up with some intrinsic solutions for close-range spatial reference. This may be due to the fact that the building blocks of intrinsic frames consist exclusively of potentially innate primitives of spatial cognition: figure-ground assignment, object mereology, and the geometry of axes and vectors. In contrast, to function reliably over time, extrinsic frame use requires habituation to an extrinsic anchoring system: in the case of geocentrism, it requires agents to learn to track their environmental bearings; and in the case of relative use, it requires them to learn not only to project their body coordinates onto the objects surrounding them, but also to translate from one person's perspective to another. This habituation may require more support from cultural transmission than intrinsic frame use does (Danziger 2001).

5 Conclusions

Across populations, verbal practices of spatial reference are highly variable. And a group's verbal practices tend to reliably predict its members' preferred strategies of cognitive encoding (Pederson et al. 1998). The work presented here has identified a second, complementary pattern: populations whose members either prefer intrinsic frames for verbal representations of small-scale locative relations or make free use of all major reference frames without a clear preference show infrequent or task-specific use of relative strategies in nonverbal cognition. Most of these groups in fact prefer geocentric solutions. We have discussed these findings in the context of the proposal of a weak, culturally malleable, innate geocentrism bias in nonverbal cognition (Haun et al. 2006). While such a bias at first appears compatible with the apparent prevalence of cognitive geocentrism in a significant majority of our populations, it is not immediately obvious how such a bias would be consistent with the absence of a linguistic preference for geocentric frames in the same populations, or with

4 In Experiment 5 of their word acquisition study, Shusterman and Li (2016) make impressive efforts to eliminate the intrinsic possibility.

5 This proposal is elaborated further in Bohnemeyer et al. (2016), who propose a theory of the cultural evolution of referential practices.

6 It has been claimed that Guugu Yimithirr speakers of Australia's Cape York Peninsula are an exception (Haviland 1979; Levinson 1997); but this claim turns out on closer inspection to be restricted to the transverse axis (Haviland 1993: 5, 1998: 28–29).

the absence of robust evidence of any nonverbal preference other than for intrinsic coding in two of our populations. It is evident, then, that much more research is needed to understand the role of both biology and culture in spatial cognition.

Supplementary Materials

https://osf.io/7gmsy/?view_only=9b1fe07f74334360912730e1733cad2a.

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