



# Contours of time: Topographic construals of past, present, and future in the Yupno valley of Papua New Guinea

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## ABSTRACT

Time, an everyday yet fundamentally abstract domain, is conceptualized in terms of space throughout the world's cultures. Linguists and psychologists have presented evidence of a widespread pattern in which deictic time—past, present, and future—is construed along the front/back axis, a construal that is *linear* and *ego-based*. To investigate the universality of this pattern, we studied the construal of deictic time among the Yupno, an indigenous group from the mountains of Papua New Guinea, whose language makes extensive use of allocentric topographic (uphill/downhill) terms for describing spatial relations. We measured the pointing direction of Yupno speakers' gestures—produced naturally and without prompting—as they explained common expressions related to the past, present, and future. Results show that the Yupno spontaneously construe deictic time spatially in terms of allocentric topography: the past is construed as downhill, the present as co-located with the speaker, and the future as uphill. Moreover, the Yupno construal is not linear, but exhibits a particular geometry that appears to reflect the local terrain. The findings shed light on how, our universal human embodiment notwithstanding, linguistic, cultural, and environmental pressures come to shape abstract concepts.

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## 1. Introduction

A quintessential feature of human cognition is the capacity to reason about domains we cannot experience directly, such as time, number, and causality (Fauconnier & Turner, 2002). But do humans everywhere share the same fundamental abstract concepts? Evidence from linguistic patterns and psychological experiments suggests that abstract concepts are very often grounded in spatial concepts (Gattis, 2001), with egocentric spatial distinctions such as front/back and up/down being particularly powerful in providing abstract conceptual structure (Lakoff, 1993; Talmy, 2000). At the same time, it is now known that some cultural–linguistic groups de-emphasize egocentric distinctions and rely principally on cardinal directions (Levinson,

2003) or even on environmental features such as terrain for conceptualizing space (Dasen & Mishra, 2010). Does an environment-based spatial system shape how people in such cultures understand abstract domains like time?

Temporal reasoning is an everyday human ability, equally fundamental in post-industrial and hunter-gatherer societies. Philosophers (McTaggart, 1908), physicists (Zeh, 1989), psychologists (Fraisie, 1963; Friedman, 1990), and linguists (Comrie, 1985; Moore, 2006) distinguish two basic categories of time concepts—deictic or tensed time (“A-series”), and sequence or tenseless time (“B-series”). Deictic time assumes the present—*now*—as the reference point and derives temporal categories—*past* and *future*—relative to it, as exemplified in the English sentence “The week *ahead* looks good.” Sequence time concerns the relation of one temporal landmark to another, with no mandatory anchoring to the present moment, as in “Spring *follows* Winter.”

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Across the world's languages, the domain of time—like other abstract domains—is structured in terms of space (Haspelmath, 1997). Words for *front*, *back*, *ahead*, and *behind* are ubiquitously recruited to express temporal distinctions along an axis in opposite directions (Clark, 1973; Traugott, 1978). Numerous paradigms in experimental psychology have corroborated this linguistic evidence, demonstrating that both deictic and sequence time are spatialized in real-time reasoning (Boroditsky & Ramscar, 2002; Miles, Nind, & Macrae, 2010; Núñez, Motz, & Teuscher, 2006; Torralbo, Santiago, & Lupiáñez, 2006; Tversky, Kugelmass, & Winter, 1991). Exactly which spatial axis is used varies by culture. Literate, post-industrial cultural groups all have been found to spatialize time along one or another ego-centric axis, including front/back (Miles et al., 2010) and left/right (Chan & Bergen, 2005) in English and Spanish (Torralbo et al., 2006), right/left in Hebrew (Fuhrman & Boroditsky, 2010), and up/down in Mandarin (Boroditsky, Fuhrman, & McCormick, 2010). The Aymara of the Andes—a pre-industrial culture with no writing tradition—exhibit a striking front/back reversed pattern for deictic time (Núñez & Sweetser, 2006), with past in front of ego and future behind. Which spatial axis is used also appears to depend on the temporal category—deictic or sequence—though psychological studies to date have rarely distinguished the two in a clear manner. That is, a given culture may favor one axis for sequence time and a *different* axis for deictic time. Aymara people, for instance, exhibit the unusual front/back reversed pattern for deictic time, but the common left-to-right pattern for sequence time (Núñez & Sweetser, 2006). This assignment of different temporal categories to different ego-centric axes is also very clearly evident in American Sign Language, in which deictic time is mapped onto the front/back axis and sequence time onto the left/right axis (Emmorey, 2002). Though further research is needed, the existing evidence suggests a cross-cultural tendency for deictic concepts to be conceptualized on the front/back axis and for sequence concepts to be conceptualized along some other axis, either left/right (English, Spanish, Hebrew) or up/down (Mandarin).

Space itself is subject to different kinds of conceptualization, and recent research has revealed that not all cultures rely to the same extent on egocentric spatial distinctions. Some groups favor allocentric coordinates, such as cardinal directions (*north/south*) or environment-based contrasts (*downhill/uphill*), even when describing spatial relations on very small scales (Pederson, Danzinger, Wilkins, & Levinson, 1998). Moreover, these linguistic differences have been shown to affect non-verbal reasoning strategies, such as memory for spatial arrays (Majid, Bowerman, Kita, & Haun, 2004) and even for body movements (Haun & Rapold, 2009). Do allocentric coordinates structure how abstract domains are construed in such cultures? And, if so, what are the particular properties of such construals?

Recently, one group favoring cardinal directions—residents of Pormpuraaw, an Australian aboriginal community—has been found to represent temporal order along an east-to-west linear axis, with earlier times mapped eastward and later times mapped westward regardless of

body orientation (Boroditsky & Gaby, 2010). The study provides an important existence proof that allocentric coordinates can be recruited for construing time. It also raises a number of further questions. First, given the Pormpuraaw study's focus on sequence time, it raises the question of whether allocentric coordinates may also be recruited for *deictic* time. This study's primary task required participants to sort photos that represented temporal sequences (e.g. a man at different life stages), and it also explored deictic time by means of a secondary dot-drawing/stone-placing task. In this task participants were asked to locate deictic time landmarks (e.g. tomorrow) relative to a pre-defined deictic center (now). Because the task imposes the deictic center at a location that is external to the participant, it does not necessarily provide clear insights into how notions of past, present, and future are anchored to the ego (or elsewhere) in a genuinely spontaneous way. A second, and perhaps more important, question raised by the Pormpuraaw study is that of whether different *types* of allocentric systems—for example, cardinal-based vs. environment-based systems—might give rise to differently structured abstract construals.

Surprisingly little is known about spatial construals of deictic time beyond those clues offered by linguistic patterns. Nothing, for instance, is known about deictic time in groups relying on environment-based absolute terms. To sum up the existing evidence, Western and non-Western groups studied so far typically exhibit a conceptualization of deictic time in terms of an ego-based front/back axis: with rare exceptions (Núñez & Sweetser, 2006) future is in front, past behind, and present co-located with the ego. On the current evidence, the structure of deictic time concepts appears to be (i) represented as a linear axis, (ii) grounded in the front/back asymmetries of the human body. Groups relying on topography-based systems, which in contrast with cardinal distinctions may be sensitive to properties of the local terrain and not necessarily organized along straight idealized axes, provide an important opportunity for investigating the universality of these features.

We investigated spatial construals of deictic time categories (past, present, future) in the Yupno, an indigenous group from the Finisterre Range of Papua New Guinea. The Yupno are a geographically isolated, small-scale cultural group with no writing tradition and limited exposure to Western cultural practices (Wassmann, 1993). Yupno speakers rely heavily on topographic contrasts (*downhill/uphill*) for conceptualizing space on different scales, from the microscale of “table-top” space to the macro-scale of the valley (Wassmann, 1994). Very commonly *uphill* and *downhill* terms are used in a way that reflects the macro-scale declivity of the valley, from the high-altitude source of the Yupno river down to where it flows into the sea. Do the Yupno recruit such contrasts for reasoning about past, present, and future time? Isolated expressions in the language hint at the possibility, such as *omoropmo bilak* (down-there-other-side year), which may be glossed as “a few years ago.” But language alone does not provide a transparent window into conceptual structure (Murphy, 1996), making convergent evidence imperative. For instance, English speakers have been shown in several studies to recruit

the left/right axis for construing sequence time (e.g. Fuhrman & Boroditsky, 2010), though nothing in the English language suggests this would be the case. An additional empirical source of evidence is spontaneous manual gestures, which are a ubiquitous (Iverson & Goldin-Meadow, 1998) and largely subconscious accompaniment to human speech (McNeill, 1992) and which are well-suited for the investigation of deictic concepts (Núñez & Sweetser, 2006). Gestures provide ecologically valid, fine-grained, real-time information in three dimensions about how abstract concepts are spontaneously spatially structured—information that may be complementary to the information provided in speech (Goldin-Meadow, 2003). Several recent studies have confirmed that speakers do in fact gesture when talking about and reasoning about time, and, moreover, that they do so systematically (Cooperrider & Núñez, 2009; Núñez & Sweetser, 2006).

## 2. Methods

### 2.1. Participants

The study took place in the remote Upper Yupno valley (Finisterre Range), Papua New Guinea, in August–September 2009 (Fig. 1). The Upper Yupno community, spread over various small villages, has a population of about 5000, and has no electricity or roads. The residents are largely uneducated and live by subsistence farming (Keck, 2005; Wassmann, 1993). 27 Yupno adults from the village of Gua (7 women) participated in this study, in semi-structured interviews both outdoors and indoors. The Yupno do

not measure age and, therefore, participants' ages were estimated by two local informants. The age range was approximately 20–70 years old. Although the Yupno are largely uneducated, some participants had attended school for 3–4 years in the past. Aside from sporadic contact with missionaries, the Yupno are largely unexposed to Western cultural practices due to the remoteness of the Finisterre Range. Calendars, clocks, and time-lines are extremely rare in the Yupno valley, and there are no known artifactual practices for reckoning, tracking, or representing time.

All participants in the present study spoke the Yupno language as their native tongue, and some had additional proficiency in *Tok Pisin*, the national creole. Yupno is a non-Austronesian (Papuan) language and is largely undocumented (linguistic documentation is now being carried out but is incomplete). Details about spatial reference in Yupno grammar have been presented in a previous ethnographic report (Wassmann, 1994).

### 2.2. Procedure

Based on unpublished field notes and linguistic data provided by local informants, we assembled a set of 15 Yupno temporal expressions that covered the different deictic categories (past, present, future) on different scales (roughly corresponding to days, weeks, and years) (see below under “Data analysis”). A handful of expressions also concerned duration and sequence time, but these are not analyzed in the present report.

We recorded a native speaker of Yupno saying the expressions with a digital voice recorder. The expressions

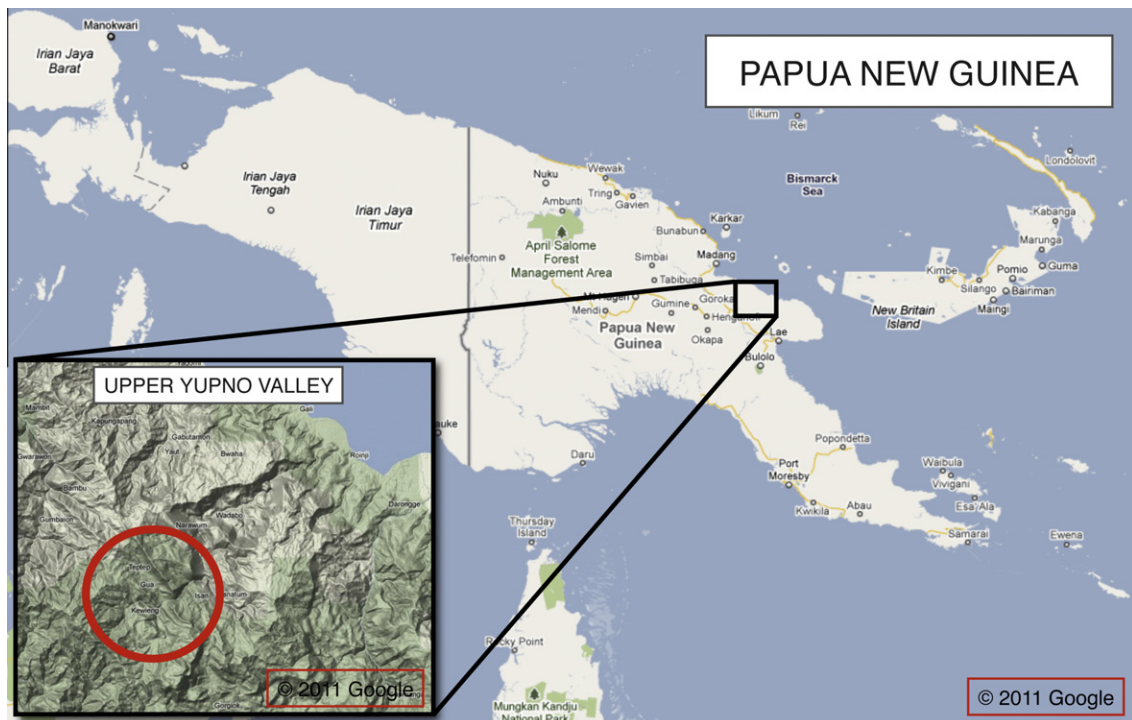


Fig. 1. The location where the Yupno people live in the Upper Yupno valley, Finisterre Range, Papua New Guinea.

were imported into a playlist and played during interviews from a laptop computer. Interviews were video-recorded with a high definition camera mounted on a tripod, which was placed far enough from participants so as to not be distracting or invasive, but close enough to allow details of their gestures and facial expressions to be recorded. All electronic equipment was powered by portable solar panel technology.

We carried out semi-structured interviews with participants in pairs or alone, both outdoors and indoors. Outdoor interviews took place in an open marketplace within the main settlement area. Indoor interviews took place in three separate houses (with entryways oriented at 90°, 150°, and 345° clockwise from North), all of which were in the main settlement area. After obtaining verbal consent, we explained to participants through a Yupno-English bilingual assistant that we were interested in Yupno culture and language, and that, specifically, we would like them to explain some expressions in their own words. No indication was made to either the participants or the field assistants that our particular interest was in gesture. Interviews were structured around the 15 temporal expressions, but expressions were sometimes repeated for clarification and occasionally some were skipped. Approximately mid-way through each interview, participants were asked to move to a different position for lighting reasons, such that they were facing in roughly the opposite direction. The cardinal facing orientations of the camera for each interview segment were recorded in the field.

**Table 1**  
Target temporal words and phrases.

Category	Yupno phrase morpheme gloss	English translation	Time scale
Present	<i>abjuk</i> now	'now', 'today'	General
	<i>abjuk sonda</i> now week	'this week'	Weeks
	<i>abjuk bilak</i> now year	'this year'	Years
	<i>kalip bishap</i> time past	'past times'	General
	<i>jare</i> day before yesterday	'day before yesterday'	Days
	<i>apma yesterday</i> <i>apma sonda</i>	'yesterday' 'last week'	Days Weeks
Past	<i>apma sonda</i> yesterday week		
	<i>omo-ropmo bilak</i> down there-year	'a couple years ago'	Years
	other side <i>apma bilak</i>	'last year'	Years
	yesterday year <i>kalip si ngan</i>	'a long time ago'	Generations
	past INTENS LOC		
	<i>don bishap</i> future time	'future times'	General
	<i>usa-don</i> daybreak-LOC	'tomorrow'	Days
	<i>padang</i> day after tomorrow	'day after tomorrow'	Days
	<i>usa-don sonda</i> daybreak-LOC week	'next week'	Week
	<i>usa-don bilak</i> daybreak-LOC year	'next year'	Years
Future	<i>don si ngan</i> future INTENS LOC	'a long time from now'	Generations

### 2.3. Materials

The target words and phrases we defined for analysis are summarized in Table 1. Importantly, the phrases do not contain words or morphemes that are explicitly topographic, with only one exception (*omoropmo bilak*). Note that several expressions employ the locatives *ngan* (implying containment and comparable to 'within') and *-don* (a generic locative comparable to 'at'), but these are not specifically topographic terms.

### 2.4. Data analysis

Analysis of participants' gestures was carried out in different stages by separate coders. None of the coders had been present at the interviews in the field. Further, coders had no experience with Yupno language or any knowledge of where participants faced relative to the topography of the valley (see Appendix A for details).

In the first stage, a coder used Elan (available online: <http://www.lat-mpi.eu/tools/elan/>) to annotate all gestures—defined as non-instrumental, effortful motor actions—made by participants that were co-produced with one of the pre-selected set of target temporal words/short phrases mentioned above. Non-manual gestures were set aside and were not analyzed further in this report. Manual gestures were singled out because—in contrast to head gestures—they encode directional vectors with much higher precision. The resulting 867 manual temporal gestures were then passed onto the next coding stage.

In the second stage, two further coders analyzed each of the 867 manual gestures, rating them on three morphological criteria: stroke-iness, displacement, and directionality. Stroke-iness was defined as the degree of effort or intensity in the movement, and was judged on a 1–5 Likert scale (1 = not intense, 5 = very intense). Displacement was defined as the size or amplitude of the movement (1 = very low amplitude, 5 = very high amplitude). Directionality was defined as the degree to which the gesture trajectory displayed a clear direction in space (1 = very unclear directionality, 5 = very clear directionality). The correlation of scores given by the two coders to all 867 gestures was highly statistically significant ( $p < 0.001$  for all three criteria; stroke-iness:  $r = 0.46$ ,  $t = 15.16$ , 865 df; displacement:  $r = 0.76$ ,  $t = 37.30$ , 865 df; directionality:  $r = 0.48$ ,  $t = 15.97$ , 865 df); interclass correlation coefficient (ICC) = 0.46 (stroke-iness), 0.79 (displacement), 0.47 (directionality).

The goal of the second stage was to indentify a subset of the manual gestures with the clearest overall morphological profile. We wanted to eliminate "beat gestures"—which may incidentally exhibit directionality but which are irrelevant to our hypothesis—as well as gestures for which a clear directionality could not be determined. The following procedure was used to determine the final subset. For each gesture, we calculated the mean of the Likert scale scores given by the two coders for each morphological criterion, and also calculated the size of the discrepancy between codes. Since the most important morphological feature for testing the allocentricity hypothesis is directionality,



we weighted directionality the most. The overall score was determined as follows<sup>1</sup>:

#### Overall morphology score

$$= (0.6 \times \text{mean directionality score}) \\ + (0.3 \times \text{mean stroke-iness score}) \\ + (0.1 \times \text{mean displacement score})$$

We then did a median split on the morphology scores, and accepted only gestures equal to or above the median (median = 3.8). Each participant was then capped at 10 gestures per facing direction, or 20 gestures total so that prolific gesturers were not over-represented in the final corpus. If a speaker produced more than 10 gestures with a morphology score above or equal to 3.8, we took only the 10 highest scoring gestures. Finally, we eliminated any gesture with an inter-coder discrepancy of more than 1 on the criterion of directionality. This paring procedure resulted in a subset of 214 gestures and included gestures from 17 participants.

In the third stage, two additional coders used a graphical interface to assign a trajectory to each gesture, relative to the speaker's body. The interface was designed in Keynote software and featured, for each gesture, an idealized torso seen from three angles. Coders first made a categorical distinction between gestures that were directed at the ground and gestures that were directed elsewhere. With respect to this classification—"directed-at-the-ground" vs. "outward" pointing gestures—coders had strong agreement (94.4%; Kappa 0.83, 95% confidence interval 0.74–0.92). Gestures for which the coders did not initially agree—5.6%—were collaboratively re-evaluated by the coders to see if a joint agreement could be reached. As a result, nine of these gestures were reclassified with common agreement, and two lingering disagreements were eliminated from further analyses. For the outward pointing gestures, coders placed arrows with respect to an idealized torso, corresponding to the gesture's trajectory, from top (bird's-eye), front (head-on), and side (profile) views. Circular correlation coefficients were 0.78 for the top view ( $t(139) = 6.27$ ,  $p < 0.001$ ), 0.85 for the front view ( $t(155) = 8.56$ ,  $p < 0.001$ ), and 0.73 for the side view ( $t(139) = 5.76$ ,  $p < 0.001$ ). The third stage thus resulted in a category of directed-at-the-ground gestures (which was used to test the presence of the deictic center, or "present" time), as well as mean body-centered trajectories for the outward-directed gestures from top, front, and side views.

In the fourth stage, two more coders used a graphical interface to assign a facing direction to each participant for each interview segment that had a selected temporal

gesture in it (there were a total of 38 such interview segments). For outdoor interviews, the facing direction was assigned relative to the plane of the camera, the cardinal orientation of which had been recorded in the field. For indoor interviews, the facing direction was assigned relative to the traditional central fireplace running along the axis of the house, the orientation of which had also been recorded. The overall concordance correlation coefficient (CCC) between coders for the 38 interview segments was 0.85. The fourth stage resulted in an estimate of each participant's cardinal facing direction.

In the fifth stage, we combined the directionality of the gestures relative to the speaker's body (results of the third stage) with the participants' facing directions (results of the fourth stage) in order to reconstruct the absolute orientation of the gestures in the topography of the Upper Yupno valley.

Several gestures were ultimately eliminated from the final corpus because the co-production of a temporal target word with the gesture could not be confirmed with certainty.<sup>2</sup> The final reported results are thus based on 171 gestures from 16 participants (see Appendix B for details regarding temporal category, location where these gestures were produced, and coding view).

When appropriate, top- and front-view gesture directionality data were analyzed according to circular statistics techniques (Fisher, Lewis, & Embleton, 1987).

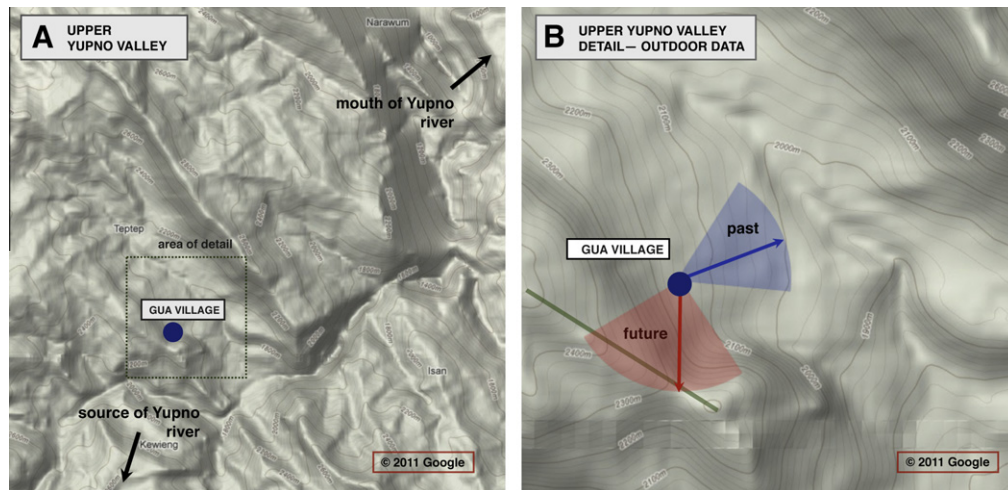
### 3. Results

#### 3.1. Present category gestures

The data show that the Yupno spatialize deictic temporal categories systematically in gesture. We first investigated whether the Yupno show a clear deictic center (present). We found that temporal deictic categories (past, present, future) were extremely significantly related to whether gestures were pointing directly to the ground or directed elsewhere ( $\chi^2 = 80.70$ , 2 df,  $n = 171$ ,  $p < 0.001$ ), with a large effect size (Cramer's  $V = 0.69$ ). A post-hoc test revealed that the major contributor to significance was the present-category gestures (co-produced with present-category expressions for *now/today*, *this week*, and *this year*), which were overwhelmingly directed at the ground (26 out of 31 present-category gestures; adjusted standardized residuals = 9.0). These results confirm that the Yupno spatial construal of time system does have a deictic center, which is spatially co-located with the speaker.

<sup>1</sup> The overall morphology score was used to establish a cut-off point and thus to determine which gestures would be included in subsequent analysis stages. The weightings of the three criteria were motivated by an interest in (i) retaining gestures exhibiting clear directionality while (ii) eliminating beat gestures and non-gestural movements that might incidentally display directionality but which would only add noise to the data. Given these two goals, directionality was weighted most heavily. Additionally, stroke-iness was weighted more than displacement because while the former is useful in eliminating both beat gestures and non-gestural movements, the latter is only useful in eliminating beat gestures.

<sup>2</sup> Results also do not include 20 gestures from a single outlier participant who, during an indoor interview, gestured egocentrically according to a present co-located, past in front, and future behind pattern. In fact, since the anomalous nature of this pattern was immediately evident, we interviewed the participant again on a separate day, this time outdoors, to confirm his outlier status. He continued to gesture according to the same egocentric pattern in three different facing orientations. Informants reported that this participant had spent several years outside of the Yupno valley, though he was not strictly unique among participants in this respect. Importantly, the main results reported below are not affected when this participant is included (see details in footnote 5).



**Fig. 2.** The topography of the Upper Yupno valley surrounding the village of Gua. (A) Shows the approximate directions of the source and mouth of the Yupno river. (B) Shows a detail of the Gua area with mean pointing directions for past- and future-category gestures produced outdoors, including 95% confidence cones (based on 1000 parametric bootstrap estimates). The past points downhill through the elevation lines towards the mouth of the river. The future points uphill towards the closest mountain ridge (green line), in the direction of the Yupno river's source. Strikingly, the Yupno spatial construal of past and future reflects the local topography and is not organized in terms of the usual opposite directions along a line. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

### 3.2. Past and future category gestures

We next investigated whether the Yupno showed distinct pointing directions for gestures co-produced with words in the derived temporal deictic categories, past and future. Analyses are presented first for gestures produced during outdoor interviews and then for gestures during indoor interviews. In both cases, we discuss analyses of the top and front views only.<sup>3</sup>

#### 3.2.1. Outdoor interviews

**3.2.1.1. Top view.** The top-view analysis of outdoor gestures co-produced with past-category terms (*yesterday, last year, a long time ago*) and future-category terms (*tomorrow, next year, a long time from now*) reveals that these pointed in a non-isotropic manner. Kuiper's tests of uniformity show that both distributions had a significant concentration in a single direction (past,  $n = 18$ : Kuiper's  $V = 2.1$ ,  $p < 0.01$ ; future,  $n = 11$ : Kuiper's  $V = 1.82$ ,  $0.025 < p < 0.05$ ). The mean pointing directions of the gestures co-produced with past- and future-category terms were  $69.21^\circ$  (clockwise from North; circular variance 0.45) and  $180.84^\circ$  (circular variance 0.49), respectively (Fig. 2B). In both cases the proportion of gestures pointing within a  $90^\circ$  quadrant around the corresponding mean direction was significant (12 past-category gestures out of 18, and 8 future-category gestures out of 11; Binomial test,  $p = 0.002$  and  $p = 0.001$ , respectively). We found no evidence that the directionality of these gestures was associated with either the front/back

or left/right bodily axes (two-tailed Fisher exact probability test:  $p = 1.0$  and  $p = 0.659$ , respectively). One-tail circular correlation coefficient tests provided no evidence of positive association, either (past:  $0.11$ ,  $t(16) = 0.44$ ,  $p = 0.330$ ; future:  $-0.75$ ,  $t(9) = -2.79$ ,  $p = 0.997$ ).

A high concentration  $F$ -test circular ANOVA shows that the mean directions of future- and past-category gestures are statistically different ( $F(1,27) = 19.06$ ,  $p < 0.001$ ). Crucially, however, these mean directions reveal that the Yupno future-past structure is not organized along a single axis. A nonparametric density estimate of the distribution of the sample mean directions of future- and past-category gestures (based on 1000 parametric bootstrap estimates) yielded 95% confidence cones that do not include each other's opposite direction. The 95% confidence cone of past-category gestures ( $32.41^\circ$ ,  $94.89^\circ$ ) excludes the opposite to the mean direction of future-category gestures ( $0.84^\circ$ ). And the 95% confidence cone of future-category gestures ( $145.93^\circ$ ,  $238.98^\circ$ ) excludes the opposite to the mean direction of past-category gestures ( $249.21^\circ$ ). This suggests that, strikingly, the Yupno spatial construal of past and future exhibits a *nonlinear* or *bent geometry*.<sup>4</sup> In other words, it is not organized in terms of the usual opposite directions along a line. Fig. 2B depicts the local topography surrounding the village where the interviews took place, and shows that the mean direction of past-category gestures points downhill through the elevation lines towards the mouth of the river. The mean direction of future-category gestures points uphill—intercepting the line defined by the closest mountain ridge—and pointing toward the source of the Yupno river (Fig. 2A; see Fig. 3A–D for gesture exam-

<sup>3</sup> Analyses of the side view turned out to be considerably less informative than analyses from the top and front views, and so we do not report them here. The reason is that gestures produced during indoor interviews were very often aligned with the fireplace and therefore directed to one side of the participant or the other. As a result, they were orthogonal to the plane of the side view.

<sup>4</sup> Here we use these terms by analogy to how they are used in chemistry to characterize molecular geometry, which describes the arrangement of three or more atoms placed at an expected bond angle that differs from  $180^\circ$ .



**Fig. 3.** Examples of temporal gestures related to the past and future category. A participant outdoors produces a backward gesture associated with the Yupno word for *yesterday* when facing uphill (A) and a frontward gesture when facing downhill (B). He produces contrasting, upward gestures associated with *tomorrow* (C and D). Outdoors, Yupno temporal gestures are allocentrically oriented according to the macro-scale topography. A different speaker indoors explaining *yesterday* points toward the entryway of the house with the right hand (E) in one sitting position and the left hand (F) in the opposite position. When referring to *tomorrow* he produces gestures directed away from the entryway (G, H). Indoors, Yupno temporal gestures are allocentrically oriented along the central axis of the house, and future gestures tend to have a steep slope. Arrows indicate the approximate trajectory of the hand in each case.

ples). The two vectors are joined at the deictic center (present), the speaker's location.

Interestingly, the upward direction of future-category gestures also manifested in another form, not apparent from the top view. Out of the 23 outdoor gestures co-produced with future-category words nearly half of them (12) could not be coded for directionality from the top because almost all (11) pointed sharply upwards. Outdoors gestures pointing straight up were overwhelmingly co-produced with future-category words, not past-category words ( $\chi^2 = 6.05$ , 1 df,  $n = 49$ ,  $p = 0.014$ , Cramer's  $V = 0.35$ , adjusted standardized residuals = 2.46). Moreover, straight upward future-category gestures were produced more commonly during outdoor interviews than indoors interviews ( $\chi^2 = 6.27$ , 1 df,  $n = 62$ ,  $p = 0.012$ , Cramer's  $V = 0.32$ , adjusted standardized residuals = 2.5).

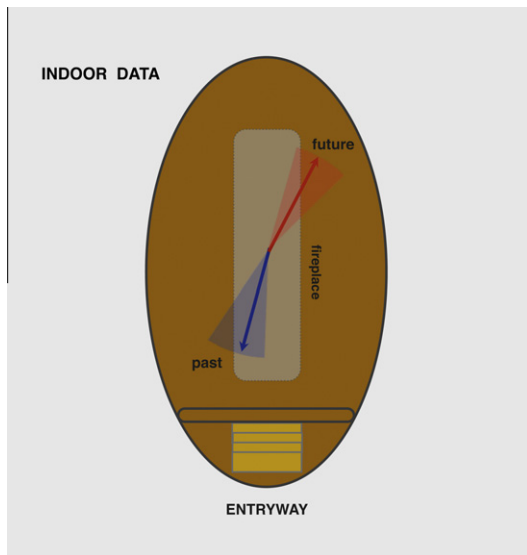
**3.2.1.2. Front view.** We further investigated the steepness of future category expressions by conducting analyses of the front view. Outdoor future-category gestures were primarily oriented towards the upper quadrant. We found a significant relation between temporal category of gestures (past/future) and frequency of gesture directionality falling within a 90° quadrant around the speaker's vertical axis. Whereas 18 out of 23 future-category gestures fell in this upper quadrant, only 5 out of 23 past-category gestures did so ( $\chi^2 = 14.70$ , 1 df,  $n = 46$ ,  $p < 0.001$ , adjusted standardized residuals = 3.8), and with a large effect size (Cramer's  $V = 0.57$ ). Further, the pointing direction of future-category gestures was very homogenous, with an interquartile range (IQR) of only 24.97°. A test for Homogeneity of Concentration Parameters shows that this distribution is significantly more homogenous than the past-category distribution (IQR = 139.08°;  $\chi^2 = 8.196$ , 1 df,

$p = 0.004$ ). Finally, while a significant majority of future-category gestures fell in the upper quadrant ( $\chi^2 = 34.80$ , 1 df,  $n = 23$ ,  $p < 0.001$ ), we found no evidence that past-category gestures fell in the opposite lower quadrant ( $\chi^2 = 0.014$ , 1 df,  $n = 23$ ,  $p = 0.904$ ), thus suggesting that the Yupno construal is not organized around a vertical temporal axis from bottom (past) to top (future). Consistent with the bent geometry observed from the top view, the front view data suggest that the observed future-is-up but past-is-not-down is based on contrasting differences in terrain declivity (see Fig. 3, for gesture examples).

### 3.2.2. Indoor interviews

**3.2.2.1. Top view.** We observed that Yupno temporal construals were spatialized somewhat differently indoors. Traditional Yupno houses are level with oval floor plans. They have an entryway at one end and a central fireplace running along the axis of the house. In a separate study we experimentally documented that, when inside traditional houses, Yupno participants de-emphasize the geocentric orientation of the house, and instead systematically re-map the downhill/uphill asymmetry of the macro-world onto the toward the door/away from the door asymmetry of the house (Cooperrider & Núñez, 2010). Strikingly, in the present study, we found that this indoor spatial re-mapping is recruited for temporal construals. The top view mean directions of time-category gestures obtained indoors were 136.40° (circular variance 0.21) for past-category gestures and 309.66° (circular variance 0.71) for future-category gestures. A high concentration  $F$ -test circular ANOVA confirmed that these orientations are significantly different from the corresponding ones obtained outdoors (past-category gestures





**Fig. 4.** Mean pointing directions for past- and future-category gestures with 95% confidence cones (based on 1000 parametric bootstrap estimates). Data from three houses with three different directions (90°, 150°, and 345° clockwise from North) are collapsed along the central axis of the house. Pointing directions indoors reflected the structural asymmetries of traditional Yupno houses, with the past gestures pointing along the fireplace toward the entryway and future gestures pointing away from it.

( $F(1,61) = 21.36$ ,  $p < 0.001$ ; future-category gestures ( $F(1,38) = 23.31$ ,  $p < 0.001$ ).

Most importantly, despite the fact that we conducted indoor interviews in three different houses (with entryways oriented at 90°, 150°, and 345°) and with participants sitting on both sides of the fireplace, Yupno participants primarily produced past-category gestures pointing toward the houses' entryways, and future-category gestures pointing away from them (Fig. 4; see Fig. 3E–H for examples). After collapsing the data of the three houses along the central axis of the house (with 0° indicating the direction towards the entryway) the mean direction for past-category gestures was 15.9° and for future-category gestures was 207.5°, with 95% confidence cones (based on 1000 parametric bootstrap estimates) being (1.5°, 34.1°) and (196.7°, 225.5°), respectively.<sup>5</sup> We observed that the proportion of past- and future-category gestures falling within a narrow 30° cone around the axis of the fireplace (47 gestures out of 74) was extremely significant ( $\chi^2 = 116.93$ , 1 df,  $n = 74$ ,  $p < 0.001$ ), with past gestures overwhelmingly falling within a 30° cone towards the entryway of the house (28 out of 45 gestures; Binomial test,  $p < 0.001$ ) and future gestures falling within a 30° cone away from the entryway (11 out of 29 gestures; Binomial test,  $p < 0.001$ ).

<sup>5</sup> The excluded outlier participant mentioned in footnote 2 contributed gestures to the indoor data base, but when included in the analyses, the results are only slightly altered: the mean of indoor past gestures becomes 10.8° (i.e., only a 5.1° change towards the fire place), and the mean of indoor future gestures becomes 213.0° (i.e., only a 5.5° change away from the fire place). The outdoors results are not affected at all, as this participant did not contribute any gestures to the final outdoor corpus.

The mean direction of these axis-aligned gestures was 0.44° for the past category and 183.24° for the future category, with a 95% confidence cone of (357.41°, 3.65°) and (178.72°, 197.24°), respectively.

**3.2.2.2. Front view.** Analyses from the front view reveal that the future-upward pattern described above for outdoor gestures was also evident indoors, with a medium-to-large effect size. While 26 out of 39 future-category gestures produced indoors fell in the upper quadrant, only 13 of the 47 past-category ones did so ( $\chi^2 = 13.09$ , 1 df,  $n = 86$ ,  $p < 0.001$ , Cramer's  $V = 0.39$ , adjusted standardized residuals = 3.6). In contrast, front view analyses of past-category gestures show that they were primarily directed horizontally, as defined by the 60° cones at each side of the speaker's horizontal axis ( $\chi^2 = 3.84$ , 1 df,  $n = 47$ ,  $p = 0.05$ ). We found no evidence that this horizontal directionality was associated with indoor/outdoor contexts ( $\chi^2 = 0.069$ , 1 df,  $n = 70$ ,  $p = 0.793$ ). Pooling these indoors data with the front-view analyses of past category gestures produced outdoors, the horizontal pattern persists ( $\chi^2 = 4.83$ , 1 df,  $n = 70$ ,  $p = 0.028$ ). These results show that the Yupno temporal construal exhibits a nonlinear geometry evident from the front view as well, with the past extending more or less horizontally away from the deictic center (present) and the future pointing more steeply upward.

#### 4. Discussion

Our results provide evidence of a construal of deictic time among the Yupno of Papua New Guinea that is based on allocentric topography: the present is collocated with the speaker, the past is associated with the macro-scale downhill of the valley, and the future with the macro-scale uphill. Topography also shapes the Yupno construal in a more fine-grained way, in that future-related gestures are oriented upwards whereas past-related gestures are oriented along the horizontal. While the Yupno pattern constitutes a striking counter-example to reported cross-cultural trends in several respects, it does lend support to at least two broader generalizations about time concepts cross-culturally. First, mounting evidence suggests that humans everywhere conceptualize time in terms of space. Everyday reasoning about, for instance, relations between temporal entities or displacement in time seems to be universally grounded in spatial reasoning. Second, the temporal deictic center—*now*—is strongly associated with the speaker's current location. No cases have yet been documented in which the deictic center (i.e. present) is systematically associated with some *external* feature of the environment, such as a salient landmark. So far these two properties of the human conceptualization of time appear cross-culturally robust, yet further research may well bring to light instructive counter-examples.

The Yupno temporal construal stands out sharply against prevailing cross-linguistic patterns with respect to three distinct features: (1) its *topographic allocentricity*; (2) its *nonlinear (bent) geometry*; and (3) its subtle *reorganization in indoor spaces*.



#### 4.1. Topographic allocentricity

The Yupno pattern is fundamentally allocentric. That is, it is not grounded in the asymmetries of the conceptualizing ego, such as front/back, up/down, or left/right, as are all known construals of time in the western industrialized world. When Yupno speakers point to the past or future, they point in approximately the same direction regardless of how their bodies are oriented in space: if they are facing downhill, the past is in front of them; if they are facing uphill the past is behind them. These findings are in line with another study that documented an Australian aboriginal community—the Pormpuraaw—which recruits allocentric (cardinal) construals to construe time, associating earlier events with the east and later events with the west (Boroditsky & Gaby, 2010). While in the Pormpuraaw case the origin of the supporting cardinal system seems to be the sun's course, the pattern we observed with the Yupno is based on an entirely different source: allocentric topography. An interesting difference between the two allocentric systems, then, is the degree to which they are grounded in a particular locale. Cardinal axes are based on large-scale properties that are largely independent of the properties of the local terrain and thus can be shared by groups living hundreds of miles apart. Topography-based systems, however, are specific to local geographies, and thus provide a structure that is only shared by a limited number of people. This fact is consistent with Papua New Guinea's most distinctive characteristic: the extraordinary variety of biological, cultural, and linguistic forms that have been shaped and sustained by the peculiarities of environmental isolation and diversity. Indeed, the nonlinear geometry exhibited by the Yupno reflects the local properties of the Upper Yupno valley where we conducted the study. Intriguingly, it may be the case that the specific geometry we observed in Gua is different for other Yupno groups living in other villages. Further research will be needed to investigate this question. Whatever the case, beyond merely providing the barebones of a coordinate system, it is clear that topography shapes particular properties of the Yupno system construal of deictic time, properties which are considered below.

#### 4.2. Nonlinear (bent) geometry

Of considerable interest is the fact that the Yupno construal of deictic time does not appear to follow a straight axis with past and future extending in 180° opposite directions from the present. Previous studies of time concepts—both deictic and sequence—have either reported or assumed a straightforward axial organization, whether front/back, left/right, up/down, or east/west. There are two distinct senses in which the Yupno construal is not aligned on a straight axis. First, there is an evident *top-view nonlinearity*. We found in our analysis of the outdoor gestures from the top view that the average absolute bearing of future is only 111° from the corresponding bearing of the past, not the 180° that might be expected (see Fig. 2B). Surprising as this nonlinearity may first seem, these bearings make sense in light of Gua's position in

the macro-topography of the Yupno valley. The village of Gua does not lie along an imagined linear axis connecting the source of the river to its mouth, but rather off to one side of it. Secondly, we also observed an evident *front-view nonlinearity*. Based on the front view analyses, it is clear that future category gestures produced during both outdoor and indoor interviews exhibit a steep upward slope. The past exhibits no such consistent slope from the horizontal and is very commonly level to it. Here again this particular aspect of the geometry seems coupled to the local terrain surrounding Gua. As is evident in the elevation lines in Fig. 2, the terrain rises dramatically in the uphill direction from Gua toward the source of the Yupno, while the slope is considerably more gentle in the downhill direction toward the river's mouth. When put together these two kinds of nonlinearity suggest that the construal has a particular 3-dimensional geometry, a geometry that reflects particulars of the terrain of the Upper Yupno valley. Though evidence for this geometry appears to be relatively strong in our data more research will be required to determine whether it is robust to differences in task and interview setting. Further, given the possible site-specificity of the construal we have described, it would be of considerable interest to explore any differences across Yupno villages in the fine-grained geometries of their time construals.

#### 4.3. Reorganization in indoor spaces

Our results show that the Yupno temporal construal appears to be subtly reorganized in an everyday, culturally prominent indoor setting: the traditional house. When indoors the present is mapped to co-location, past is mapped toward the entryway of the house, and future is mapped away from the entryway. Crucially, the mapping remains allocentric—not ego-based—but within the coordinate system provided by the microsphere of the house. This micro-world temporal construal appears to emerge reliably regardless of the orientation of the house relative to the macro-world topography outdoors. We are unaware of any previously documented analogues to this phenomenon in other cultures, in which spatial construals of abstract concepts take on a different character in different cultural settings. This temporal reorganization appears to piggy-back on a certain Yupno construal of *space* indoors, in which the uphill-downhill contrast is mapped systematically onto the *away from the door/toward the door* contrast. An object further away from the door may be said to lie uphill, regardless of the fact that the houses are flat and regardless of the orientation of the house in the valley. Though much remains to be understood about this spatial construal (see Cooperrider and Núñez (2010) for discussion), its roots likely lie in a conceptualization of the house as a microcosm of the outside world (Wassmann, 1993). Different factors serve to support the microworld construal. For one, the long and straight axis of the house—as defined by the fireplace—may provide a salient proxy for the *uphill/downhill* distinction when topographic landmarks are not immediately visible. Second, traditional Yupno houses closely follow a common structural template, mak-

ing possible the stability of the pattern. Interestingly, indoor gestures also exhibit aspects of the nonlinear geometry observed outdoors. While from the top view we found a clear linear geometry with the mean past-category and future-category gestures opposed by roughly 170°, the front-view nonlinearity was preserved: future gestures tended to point more sharply upwards than past gestures, which are more often level to the horizontal. Curiously, the future-upward pattern was less pronounced indoors than outdoors. A possible interpretation of this difference is that the fireplace serves as an “attractor” which subtly reshapes the geometry of the construal in three dimensions.

#### 4.4. Why is the future uphill?

What motivates the Yupno pattern? What conditions make such a conceptualization possible? Already discussed above is the strong cross-linguistic association between the deictic *now* and speaker's location. Less well-understood are the factors that determine how the derived deictic categories—past and future—are mapped to space in a particular culture. While human anatomy may make certain egocentric axes salient (Clark, 1973) (e.g. front/back, left/right, up/down), grammatically prescribed linguistic distinctions serve to channel attention to topographic contrasts (Majid et al., 2004). Uphill/downhill contrasts figure prominently in Yupno grammar, emerging in basic motion verbs (*come-down/come-up*) and even demonstratives (*that-downhill/that-uphill*). A previous study reported that, while the Yupno language makes a number of possible spatial construals in principle available, speakers rely heavily on topographic information (Wassmann, 1994). Attunement to topography is not just a matter of grammatical prescription, then, but also of culturally shared habits of talking about and reasoning about space. While such attunement explains the recruitment of the uphill/downhill contrast for time construal in the first place, it offers no explanation for *how* the derived temporal categories of past and future are to be mapped onto that contrast. Why in the Yupno case is the past *downhill* and the future *uphill*, not the other way around? One probable factor is that, traditionally, the Yupno believe that their ancestors traveled up from an island offshore to settle in the Yupno valley (Wassmann, 1993). This may motivate an association between the ancestral past and the macro-scale downhill direction. More generally, the pattern may be motivated by an entrance schema. When inside the valley—or inside a traditional house—the entering action (from below) becomes metonymic for past times, and future as higher up is derived by contrast. Cultural factors thus appear to motivate the choice of certain contrastive spatial concepts for time construals, as well as the particulars of how temporal categories are mapped to the contrast.

## 5. Conclusion

Abstract concepts are commonly grounded in spatial concepts. However, as the present case study demonstrates, exactly which spatial concepts are recruited is cul-

turally shaped, not universally given. The prominence of topographic spatial construals in Yupno language and culture gives rise to a spatial construal of time unlike any other that has been described, one which is allocentric, is characterized by a distinctive 3-dimensional geometry, and is subtly reorganized in a particular cultural setting. The present study focused on a particular abstract concept—deictic time—it raises the intriguing possibility that topographic space groups like the Yupno differ in how they structure other bedrock abstract concepts, such as causality and number. Only by careful investigation of different cognitive domains, in radically different linguistic, cultural, and ecological circumstances, can the study of the mind take the true measure of human conceptual diversity.

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## Appendix A

Gesture coders underwent training prior to analysis of the final corpus in order to ensure consistency in the use of the Likert scales (stage 2) and graphical interface (stage 3). In preparation for stage 2, coders were presented with a set of examples of gestures from the interviews that were not time related and which were selected to vary along a number of morphological dimensions. Each practice example was discussed by the entire San Diego-based research team until the coders began to judge the three morphological criteria (directionality, stroke-iness, displacement) consistently. In preparation for stage 3, coders were presented with a set of examples of gestures from the interviews that were directionally oriented but not time related. Each example was discussed by the research team until the coders exhibited facility with the graphical interface and achieved consistency in assigning vectors in the three views (front, top, and side).

## Appendix B

Numbers of gestures in the final data set, by temporal category, location where they were produced, and coding view. Not every gesture could be coded from both top and front views because gestures were often orthogonal to one of the views. From the top view gestures pointing directly downward or upward could not be meaningfully coded; from the front view gestures pointing straight ahead or backward could not be coded.

	Past		Present		Future		Total	
	Top view	Front view	Top view	Front view	Top view	Front view	Total Top view	Total Front view
Outdoors	26		11		23		60	
	18	23	2	10	11	23	31	56
Indoors	52		20		39		111	
	45	47	3	20	29	39	77	106
Total	78		31		62		171	
	63	70	5	30	40	62	108	162

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