Reference frames in language and cognition: Cross-population mismatches - supplemental materials

In this document, we first provide ethnographic and linguistic background information on the study populations and illustrations of their verbal practices of spatial reference. This is followed by more detailed information about the quantitative results of the studies we report on.

1.Population sketches

1. 1. Aṣ-Ṣāniʕ Arabic

'Aṣ-Ṣāniʕ Arabic' (AA) is a term used in Cerqueglini (2015) and elsewhere for a tribal variety of Negev Arabic, a northwestern Bedouin Hijazi dialect with distinct age-based varieties (Shawarbah 2012: 11) spoken in the Israeli Negev town of Lakiya (AA: Ligiyyih) by some 20,000 speakers. Elders over age seventy born before the transition from nomadism to sedentarism speak the traditional variety. People under age thirty speak a koineized vernacular with elements of sedentary Palestinian varieties. The middle generation shows transitional features. Spatial representations of elders and young people are so different as to often prevent mutual understanding. In language, elderly AA speakers have no right/left distinction, using geocentric strategies instead, while the front/back axis is treated intrinsically, relatively, and geocentrically according to ontological and axial constraints related to the Ground (Cerqueglini 2015). Young speakers show almost no linguistic geocentric strategies, are insensitive to the traditional ontology and axial constraints of the Ground, and have developed the right/left distinction, showing a strong bias for intrinsic strategies. Interestingly, in cognition, AA speakers across all ages use geocentric strategies almost exclusively.

In this study, 50 young AA informants were tested using the linguistic Ball and Chair and the cognitive Animals tasks. The informants responded using intrinsic and egocentric frames, with a significant preference for intrinsic strategies, similarly to what Alshehri et al. (2018) and Alshehri (here) found for Hijazi Arabic. The following examples show massive use of the intrinsic frame. All four spatial relators are used intrinsically.

(1) al-kuṛah ʕa-yimīn al-kursi: ʕa-janb-ih al-yimīn
DET-ball on-right DET-chair on-side-POSS.3SG DET-right
'The ball is right of the chair, on its right side'

(2) al-kuṛah wara al-kursi: wara ðʕahr al-kursi:
DET-ball behind DET-chair behind back DET-chair
'The ball is behind the chair, behind the back of the chair'

Young AA speakers pay much attention to the Ground's body parts, which they often accurately detail. This and other aspects are worth exploring and comparing to the referential strategies of the tribal elders and to other Arabic varieties.

1.2. Hijazi Arabic

Hijazi Arabic is a dialect of Arabic spoken in the western provinces of Saudi Arabia along the coast of the Red Sea, specifically Makkah and Madina provinces. The dialect is classified as a sub-dialect of Gulf Arabic spoken in the Arabian Peninsula (Lewis 2009). The dialect is spoken by over 6 million speakers, most of whom are urbans but some are Bedouins living in rural areas in the highland adjacent to the coast of the Red Sea (Watson 2012, Versteegh 2014). All of the Hijazi participants were from the urban majority. The data discussed here were collected using the Ball and Chair task. All of the Hijazi participants were from the urban majority.

In the Ball and Chair data, Hijazi Arabic participants, all are from the urban majority, are found to use both intrinsic and relative frames frequently, as reported in Alshehri et al (2018). However, intrinsic frames are found to be used significantly higher than relative frames in the small-scale domain. Other reference frame types are also found to be used with much lower frequency. Absolute frames (that at least are not conflated with other frames) are not found in the data, they are however attested in this dialect especially among older generations. The high frequency of the intrinsic frame use has also been reported in Negev Arabic, another related dialect of Arabic spoken in the southern Israeli desert (Cerqueglini 2020). The following example shows the use of the two most common frames, intrinsic and relative, in the same utterance:

(3) El-kora gudda:m el-kursi: ʕla: el-jasa:r
DET-ball in front of (INT) DET-chair on DET-left (REL)
'The ball is in front of the chair to the left.'

(4) Law tushu:f el-kursi: elli ʕla: dˁahr-ah wa
If IMPERF.2S-see DET-chair who on back-POSS.3SG and
mitaʒah jami:n, el-kora ʕla: el-jami:n
towards right, DET-ball on DET-right (REL)
fawq-ah
above-POSS.3SG
'If you see the chair sitting on its back and (head) towards the right, the ball is on the right above it.'

In the Ball & Chair data, the preference to use relative frames seems to diminish with higher levels of education and literacy (frequency of reading and writing). Age does not show any significant effect on the use of intrinsic and relative frames of reference. However, it is reported that the use of absolute frames diminish greatly among younger generations in Negev Arabic (Cerqueglini 2020). Similar absolute frame use is expected to occur among Hijazi speakers as well.

1.3. Bashkir

Bashkir speakers make use of relative and intrinsic reference frame types; the intrinsic frame comes with two mapping types (at least for the chair, which was used as the reference point in this task): function-based and shape-based. All this results in massive ambiguity in descriptions, a high degree of variation across speakers, versatility for the same speaker, and a large number of misunderstandings. Coping strategies used by speakers to avoid misunderstanding include providing multiple descriptions and identifying explicitly the intended frame of reference:

(5) Ärgähän-dä tup jat-a uŋ jaq-ta…
between-3-LOC ball sit-PRS right side-LOC
hineŋ jaɣ-əŋ-dan hul jaq-ta bul-a inde
2SG.GEN side-2SG.GEN-ABL left side-LOC be-PRS now
'In between, the ball is sitting on the right side… from your side, it is now on the left side.'

(6) Ultərɣəs ultər-ɣan-da uŋ jaq-a tup,
chair sit-PC.PST-LOC right side-LOC ball
beð-gä qara-ɣan-da art jaɣ-ə,
1PL-ALL watch-PC.PST-LOC back side-3
art-ə-nda tup jat-a-mə (Alf, 4.4)
back-3-LOC ball lie-PRS-Q
'From the point of view of the sitting chair, the ball is on the right side, from our point of view, the ball is on the back side, at its back.'

There is also a high degree of variation in reference frame choice in the non-verbal task.
The factors that have proved significant for the choice of reference frame in the verbal task are lexical choice (some lexical expressions have a bias towards a particular reference frame and a particular mapping), the orientation of the reference object (whether or not it is facing the observer), the way the spatial configuration is aligned with the observer's perspective, as well as the speaker's age (the relative frame was used more often by younger speakers). Gender and education level showed no effect.

Interference with Russian was measured by counting the number of expressions involving Russian elements. This measure did not predict the choice of reference frame type or mapping type, but it did correlate with the choice of reference frame in the non-verbal task, suggesting that interference with Russian may be reflected in cultural practices but not in the conventional use of spatial expressions.

1.4. Bilingual Taiwanese Mandarin (L1 Min Man)

Han Chinese immigration to Taiwan began in the 17th century. The dominant languages of the immigrants were Hokkien (Southern Min) and Hakka, with Mandarin being used for official

purposes until the onset of Japanese colonial rule in 1895. When the government of the Republic of China retreated to Taiwan at the end of the Chinese Civil War, it established Mandarin as the official language of Taiwan. Mainlanders who immigrated to Taiwan in the wake of the civil war used Mandarin as a lingua franca, and their descendants speak Mandarin as their first language. During the martial law era, which ended in 1987, the government aggressively promoted the use of Mandarin and discouraged that of other linguistic varieties. Today, both Mandarin (TMC) and Taiwanese Southern Min (TSM) are spoken by over 80% of the population. However, monolingual TSM speakers were almost without exception born under Japanese rule. The bilingual TMC speakers in this study focused on learning TSM as their first language. They were often initially raised by TSM-dominant or TSM-monolingual grandparents and their education was taken over by their parents when they were ready for pre-school education. In most cases, the exposure and use of TMC has increased over time and become dominant.

Lin (2017) shows that monolingual TSM speakers prefer geocentric frames for both linguistic and nonverbal tasks, whereas monolingual TMC speakers prefer relative frames both verbally and nonverbally. TSM-TMC sequential bilinguals were verbally tested in TMC. Their behavior in the linguistic task is in line with influence from both languages, showing more relative frame use than monolingual TSM speakers and more geocentric use compared to monolingual TMC speakers, with intrinsic and direct frames actually representing the largest percentage share. In contrast, in the nonverbal task, a clear preference for geocentric reconstructions emerged. The following examples illustrate direct (7) and absolute (8) frame use in Trial 4 of the Talking Animals task:

(7)	Nà	zhī	niú	zhàn	zaì	(wǒ de) yòu	(shuǒ)		biēn
	that	CL	cow	stand	be.at	right	(hand)		side

'That cow is standing at (my) right (hand) side.'

(8)	Nà	zhī	niú	mièn	duì	nán	biān
	that	CL	cow	face	at	south	side

'That cow is facing the south.'

1.5. Dhivehi

Dhivehi (or Maldivian) is an Indo-Aryan language closely related to Sinhala. It has between 335,000 and 410,000 speakers, primarily in the Maldives, where it is the national language (Gnanadesikan 2017: 11).

Dhivehi speakers use a mixture of frames of reference, with intrinsic frames the most prevalent across the whole community (Lum 2018; Palmer et al. 2017). Egocentric frames include relative frames as well as the use of the speaker or hearer as a landmark. Geocentric frames mainly involve cardinal directions, although landmark-based frames are also used. The main landmarks invoked are nearby buildings (especially houses, which in the Maldives have individual names), villages or islands, though some speakers also draw upon nearby objects like

doors, windows, etc., or topographic features such as the inland area, beach, lagoon shore and oceanward reef. A few older speakers also use sidereal compass directions (e.g., ayyūgu īrāǹ 'Capella rising', i.e. northeast), a system once widely used for navigation at sea. In addition to these various systems, there are also special uses of 'front' and 'back' terms in certain contexts, where the 'front' of an object may refer to the side nearer to the center of a ring-like configuration of objects (see Lum Forthcoming; 2018).

Egocentric frames are favored especially by urban speakers, younger speakers, women and indoor workers. Cardinal directions are typically favored by rural speakers – especially those on fishing islands – as well as by older speakers, men and particularly fishermen. Lum (2018) argues that the connection with men and with older speakers may be explained by the fact that individuals from these groups are more likely to have directly participated in the traditional fishing economy, which required wayfinding at sea, or they grew up during a time when a relatively high proportion of speakers in the community participated in that economy (see also Palmer et al. 2017).

Most individual speakers are competent in the (egocentric) relative left-right system or the (geocentric) cardinal direction system but not both, and some speakers are not competent in either. However, most speakers rely to various degrees on intrinsic frames, which they combine with egocentric or geocentric strategies. For example, (9) below combines a cardinal (geocentric) orientation description with an intrinsic locative description:

(9) mīhā hurū ir-aṣ enburī=geǹ;
person stand.PST.FOC east-DAT turn.CVB=SUC

gaha hurū mīhā-ge furagaha farāt-u
tree stand.PST.FOC person-GEN back side-LOC
'The person is turning to the east; the tree is behind the person.'

DIV_MT_LGn_20140413_3_1_FS3_FR3_W, 3:36 (Lum 2018: 208)

In non-verbal tasks, Dhivehi speakers also employ a mixture of frames (Lum 2018) at the group level. As shown in §2 below, in Animals in a row and in Steve's mazes, a majority of participants were 'untypable', each producing a majority of responses that could not be coded as unambiguously egocentric or geocentric. However, Lum (2018) argues that it is in fact possible to interpret these 'untypable' responses further. In Animals-in-a-row, most of the untypable participants preserved the intrinsic order and orientation of the animals, and placed the animals 'monodirectionally' (i.e., always facing left or always facing right), like the Mopan participants described in §1.6 above. This result suggests intrinsic coding rather than mixed (egocentric and geocentric) coding, since a mixed coder would orient some arrays facing leftward and some rightward, depending on the orientation of the stimulus array (see Lum 2018: 309-310). Nonetheless, some individual participants did produce an overall geocentric response pattern, or an overall egocentric response pattern, such that a mixture of FoRs were used across the whole

sample. In Chips recognition, the predominant strategy was geocentric, with smaller numbers of egocentric or untypable coders.

1.6. Kilivila

Kilivila reference frame use in the small-scale domain has been studied by Gunter Senft as thoroughly as reference frame use in any of the languages in our sample. Senft discusses his findings in Senft (2001) and Senft (2006). Senft (2001) draws on linguistic data from no fewer than three referential communication tasks targeting reference frame use: Men and Tree; Route Descriptions, and Eric's Maze. Neither paper provides actual numbers on the results of these referential communication studies. However, in both works, Senft offers the following three generalizations:

- For the task of locating a 'figure' (entity whose location, orientation, or movement is at issue; Talmy 2000) with respect to a 'ground' (reference entity), Kilivila speakers appear to prefer intrinsic frames.
- In contrast, orientation descriptions are pervasively anchored to landmarks. However, in the tabletop elicitation tasks Senft carried out, these landmarks are often the bodies of speech act participants, such as in example (10) below.
- 'Object-centered' terms (Carlson-Radvansky & Irvin 1992, 1993), with meanings such as 'front', 'back', 'left', 'right', are compatible with both allocentric and egocentric interpretations, but the former are preferred except with grounds that lack relevant intrinsic facets.

The following example, a description of Men & Tree Photo 2.8, illustrates:

(10)

Kwe-yuwela	te-ta	tomwota	la-bani	kay	o
CL.INAN-again	CL.HUM-one	person	1PST-find	tree	LOC

kakata	kaitukwa	wa	e	mata-lae-semwa.	
right	walking.stick	only	and	eye-3SG	3-come.toward.speaker

'A thing again, one person I found, (a) tree at (his) right, a walking stick only, and his eyes look at me.' (Senft 2001: 535-536)

The tree is located intrinsically with respect to the man, while the orientation of the man is described with the help of an extrinsic anchor, a landmark of sorts - in this case, the speaker herself.

1.7. Mopan

Mopan belongs to the same branch of the Mayan language family as Yucatec (cf. below). The amount of structural and lexical variation within that branch of four languages is broadly comparable to the amount of variation found in any of the major branches of Indo-European. Mopan and Yucatec speakers are traditionally tropical horticulturalists, but the Mopan communities in Belize and Guatemala are much more remote and have until recently had much less intensive contact with the outside world compared to the communities in which our Yucatec data was collected.

The fact that both Mopan and Yucatec are included in our sample is perhaps less surprising than the fact that they are found at opposite poles of a continuum within the sample, with the Mopan speakers being the most consistently intrinsic verbal coders in the sample, while the Yucatec speakers, along with the Bilingual Mandarin speakers and the rural New World Spanish speakers, display the greatest amount of versatility in reference frame use, with direct, allocentric intrinsic, relative, landmark-based, and absolute frames all robustly used in reference to small-scale space.

To understand the Mopan approach to representing spatial relations in the small-scale domain, it is perhaps useful to use the spatial practices of the Kilivila speakers discussed in the previous section as a point of comparison. As mentioned, Kilivila speakers consistently rely on allocentric intrinsic frames for locative relations (making use of relative frames only when forced to work with referential grounds that do not afford an intrinsic perspective). But they resort to geocentric frames in order to represent the horizontal orientation of objects. Mopan speakers show the same resolute intrinsicness in their locative descriptions, but do not appear to be habituated to verbally expressing the lateral orientation of objects at all.

Consider the Men and tree pictures 2.3 and 2.5, represented in Figure 1. These two pictures are (near-) mirror images of one another. As first discussed in Danziger (2001), the Mopan speakers who participated in the Men and tree task did not produce verbal descriptions that discriminated among these pictures. An example is (11), which was produced as a description of 2.5 and matched to 2.3:

(11)	Ka’	a-käx-t-e’	a=nene’	tz’ub’	ada’,
	COMPL	A2-find-TR-TR.IRR	DEF=little	child	DEM.1

a	t-u-ta’an	ke’en-Ø	a=topo.
REL	PREP-A3-front	be.located-B3SG	DEF=bush

‘‘You should find this little child, who has the flower at his front’. (Danziger 2001: 209)

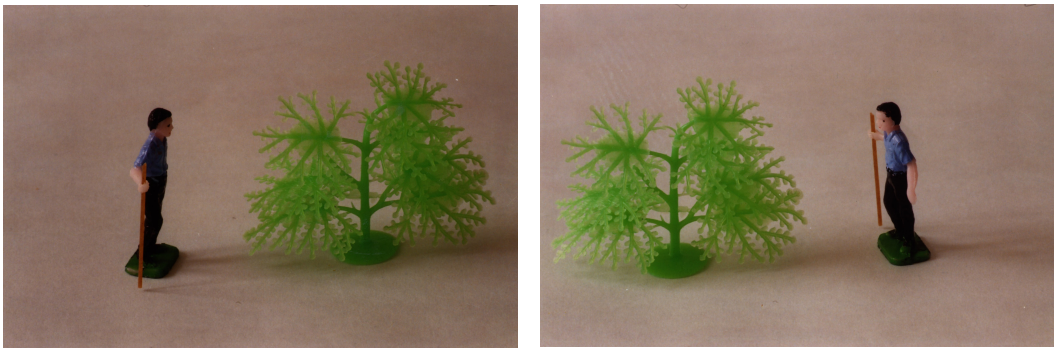

Figure 1. *Men and Tree 2.3 and 2.5*

Danziger (1999, 2011) presents several mirror image discrimination studies, the results of which support the hypothesis that Mopan speakers are not as a population accustomed to encoding lateral orientation either verbally or non-verbally.

The results of the Men and tree study and two recall/recognition tasks originally presented in Danziger (2001) are summarized in the main article and in Table 6 below. On both nonverbal tasks, participants initially produced mostly non-typable responses. This is in line with the hypothesis of cognitively intrinsic coding, as these tasks do not have distinct intrinsic response types. The results in Table 6 were obtained with modified protocols. In the case of Animals in a Row, Danziger asked the participants to pay attention to the orientation of the toy animals. This manipulation resulted in geocentric coding with most participants. In the case of Steve's mazes, Danziger had the participants draw the inferred path on the stimulus map before proceeding to the test phase. This plausibly caused many of the participants to mentally simulate the moving figure (a toy man), leading to relative coding.

1.8. Murrinhpatha

Murrinhpatha has no morphemes, words or structures that require an absolute frame of reference for their interpretation. The intrinsic reference frame is encoded by words (e.g. *kangkarl* 'up, above', *ngurru*, 'side') and morphemes (e.g. *-warra* 'in front, ahead'). When referring to near or distant locations within natural speech, speakers make prolific use of landmarks, directional pointing gestures and deictic expressions (Blythe et al. 2016). Murrinhpatha does not straightforwardly express the relative frame of reference. In the man-and-tree task, certain intrinsic terms are deployed in a relative fashion, but this usage is very marginal in naturalistic settings.

In the Man & Tree task (Gaby, Blythe & Stoakes, 2016), two participants sit side-by-side with a screen between them. They are required to describe different spatial arrays in which the intrinsic relationships between figure and ground differ only subtly. The screen covertly pressures participants into adopting absolute or relative reference frames in describing the array, supposedly disfavouring intrinsic frames as well as deictic and gestural reference. Despite the

screen, Murrinhpatha speakers continued describing the scenes using handpoints and deictic expressions (e.g., line 1-3 of example (12)), as well as landmarks (e.g., the shop, in line 2). It's not clear whether co-participants were able to observe the pointing. Line 3 also illustrates the use of the "direct" frame of reference where the tree's location is described implicitly with respect to the man, where the speaker becomes a landmark used to anchor the spatial reference.

Figure 2. *Men and Tree R41*

(12) 20150608JB_ManTree2Sync_520386_525611

1	kanyika kanyiwangu [memmirlgathu] ngarra	
	kanyi-ka kanyi-wangu mem -birl -gathu ngarra	
	PROX -TOP PROX -THITHER 3SG.DO.RR(10).S-look.back-HITHER LOC	
	{In} this one, he looks back this way, towards	
	[((points right/south))]	
2	[shop pangu erianuwanguya.]	
	shop pangu eria-nu -wangu -ya	
	shop DIST area-DAT-THITHER-CL	
	there towards the shop, in {that} area.	
	[((points twice right/south)).]	
3	[Thay kanyigathu pirrim.]	
	Thay kanyi-gathu pirrim	
	tree this -HITHER 3SG.S.STAND(3).NFUT	
	The tree is this side	
	[((open palm point toward self))]	

While absolute relators are not even lexicalized in Murrinhpatha and the use of relative frames of reference is marginal at best, in the non-linguistic problem-solving tasks Murrinhpatha speakers adopt both relative and absolute solutions (Gaby, Blythe & Stoakes 2016). The choice of strategy may be influenced by a variety of factors, including the task and/or axis involved. For example, in the chips recognition task, the proportion of absolute (as opposed to relative) frame of reference solutions was much higher along the lateral axis than along the sagittal axis. In the animals-in-a-row task, participants showed a preference for the absolute frame of reference in orienting the animal figures (e.g. facing them westwards if the animals faced westwards in the stimulus array), but not the order they were placed in (e.g. placing the cow as the easternmost animal even if it was not the easternmost animal in the stimulus array). It should also be acknowledged that there were many 'untypable' responses, which conform neither to the predicted relative-consistent nor absolute-consistent frames. We have not been able to discern whether these responses are the result of participant error, or an alternative construal of the spatial array that does not align with any of the frames of reference the tasks were designed to differentiate.

1.9. Rural Mexican and Nicaraguan Spanish

Spanish data was collected as part of a larger project that compared Spanish to local Indigenous languages. Barcelona Spanish was collected to compare European Spanish to New World Spanish. The Mexican and Nicaraguan Spanish speakers were chosen because they were in locations with roughly comparable topography and population density as the Indigenous populations to which they were compared. The populations roughly matched along other demographic variables such as self-reported literacy and education levels as well. Spanish was chosen because it is the likely second language of the Indigenous populations. Many of the speakers of the Indigenous languages also spoke Spanish; second language use may introduce different frame of reference preferences into the indigenous languages. Spanish-speaking participants in Mexico (Santa Ines and San Miguel Balderas) were all monolingual. The participants from Nicaragua (Rosita) were bilingual, speaking Spanish and a local Indigenous language. Most Barcelona Spanish speakers were also bilingual, having a command of Catalan.

While the Spanish varieties do not differ in structural resources expressed within the domain of spatial P, subsequent analyses of spatial relator use in Barcelona and Rosita Spanish varieties show asymmetries in the conceptual application of spatial relators along the x-axis. For example, Rosita Spanish speakers apply the relators *frente* 'front', *enfrente (de)* 'in front (of)', and *atrás* 'behind', *detrás (de)* 'behind' less often in relative FoR contexts along the x-axis than Barcelona speakers, and further, they deploy more spatial relators in accomplishment of the intrinsic FoR than Barcelona Spanish speakers (Eggleston 2012). This behavior indicates the conceptual encoding of spatial relators across language varieties is not uniform, and is culturally- or community-specific. This is unsurprising; spatial relator application asymmetries have been found between other language varieties, *viz.* British and American English (Pederson 2003). Below are examples of relative FoR usage in Barcelona Spanish (13) and Rosita Spanish (14).

(13) detrás de la silla... perdón,
of+behind p det chair.n pardon
la veo detrás de la silla
acc:3sf see.v:pres-1s of+behind p det chair.n
'behind the chair, pardon, I see it [the ball] behind the chair.'
(BC2_DA 3:29-3:32) (2-9) (Eggleston 2012: 148)

(14) la pelota está atrás de ella
det ball.n be.v-pres:3s to+behind p nom:3sf
pegada a la pared, sobre el suelo
stuck.v-ppart p det wall.n p det ground.n
'the ball is behind it (the chair), stuck to the wall, on the ground.'
(BC2_YL 3:42-3:44) (2-9) Eggleston 2012: 151)

Rosita Spanish speakers applied the spatial relator *al lado* 'to the side' in intrinsic FoR contexts more often than Barcelona speakers. Rosita speakers apply *al lado* constructions in (15) and (16), describing the location of the ball relative to a canonical use of the chair, pictured in the stimulus. Meanwhile, (17) shows Barcelona Spanish typical use of *al lado* in a relative FoR context.

(15) en el aire está la pelota al lado izquierdo
p det air be.v-pres:3s det ball.n p+det side.n left
'In the air, the ball is to the left side.'
(BC2_YL 3:19-3:21) (2-1) (Eggleston 2012: 159)

(16) encuentre la pelota... la silla con la
find.v-imp:2s.fml det ball.n det chair.n p det
pelota, que está al lado derecho
ball.n comp be.v-pres:3s p+det side.n right
'Find the ball… the chair with the ball on the right side.'
(BC2_YC 2:29-2:38) (2-8) (Eggleston 2012: 154)

(17) la pelota está al lado derecho
det ball.n be.v-pres:3s p+det side.n right
'The ball is to the right hand side.'
(BC4_SC 00:00.49-00:00.50) (4-12) (Eggleston 2012: 136)

1.10. Yucatec

Yucatec speakers freely make use of all major reference frame types. Egocentric frames are represented both by the 'direct' (egocentric intrinsic; Danziger 2010) and the 'relative' (egocentric extrinsic; Levinson 1996, 2003) subtypes, both of which occur frequently and without apparent restrictions. Speakers who have attained higher levels of formal education and/or report more frequent reading and writing are more likely to use relative frames in both discourse and recall memory than speakers with lower education levels and frequency of reading/writing. In contrast, there is no evidence of age or gender effects. Bohnemeyer et al. (2015) also report an L2 effect for their sample of six Mesoamerican populations including Yucatec speakers (speakers who use Spanish more frequently as a second language are also more likely to use relative frames when speaking their indigenous L1), but it is not clear whether this effect holds for Yucatec speakers in isolation.

Commonly used geocentric frame types include cardinal-direction-based absolute frames and frames based on ad-hoc landmarks. In contrast, no common use of frames based on land or water forms has been attested, in line with the natural environment of most speakers lacking affordances for such frames (no mountains or rivers). While both genders make frequent use of landmark-based frames in small-scale space, all studies have found evidence of a striking gender effect on the use of cardinal direction terms across domains, which seems to be largely restricted to male speakers. Bohnemeyer & Stolz (2006) and Bohnemeyer (2011) attribute this asymmetry to practice domains. Cardinal directions play a salient role in practices such as the making of slash-and-burn gardens, the building of traditional houses, and the arrangement of food offerings on an altar, all of which are traditionally largely restricted to males.

Aside from the absence of restrictions on the use of any major frame type in the small-scale domain, Bohnemeyer (2011) argues that a hallmark of Yucatec frame use in discourse is the versatility with which Yucatec speakers combine multiple frame types in a single utterance. This is illustrated by the following example from the Ball & Chair study, which combines in a single sentence an intrinsic, a relative, and an absolute proposition:

(18)

T-u=tséel,		te=x-ts'íik	te-estée-le=chik'in=o'
PREP-A3=side		PREP:DEF=F-left	PREP:DEF-HESIT-DET=west=D2
hun-p'éel	bòola	yàan=i',	ch'uy-k'ah-a'n
one-CL.IN	ball	EXIST(B3SG)=D4	hang-MIDDLE-RES(B3SG)
le=bòola=o',	hach	t-u=toh-il	
DET=ball=D2	really	PREP-A3=straight-REL	
tu'x	k-u=kutal		máak=o'
where	IMPF-A3=sit:INCH.INC		person=D2,
ti'	ch'uy-k'ah-a'n		le=bòola=o'
there	hang-MIDDLE-RES(B3SG)		DEF=ball=D2

'On (the Chair's) side, on the left in the, uh, the west, there is a ball, the ball is suspended, exactly at the height (lit. in its straight) of the seat (lit. where one sits), that's where the ball is suspended.'

1.11. Other populations

As mentioned, we have aimed to include here all studies that have probed the use of reference frames in both discourse and recall memory and found no clear evidence of a linguistic bias for extrinsic (relative or geocentric) frames in the linguistic tasks. Terrill & Burenhult (2008) present data from speakers of the Mon-Khmer language Jahai (Malaysia) and the Papuan isolate Lavukaleve (Solomons), which draw a linguistic picture strikingly similar to Senft's (2001, 2006) portrait of Kilivila speakers: locative descriptions are overwhelmingly or exclusively intrinsic, whereas orientation descriptions are predominantly geocentric. (However, the authors treat orientation as a kind of reference frame, rather than a type of spatial representation. See Bohnemeyer (2012) and Bohnemeyer & O'Meara (2012) for a critique.) But as far as we know, Burenhult and Terrill did not perform nonverbal tests of their study populations.

2. Additional information on quantitative results

The tables below provide more detailed information about the results that were obtained from each study population. The graphs in the main article are based on the figures in these tables.

The categories 'relative' and 'geocentric' are defined in §1 of the main article. The 'other' category in these tables comprises uses of 'direct' (egocentric intrinsic) and allocentric intrinsic frames. We include in this category frames in which the body of the speaker or addressee is treated as ad-hoc landmarks, as in 'The cow is facing me' or 'The ball is toward you from the chair'. Such descriptions are egocentric in terms of their **anchor**, the entity after whose axes the axes of the reference frame are modelled (Danziger 2010; Levison 2003). Otherwise, however, they behave like landmark-based frames: they are generated by a half-axis defined as a vector pointing at the anchor (Bohnemeyer 2012; Bohnemeyer & O'Meara 2012).

Also included in the 'other' category are vertical descriptions such as 'The ball is above the chair'. Such descriptions can be interpreted relatively, geocentrically, or intrinsically, with gravity-based geocentric interpretations apparently representing a universal prototype (Alshehri et al. 2018).

Figures from verbal tasks capture frame use in both locative and orientation descriptions. However, 'topological' locative descriptions in the sense of Piaget & Inhelder (1956), which are not frame-dependent (e.g., 'The ball is between the chair's legs'; 'The cow is near the sheep'), are excluded.

The recall memory tasks have designated egocentric and geocentric responses. Responses that do not unambiguously fall in either category are treated as untypable. In some of the tables below, such untypable responses are listed in the 'other' category, whereas in others, they are excluded. No practical ambiguity arises since there is no other use of the 'other' category with responses to nonverbal tasks except for the untypable responses. We included untypable responses in particular in those datasets, where they occurred with such frequency and regularity that the researchers suspect they represented not simply errors, but instances of intrinsic coding.

The recall memory tasks generally do not permit to distinguish between relative coding, where the participant projects her body's axes onto the stimulus configuration, and direct coding,

where the participant memorizes distinct parts of the configuration with respect to distinct parts of her body (e.g., 'The cow is closest to my left and the sheep is closest to my right. The pig is in the middle'). In this sense, the label 'relative' is a simplification when applied to these tasks, and it would be more appropriate to categorize the relevant responses as egocentric, without specification of subtype (relative vs. direct). However, our data from array reconstruction tasks such as *Animals in a row* reflects predominantly the orientation of stimuli, which requires relative coding, as the participants face the stimulus arrays transversally.

Table 1. *Quantitative results of the Aṣ-Ṣāniʕ Arabic studies*

Task Type	**Task**	**Study**	**N of Participants**	**Unit of Observation**	**Breakdown of response strategies**		
					Relative	**Geo-centric**	**Other**
Linguistic (Communicative)	Ball and Chair	Unpublished	25 Dyads	Propositions (N= 596)	18.5%	2.7%	78.8%
Recall Memory	New Animals (facing direction data)		50	Trials (N= 293)	2.4%	97.6%	N/A

Table 2. *Quantitative results of the Hijazi Arabic studies*

Task type	**Task**	**Study**		**Unit of**	**Breakdown of response strategies**

			N participants	obser-vation	Relative	Geo-centric	Other
Linguistic (referential communication)	Ball & Chair	Alshehri et al (2018)	5 dyads	Propo-sitions (N=277)	36.8%	5.1%	58.1%
Recall memory	New Animals (facing direction data)	Unpub-lished	16	Trials (N = 93) (N = 93)	35.5%	64.5%	N/A

Table 3. *Quantitative results of the Bashkir studies*

Task type	Task	Study	N participants	Unit of obser-vation	Breakdown of response strategies		
					Relative	Geo-centric	Other

Linguistic (referential communication)	Ball & Chair (excluding vertical descriptions)	Nikitina (2018)	6 dyads	Propo-sitions (N = 230)	23.9%	0%	76.1%
Recall memory	New Animals (facing direction data)	Nikitina (2018)	12	Trials (N = 72)	33.3%	66.7%	N/A

Table 4. *Quantitative results of the bilingual Taiwanese Mandarin studies (reported percentages of verbal responses do not sum to 100 because observations may instantiate multiple frame types simultaneously)*

Task type	**Task**	**Study**		**Unit of**	**Breakdown of response strategies**

			N participants	observation	Relative	Geo-centric	Other
Linguistic (referential communication)	Talking Animals	Lin (2017)	38 dyads	Participants X trials X items (N=304380)	49%	31.6%	49%
Recall memory	New Animals (facing direction data)		26	Trials (N = 156)	40.4%	59.7%	N/A

Table 5. *Quantitative results of the Dhivehi studies*

Task type	Task	Study	N participants	Unit of observation	Breakdown of response strategies		
					Relative	Geo-centric	Other

Linguistic (referential communication)	Man & Tree (Senghas version)	Unpublished; Lum (2018); Palmer et al. (2017)[1]	50 dyads	Propo-sitions (N = 4604)	12.9%	37.8%	49.2%
Recall memory	Animals-in-a-row	Lum (2018)	78	Participants[2]	11.5%[3]	14.1%	74.4%
	Steve's mazes		43	Participants	27.9%	9.3%	62.8%
	Chips recognition up/down axis		24	Participants	41.7%	54.2%	4.2%
	Chips recognition left/right axis		24	Participants	20.8%	62.5%	16.7%

Table 6. *Quantitative results of the Kilivila studies*

Task type	**Task**	**Study**		**Unit of**	**Breakdown of response strategies**

[1] The Man & Tree results in Table 11 are based on a slightly updated version of the dataset described in Lum (2018) and Palmer et al. (2017), some additional transcripts having been subsequently coded. However, Table 11 shows only the results from Laamu Atoll, since this allows for a fairer comparison with the results from the recall memory tasks, which were conducted in Laamu Atoll only.

[2] The predominant response pattern of participants is presented here. For Animals-in-a-row, this takes into account both the direction and order of animals in each response, e.g., an individual response array was only considered relative if its order and direction were both relative, and a participant was classified as a relative coder if their overall pattern of responses across the five trials was predominantly relative.

[3] The cutoff for classification as a relative or geocentric coder in the non-verbal tasks is at least four relative or geocentric responses out of a total of five. However, see Lum (2018: 309-312) for an alternative classification of the Animals-in-a-row data that interprets many previously untypable responses and distinguishes between four coding types: relative (17%), geocentric (18%), monodirectional intrinsic (46%) and remaining untypable (19%).

			N participants	observation	Relative	Geocentric	Other
Recall memory	Animals in a row[4]	Senft (2001)	16	Participants	0%	100%	N/A
Recognition	Chips recognition up/down axis				12.5%	87.5%	
	Chips recognition left/right axis				25%	75%	
	Steve's mazes				6.3%	93.8%	
	Eric's maze				75%	25%	
	Transitive inference				37.5%	62.5%	

Table 7. *Quantitative results of the Mopan studies*

[4] Senft does not specify whether the data he cites reflect facing direction, order of animals, or both.

Task type	Task	Study	N participants	Unit of observation	Breakdown of response strategies		
					Relative	Geo-centric	Other
Linguistic (referential communi-cation)	Man and tree (Game 2)	Danziger (1999)	6 dyads	Propositions (N = 74)	12.2%	2.7%	83.6%
Recall memory	Modified Animals in a row[5]	Danziger (2001)	17	Partici-pants	17.6%	52.9%	29.4% (untypable)
Recognition	Modified Steve's mazes[6]		16		56.3%	31.3%	12.5% (untypable)

Table 8. *Quantitative results of the Murrinhpatha studies*

[5] After several attempts with the standard protocol yielded only untypable results, participants were told to pay attention to the animals and "where they are looking". See Danziger 2001 for details.

[6] After several attempts with the standard protocol yielded only untypable results, participants were invited to draw the correct pathway onto the maze surface at Table 1. See Danziger 2001 for details.

Task type	Task	Study	N participants	Unit of observation	Breakdown of response strategies		
					Relative	Geo-centric	Other
Linguistic (referential communication)	Man & Tree Game	Gaby, Blythe & Stoakes (2016)	4 dyads	Propositions (N=160)	13.8% (n = 22)	1.9% (n = 3)	84.4% (n = 135)
Recall memory	Animals-in-a-row (orientation of animals)	Gaby, Blythe & Stoakes (2016)	14 individuals	Trials (N=70) (5 per participant)	32.9% (N= 23)	61.4% (N=43)	5.7% (n=4)
	Animals-in-a-row (order of animals)	Gaby, Blythe & Stoakes (2016)	14 individuals	Trials (N=70) (5 per participant)	42.9% (n =30)	30.0% (n=21)	27.1% (n=19)
	Chips Recognition task	Gaby, Blythe & Stoakes (2016)	20 individuals	Trials (N=160)	30.0% (N=48)	51.2% (N=82)	18.8% (N=30)

Table 9. *Quantitative results of the rural Mexican Spanish studies*

Task type	Task	Study	N participants	Unit of observation	Breakdown of response strategies		
					Relative	Geo-centric	Other
Linguistic (referential communication)	Ball & Chair	Bohnemeyer et al. (2014, 2015)	5 dyads	Propositions (N=416)	36%	16%	48%
Recall memory	New Animals (facing direction data)		16	Trials (N = 93) (N = 93)	43%	57%	N/A

Table 10. *Quantitative results of the rural Nicaraguan Spanish studies*

Task type	**Task**	**Study**	**N participants**	**Unit of observation**	**Breakdown of response strategies**		
					Relative	**Geo-centric**	**Other** (
Linguistic (referential communication)	Ball & Chair	Bohnemeyer et al. (2014, 2015); Eggleston (2012)	4 dyads	Propo-sitions (N=277)	36.8%	5.1%	58.1%
Recall memory	New Animals (facing direction data)		16	Trials (N = 93) (N = 93)	35.5%	64.5%	N/A

Table 11. *Quantitative results of the Yucatec studies*

Task type	Task	Study	N participants	Unit of observation	Breakdown of response strategies		
					Relative	Geo-centric	Other
Linguistic (referential communication)	Men & Tree Game 2 (3 core photos selected by Levinson & Wilkins 2006: 12)	Bohnemeyer & Stoltz (2006)	4 dyads	Propositions (N = 23)	8.7%	21.7%	69.6%
	Ball & Chair (excluding vertical descriptions)	Bohnemeyer (2011)	5 dyads	Propositions (N = 471)	16.1%	26.1%	57.7%
	Talking Animals	Bohnemeyer et al. (Ms.)	40 dyads	Propositions (N = 1081)	15.6%	39.1%	45.2%
Recall memory	Animal-in-a-row (facing direction and order data)	Le Guen (2011)	31	Trials (N = 155)	15%	85%	N/A
	New Animals (facing direction data)	Bohnemeyer et al. (2015)	9	Trials (N = 50)	22%	78%	N/A

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