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Space–time Mappings beyond Language

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39.1 Introduction

Over the course of an average day, our experience of time is linked to spatial locations countless times. Every motion event – such as catching the train to work – involves a correspondence between a change in position and the passage of time (the train is at position α at time α, then position β at time β). The act of eating involves fine coordination of the timing of the mouth's opening and closing with the position of the fork, and this is only scratching the surface. It is perhaps unsurprising, then, that the association between space and time is arguably a human universal, documented as preceding the development of language, both ontogenetically in human infants (Srinivasan and Carey 2010, de Hevia et al. 2014) and phylogenetically in other species of great ape (Merritt, Casasanto, and Brannon 2010). This space–time linkage is reflected in linguistic metaphors the world over (though see also section 39.3.4), and also in nonlinguistic artifacts, conventions, and other manifestations of human culture and cognition (the subject of the present chapter). Of these, the sundial offers an excellent example of how the natural and the conventional spatialization of time may combine; the position of the shadow, by naturally reflecting the position of the sun, conventionally represents the hour. Other spatializations of time are more arbitrary. For example, the English writing convention of transcribing earlier uttered sounds and words to the left of those uttered afterwards is simply a matter of cultural convention, as witnessed by right-to-left and top-to-bottom writing conventions for other languages (section 39.3.2.1). Similarly arbitrary spatializations of time include calendars, timelines flow charts, and the like (see Gell 1992, Munn 1992 for a fuller discussion of these forms).

This chapter is divided into two major parts. The first (section 39.2) considers a range of lab-based explorations of examinations of the extent and nature of the link between time and space in the mind. These studies have focused upon populations co-located with the universities researchers are affiliated with (e.g. speakers of English, Mandarin, Hebrew, and Dutch). The field-based studies that are the focus of this chapter's second part, meanwhile, have widened the empirical base in terms of the languages and cultures under consideration. While many lab-based studies have presumed back-to-front and left-to-right (or, occasionally, right-to-left/top-to-bottom) timelines to be the only candidates for linguistic and conceptual construal, field-based studies have emphasized cross-cultural and cross-linguistic diversity in how temporal categories are mapped onto spatial categories, as well as examined the extent to which thought, gesture, and nonlinguistic representations of time reflect the dominant modes of talking and thinking about both time and spatial relationships. Accordingly, section 39.3 is organized according to the major qualitative divisions in how time is spatialized.

39.2 Insights from the Lab

Researchers from various disciplines and theoretical approaches have designed lab-based experiments to explore the relationship between time and space in the mind. The following sections present some of the most important findings of this research.

39.2.1 Time and Space in the Mind

In this section, we review two important debates regarding the relationship between time and space in the mind. Section 39.2.1.1 considers the degree to which the specific Time is Space metaphors instantiated in various languages reflect (and/or construct) the cognitive construal of time. Section 39.2.1.2 reports on the debate over whether space and time are on an equal footing in the mind (e.g. as part of a more general system of reasoning about magnitude), or whether space plays a more fundamental role in human reasoning, supporting cognition about the more ephemeral time.

39.2.1.1 The Psychological Reality of Metaphors

English furnishes its speakers with two major subtypes of the Time is Space metaphor (Lakoff and Johnson 1980a). The first – known as the *ego-moving* frame – takes the viewpoint of a person moving along a trajectory, where points in time are landmarks along that trajectory (i.e. *we are getting close to lunchtime*). The second – known as the *time-moving* frame – takes the viewpoint of a stationary observer, toward whom points in time move from far ahead, to nearby, to co-located, to the behind-space (i.e. *winter is fast approaching*). Many metaphorical expressions of time are compatible with both of these frames; if we say that *those days of leisure are far behind us*, we may have traveled beyond our leisure time in an ego-moving frame, or our leisure time may have reached us and then passed into the behind-space within the time-moving frame.

Many experimental studies have focused upon whether these metaphors reflect and/or construct how English-speakers conceptualize time. For example, whether a participant is or has recently been moving through space – or even *imagining* themselves moving through space – can influence whether they adopt an ego-moving or time-moving perspective when processing temporal metaphors (McGlone and Harding 1998, Boroditsky 2000, Boroditsky and Ramscar 2002). For example, someone waiting at an airport is more likely to adopt a time-moving perspective, which in turn means they will likely interpret a prompt such as (1) as indicating that the meeting has been moved to Monday.

(1) *Next Wednesday's meeting has been moved forward two days. What day is the meeting now that it has been rescheduled?*

Someone arriving at that same airport after a flight, however, will more likely adopt an ego-moving perspective, indicating that the meeting has been rescheduled for Friday.

From both the ego-moving and time-moving perspectives, the future is consistently in front of the viewpoint and the past behind. Torralbo, Santiago, and Lupiañez (2006) tested the psychological reality of these linguistic associations by presenting their participants with words with temporal connotations, placed at different positions with respect to a head in silhouette. They found participants were faster to judge the words as referring to the past or future "when the irrelevant word location was congruent with the back-past, front-future metaphoric mapping" (Torralbo, Santiago, and Lupiañez 2006: 745).

Other such judgment tasks find the mental representation of the past to be associated with the left, and the future with the right, despite the absence of any left-to-right metaphorical timeline in spoken language (cf. section 39.3.2.1 and section 39.4.2). Santiago et al. (2007), for example, asked their participants to categorize words as referring to the past or the future by pressing keys with either their left or right hand. Participants were faster to press the correct key when the right-hand key indicated the future and the left-hand key the past, but also when the words referring to the past were presented on the left side of the screen and words referring to the future on the right. The psychological reality of the left-to-right timeline was supported by studies such as (Ulrich and Maienborn 2010) and (Flumini and Santiago 2013), which further suggest that such associations are nonautomatic. That is to say, the left-to-right conceptual timeline is only activated by temporal language when the task participants are performing explicitly involves temporal judgments.

Some studies go further than simply identifying a correlation between linguistic and mental representations of time in terms of space. Casasanto

(2008b), for example, finds a telling difference between how English and Greek speakers conceptualize time, reflecting differences in the metaphorical description of time in the two languages. While English speakers describe time in terms of *length*, Greek speakers describe time in terms of *amount*. Correspondingly, the spatial extent (= *length*) of visual stimuli influenced the temporal judgments of English but not Greek speakers, whereas visual stimuli manipulating *amount* influenced the temporal judgments of Greek but not English speakers. The extent to which experimental studies reveal linguistic metaphors to correspond to nonlinguistic construals of time ~~in terms of space~~ is considered in detail by Gijssels and Casasanto (this volume Ch. 40), and so will not be discussed further here, except with reference to the origins of spatiotemporal construals (in section 39.4).

39.2.1.2 The Cognitive Primacy of Space

Given the strong conceptual relationship between time and space, a key theoretical question concerns whether this relationship is symmetrical or asymmetrical. ATOM (A Theory Of Magnitude) emphasizes symmetry, drawing on evidence that space, time, and number (as well as some other domains such as pitch and quantification) share neural structures, feeding both priming and interference in processing and reasoning in each of these domains (Walsh 2003). Conceptual Metaphor Theory (CMT), however, emphasizes the asymmetric influence of space (as the concrete source domain) in structuring the representation of abstract target domains such as time and number.

A number of studies supporting an asymmetric relationship between space and time have shown spatial information to interfere with temporal judgments, but not the reverse (e.g. Boroditsky 2000, Bottini and Casasanto 2010). For instance, participants shown a dot moving along one dimension on a computer screen judge the time taken for the dot to reach its final position as longer for dots that move further, and shorter for dots moving shorter distances, whereas the length of time the dot spent moving does not strongly affect participants' judgments of the distance travelled (Casasanto and Boroditsky 2008). Significantly, this bias extends to young children (Casasanto, Fotakopoulou, and Boroditsky 2010, Bottini and Casasanto 2013) but not to monkeys: "In monkeys, both spatial and temporal manipulations showed large bidirectional effects on judgments … human adults showed asymmetrical space-time interactions that were predicted by metaphor theory" (Merritt, Casasanto, and Brannon 2010: 191).

Other studies, however, would seem to support ATOM at CMT's expense. CMT, for example, predicts that target domains such as time and number should only be related to one another via their shared source domain, space. Yet several studies evidence a bidirectional relationship between judgments of number and time among both Arabic speakers (Xuan et al.

2007, Roitman et al. 2007) and English speakers (Kiesel and Vierck 2009, Matlock et al. 2011; cf. Winter, Marghetis, and Matlock 2015: 214).

In their review of the debate about whether ATOM or CMT best accounts for the interactions between space, time, number, and some other domains, Winter, Marghetis, and Matlock (2015) conclude that ATOM is best not interpreted in its strictest sense, that is, entailing symmetrical, bidirectional associations between (for our purposes) time and space. But they see a place for both (the more loosely defined) ATOM and CMT in explaining the relationship between time and space in the human mind: "The evolutionarily older magnitude system in parietal cortex posited by ATOM might be subject to neural reuse or recycling as a result of culture and experience (Anderson 2010; Dehaene and Cohen 2007), shaped throughout ontogeny by cultural artifacts and practices – including language and writing – to produce more directional, asymmetric mappings" (Winter, Marghetis, and Matlock 2015: 219).

39.2.2 Body Movements

Researchers do not have direct access to the cognitive processes of their subjects. Instead, we must rely upon indirect evidence of what is going on 'under the hood.' Body movements of various kinds represent a valuable source of such indirect evidence. The following sections review experimental research into what hand gestures (39.2.2.1), eye movements (39.2.2.2), and leaning and body posture (39.2.2.3) reveal about how we mentally construe time in terms of space.

39.2.2.1 Hand Gestures

Since McNeill's pioneering work (e.g. 1992) gesture has featured prominently in psycholinguistic research as a window on cognition. Speakers of English and other European languages have a well-documented propensity for gesturally locating the past in the space behind their bodies and the future in front of them (e.g. de Jorio 1832 [2000], Calbris 1990, Cooperrider and Núñez 2009). Additionally, the conventions of literacy, calendars, and other cultural artifacts provide these speakers with a well-exploited alternative: gestures that map the past to the left and the future to the right are also extremely well attested, despite the absence of equivalent metaphors in any spoken language (cf. Cienki 1998, Sweetser and Gaby this volume Ch. 40). Surprisingly, these lateral (left–right) temporal gestures frequently accompany sagittal (back–front) temporal metaphors in concurrent speech (Casasanto and Jasmin 2012). Clearly, spoken metaphors are not the only source for the space–time mappings seen in gesture (see section 39.4 for further discussion). Moreover, the particular mapping instantiated in a particular gesture has been shown to be sensitive to pragmatic context as well as the level of granularity of the time (period) indicated (see section 39.4.3). The various forms temporal gestures take in the languages of the world are comprehensively reviewed in Cooperrider, Núñez, and Sweetser (2014), some of the more unusual of which are discussed further in section 39.3.

Before moving on, it must be acknowledged that gestural timelines are not a cultural universal. Recent research on Yucatec Mayan (spoken in Mexico; Le Guen and Pool Balam 2012) found the gestures of its speakers to make instead a simple "opposition between 'current time' (mapped on the 'here' space) and 'remote time' (mapped on the 'remote/distant space'). Additionally, past and future are not contrasted" (Le Guen and Pool Balam 2012). These authors suggest that the prominence of geographically oriented gestures (where pointing gestures are overwhelmingly interpreted as indicating a specific location), "may to some extent preempt the use of gesture space for other domains like time" (Majid, Gaby, and Boroditsky 2013).

While it is true that gesture is neither linguistic nor wholly consciously produced, it remains at least somewhat conventionalized, arbitrary, and culturally transmitted (see Kendon 1983). The following sections consider some other kinds of bodily movements which have been argued to reflect temporal cognition more directly.

39.2.2.2 Eye Movements

Only relatively recently has eye-tracking technology been employed in investigating the mapping of time to space in nonlinguistic cognition. Stocker et al. (2015) measured German-speaking participants' eye movements along a blank screen as they listened to stimuli involving past, future, and same-time related sentences. They found significantly more upward saccades were made by participants listening to future-related sentences than past-related ones, suggesting that "as we mentally represent time, our mind's eye follows an upward – and possibly forward – progressing mental time line, and this is reflected in corresponding oculomotor correlates" (Stocker et al. 2015). These results are consistent with a conceptual timeline running outwards from the body along the sagittal axis (as instantiated by linguistic metaphors of the past *behind* and the future *ahead*) since, as Stocker et al. put it, "if participants were able to mentally project the future as extending sagittally out of their body, then the geometrical projection onto screen coordinates would lead to future locations higher on the screen than past location" (2015). Strikingly, the participants in this study did not show any evidence of a left-to-right mental timeline. This contrasts not only with many of the studies reported in sections 39.2.2.1, 39.3.2.1, and 39.4, but also with another eye-tracking study conducted by the same research team but with a different methodology. Instead of measuring eye-movements during the comprehension of (time-related) linguistic stimuli, Hartmann et al.'s (2014) participants were instructed to imagine themselves either one year in the past or in the future. Participants were found to gaze downwards and to the left under the past condition, and upwards and to the right under the future condition. Together, these eye-tracking studies suggest that German speakers access both sagittal (back-to-front) and lateral (left-to-right) mental timelines. Further research is required to tease apart any effects of timescale, and language comprehension versus imagination, but eye-tracking seems a fertile area for future study.

39.2.2.3 Leaning and Body Posture

It might be argued that the saccades and fixation points measured in eye-tracking studies are conditioned by habits of reading and attention, and do not directly reflect the conceptualization of time per se. Another way in which body movements have been exploited as a window on cognition circumvents this issue. Miles, Nind, and Macrae (2010) attached extremely sensitive motion sensors to their participants' legs, designed to measure sway (changes in posture or leaning direction). With sensors attached, participants were instructed to recall a typical day in their lives four years previously, or to imagine what a typical day will be like for themselves four years into the future. They found that participants remembering the past leaned backwards, while those engaging in mental time travel into the future leaned forwards. Thus, as (Miles, Nind, and Macrae 2010: 223) put it, "the embodiment of time and space yields an overt behavioral marker of an otherwise invisible mental operation."

39.3 Insights from the Field

Most of the lab-based studies described in section 39.2 assume continuity in how time is described, and focus upon the questions of how these spatial representations of time in language relate to how time is conceptualized, as well as relationships with other domains such as numerosity, size, and pitch. Meanwhile, field linguists, psychologists, and anthropologists have emphasized cross-linguistic and cross-cultural diversity in these domains. First, they do so by finding dramatic variation in how time is described in terms of space linguistically (see Sweetser and Gaby this volume Ch. 38). Second, they do so by finding that the description of spatial relationships between objects varies dramatically from language to language, and that this variation corresponds with variation in spatial reasoning, memory, and more (see, e.g., Levinson 2003, Majid et al. 2004). These findings taken together raise an intriguing question: to what extent do cross-cultural differences in construing spatial relationships engender different construals of time?

The studies discussed in this section attempt to answer that question by various means. Several of them draw on data elicited through the Temporal Representations Task introduced in section 39.3.1. Others consider evidence from gesture (cf. section 39.2.2.1), cultural artifacts, and other devices. But rather than organizing this section according to the nature of the data analyzed (as in section 39.2), the discussion below is presented according to the nature of the timeline revealed. First of all, there is a cleavage between timelines arranged according to an individual's perspective (the 'ego-centric' timelines, section 39.3.2), and those anchored by (features of) the broader environment that the individual is situated within (the 'geo-centric' timelines, section 39.3.3). The ego-centric timelines in turn divide into those extending along the sagittal axis (in front/behind, section 39.3.2.2) and those extending along the lateral axis (left/right section 39.3.2.1). Geo-centric timelines, meanwhile, may extend along an axis defined by the uphill/downhill slope (section 39.3.3.1), a river course (section 39.3.3.2) or the cardinal directions (north, south, east, and west, section 39.3.3.3). These categories do not distinguish the full array of analytical possibilities, however. Since there is not space to do justice to the proposals of, for example, Moore (2006, 2011), Bender, Beller, and Bennardo (2010), and Tenbrink (2011), the interested reader is referred to those excellent works, as well as (Tenbrink this volume Ch. 41).

39.3.1 Temporal Representation Task

Since many of the studies discussed in sections 39.3.2–39.3.4 draw upon evidence from a standard experimental task designed to elicit novel spatial representations of time, it is worth beginning with a brief overview of this task.

The Temporal Representation Task (described in full by Boroditsky, Gaby, and Levinson 2008) consists of two components. In the first, participants are presented with a set of between four and six photo-cards. The photos of each set depict a particular event or process unfolding over time. The timescales involved vary from set to set, from the very short (e.g. an egg being dropped onto a table, the shell cracking, and the contents spilling out), to the long (e.g. a young boy aging to become an old man). Participants are instructed to lay out the cards in order, and are thus covertly required to choose a spatial layout for the passage of time. Having laid out half the sets, participants are re-seated at a 90° or 180° rotation from their original orientation in order to complete the remaining trials. This rotation allows for the ego-centric and geo-centric arrangements to be distinguished from one another.

In the second component, the researcher indicated a point in front of the participant (either in the air, or by drawing a dot in the sand, or placing a counter on the ground or tabletop, depending on the experimental context and researcher involved). The participant was told that this point represented a particular deictic timepoint (e.g. *today*), and then asked where they would place other deictic timepoints (e.g. *tomorrow* and *yesterday*).

The various timelines produced in response to this task by participants around the world are discussed in the following subsections, along with insights garnered from observation, interview, elicitation, and other tasks.

39.3.2 Ego-centric Timelines

This section considers the two ways in which time has been documented to be spatialized with respect to the speaker/thinker/gesturer's body; along the lateral axis (left-to-right or right-to-left, section 3.2.1) or along the sagittal axis (in.front-to-in.back or in.back-to-in.front).

39.3.2.1 Lateral Timelines

As we have seen, the lateral left-to-right timeline used by English speakers has been attributed to writing conventions and associated graphic representations (e.g. timelines, calendars and so forth; Tversky, Kugelmass, and Winter 1991; cf. section 39.4.2). However, not all languages are written from left-to-right. Where writing conventions vary, corresponding variation has been found in other nonlinguistic representations of time. For example, in the Temporal Representation Task (section 39.3.1), speakers of Hebrew arranged the stimulus cards to show the passage of time proceeding from right-to-left, conforming to the direction of the Hebrew script (Fuhrman and Boroditsky 2010). Particularly telling is the example of Chinese, which has been written top-to-bottom, right-to-left, and left-to-right in different locations (e.g. mainland China versus Taiwan) and different eras (see also Lum in press on the effects of text messaging and the use of a Romanized script on how time is represented by speakers of Dhivehi, which is conventionally written from right-to-left). Both de Sousa (2012) and Bergen and Chan Lau (2012) find their participants' performance in experimental tasks (including the Temporal Representation Task) to conform to the writing direction to which they have had most exposure (cf. Chan and Bergen 2005).

These lateral timelines are of particular interest given the complete absence of lateral terms used to describe time in language (see section 39.4.3 for further discussion of this point). The influence of literacy on temporal representations is also considered further in section 39.4.2.

39.3.2.2 Sagittal Timelines

The conceptualization of the past as *behind us* and the future *ahead* (along an ego-centric, sagittal timeline) is familiar to all speakers of English and most other languages (cf. section 39.2). More unusual, however, is the reversal of this timeline as by the Aymara. Living in the mountainous region bordering Bolivia, Peru, and Chile, Aymara speakers are now famous for gesturing in front of themselves to indicate the past, while pointing over their shoulders to the unknowable future (Núñez and Sweetser 2006a). Like English speakers, though, the Aymara have access to an alternative, lateral timeline running from left to right. In the Aymara case, the sagittal timeline is used with reference to deictic time (e.g. *long ago, next year*), while lateral gestures are used for sequence time (*he baked the cake and then went for a walk*) (see section 39.4.3 for further discussion of how topic, granularity and pragmatic context influence the choice of coordinate frame).

39.3.3 Geo-centric Timelines

This section presents three ways in which time can be construed independently of any viewpoint, being instead anchored to the broader environment. Specifically, locating the future: uphill or upriver (39.3.3.1), downriver (39.3.3.2), or to the west (39.3.3.3).

39.3.3.1 The Future is Uphill (or Upriver)

The past is associated with the downhill direction and the future with uphill in at least three languages: Tzeltal (spoken in Mexico; Brown 2012), Yupno and Nungon (both spoken in Papua New Guinea; Núñez et al. 2012, Sarvasy 2014). Of these three, only Yupno shows strong evidence of these associations extending beyond language (though see Sweetser and Gaby this volume Ch. 38 for further discussion of the linguistic metaphors; see also section 39.4.1 for further discussion of Tzeltal).

Núñez et al. (2012) elicited temporal gestures in twenty-seven semi-structured interviews with Yupno speakers. They found gestures indicating the present time point directly to the ground (at the speaker's current position). Gestures for past and future, however, do not conform to a straight line. Instead, past gestures (in aggregate) point downhill toward the mouth of the Yupno river, while future gestures point upwards and/or uphill toward the river's source (Núñez et al. 2012: 30). As a result, the future is rotated 111 degrees from the past – rather than 180 – a fact which Núñez et al. (2012) attribute to the fact that the village of Gua (where consultants were tested) lies off to one side of the linear axis connecting the river's source and mouth. This begs the question of whether the Yupno timeline in fact runs from downriver (/past) to upriver (/future).

A further intriguing complexity of Yupno spatiotemporal construals involves how this system is transposed from outside to indoors. Measurement of gestures produced inside three houses (with entryways oriented at 90°, 150°, and 345°) showed Yupno speakers to gesture toward the entryway in order to indicate the past, and away from the entryway for the future (Núñez et al. 2012: 32). This aligns with linguistic description of spatial relationships such that objects on the entry side of the home are described as 'downhill' and those away from the entry 'uphill,' regardless of actual orientation (Núñez et al. 2012: 33, Cooperrider, Slotta, and Núñez 2016).

39.3.3.2 The Future is Downriver

A possible – albeit limited – reversal of the Yupno's uphill passage of time is seen in Mian, an Ok language of Papua New Guinea. As with Kuuk Thaayorre (section 39.3.3.3) and Aymara (section 39.3.2.2), the use of Mian spatial terms to refer to temporal meanings is extremely limited. However, the presence of *tab* 'down(river)' in examples such as (2), may indicate that time is conceptualized as flowing down(river).

(2) *am=o hebmamsâb tab tl-Ø-o=be*
time=N2 quickly down come.PFV-REAL-N2.SBJ=DECL
'The time passed quickly'. (Fedden and Boroditsky 2012: 485)

In the Temporal Representation Task described in section 39.3.1, Mian speakers employed a variety of strategies, including the representation of time flowing from left-to-right (consistent with local literacy practices), toward the body, and along a landscape-based, 'absolute' axis. Since the rivers of the region flow to the WNW, it is difficult to distinguish arrangements according to the compass directions from those aligning with the river. However, the temporal usage of *tab* 'down(river),' together with the fact that "the absolute arrangements appear to be rotated slightly clockwise off of the east-west axis" (Fedden and Boroditsky 2012: 487) is suggestive of a construal of time in terms of the riverflow. This remains a tantalizing area for further investigation.

39.3.3.3 The Future is West

Speakers of the Australian Aboriginal language Kuuk Thaayorre also produced geographically grounded arrangements of stimulus cards and dot points in response to the Temporal Representation Task (section 39.3.1). In this case, however, it was not the direction of the riverflow or slope that anchored the timeline, but the directional east–west axis (Boroditsky and Gaby 2010, ~~Gaby 2012~~). Given the sun's apparent trajectory across the sky over the course of a day, the mapping of earlier/past to the east and later/future to the west seems natural.

39.3.4 Nonlinear Timelines

We have already seen that the Yupno timeline is structured according to a "bent geometry" (Núñez et al. 2012: 30). Other timelines depart even more dramatically from the straight line model familiar to most English-speaking readers. Perhaps the most famous of these is the cyclical representation of time seen in Mayan and other Meso-American cultural artifacts, such as the traditional Long Count and other calendars (Gossen 1974, Tedlock 1982). Neither of the two Mayan populations that participated in the Temporal Representation Task (section 39.3.1) drew consistently on a particular coordinate frame to represent the passage of time spatially. For example, of the twelve Tzeltal-speakers who participated in the card-arrangement task, seven produced inconsistent responses across trials, and each of the remaining five – who were internally consistent – employed a different coordinate frame from the others: one left-to-right, one right-to-left, one near-to-far, one south-to-north, one east-to-west (Brown 2012: 8). This inconsistency may be at least partly due to the availability of no fewer than five distinct schemata for conceptualizing time, as evidenced by temporal expressions in spoken Tzeltal.

Speakers of Yélî Dnye (a language isolate spoken on Rossel Island, PNG) were likewise found to employ a range of different strategies for representing time spatially in the Temporal Representation Task: "experimental evidence fails to show a single robust axis used for mapping time to space" (Levinson and Majid 2013: 1). Levinson and Majid suggest that the lack of systematic spatialization of time in this experimental task, along with the lack of spatial expressions for time in spoken Yélî Dnye, may stem from the language's abundance of dedicated terms for deictic time categories. These include six diurnal tenses, special nominals for *n* days from coding time, and special constructions for overlapping events.

39.4 Convergent Insights, Lingering Questions and Future Directions

If conceptualizing time in terms of space is not universal, it is certainly extremely widespread. While section 39.2.1 considered lab-based investigations into the nature of the relationship between conceptual representations of time and space, in this section we consider the origins of this relationship. Section 39.4.1 presents evidence from both lab-based and cross-linguistic studies that temporal cognition does not always reflect temporal language. Clearly, then, language cannot be the (only) force shaping how humans think about time. An alternative model for conceptual representations of time are nonlinguistic conventions such as literacy, calendars, and other cultural artifacts. The influence of literacy on temporal cognition is considered in section 39.4.2. How competition between all of these models of representing time in terms of space plays out is considered in section 39.4.3, while section 39.4.4 considers some open questions for further research.

39.4.1 Spatiotemporal Thought without Spatiotemporal Language

To some extent, the way that we conceptualize time mirrors the way we talk about it. Consider, for example, the contrast between Greek and English speakers' associations of time with quantity and length respectively (section 39.2.1.1; cf. Gijssels and Casasanto this volume Ch. 40). But spatialized construals of time do not depend upon the presence of corresponding space–time metaphors in language. Among speakers of the

Amazonian language Amondawa, for example, "even when entrenched, habitual, regular linguistic space-time mapping is *absent*, the cognitive capacity for construing temporal concepts in terms of spatial arrays is present" (Sinha et al. 2011: 164).[1]

Kuuk Thaayorre likewise possesses only two polysemous terms with spatiotemporal meanings (*raak* 'place, earth, ground, time' and *kanpa* 'in front of, earlier'), in the absence of more extended spatial metaphors for time (Gaby 2006, in press). As discussed in section 39.3.3.3, however, speakers of Kuuk Thaayorre have been found to represent time as flowing from east to west in experimental tasks – a timeline with no linguistic analogue whatsoever (Boroditsky and Gaby 2010, Gaby 2012). The converse situation, meanwhile, is illustrated by speakers of Tzeltal, for whom the "systematic and consistent use of spatial language in an absolute frame of reference does not necessarily transfer to consistent absolute time conceptualization in nonlinguistic tasks" (Brown 2012: 10), such as those described in section 39.3.1 (cf. section 39.3.4).

Studies involving participants without language – such as infants and other great ape species – are another important source of evidence that linguistic metaphors of time in terms of space are not the (only) foundation of spatiotemporal cognition. Srinivasan and Carey (2010), for example, show that the use of metaphorical expressions such as *a long time* is not prerequisite to associating (spatial) length with duration. In their experiments, nine-month-old infants – like English-speaking adults – associate length and duration, but not, for example, length and tone amplitude (even after controlling for visual cues). A nonverbal study conducted with rhesus monkeys, meanwhile, showed spatial cues to interfere with the processing of temporal information, as well as the reverse (Merritt, Casasanto, and Brannon 2010).

39.4.2 Cultural Foundations of Conceptual Timelines

All forms of motion offer a strong experiential basis for associating time and space. Specific subtypes of timeline may also have experiential, cultural, and historical bases. For example, the Yupno conceptualization of time flowing from downhill to uphill may have its roots in the Yupnos' origins at the coast (Núñez et al. 2012: 34; cf. also the Yupno 'entrance schema' for indoor representations of time). The association of earlier times with the east and later times with the west (as among the Thaayorre, section 39.3.3.3) has a more immediate experiential basis in the daily arc of

[1] Although Sinha et al. (2011: 161) claim that the Amondawa "do not employ linguistic space-time mapping constructions," the polysemous term *awo* 'here' and 'now' (Sinha et al. 2011: 150) indicates that there is at least some basic-level association between deictic space and time.

Stronger claims have been made regarding the Pirahã, who – per Everett (2005) – lack any linguistic resources for talking about reference-time (as opposed to utterance-time). Everett claims this to be a consequence of a cultural Immediacy of Experience Principle.

the sun's (perceived) trajectory across the sky. Both the ego-moving and time-moving metaphors that underlie the sagittal timelines of, for example, English speakers (section 39.3.2.2) reflect our experience of travel and interaction with moving objects (Lakoff and Johnson 1980a).

But perhaps the most powerful force-shaping nonlinguistic representations of time today is literacy. We have seen that in highly literate societies, the directionality of the writing system shapes everything from the processing of temporal language, to improvised physical representations of time, to temporal gestures. The effect of the written word on temporal representations is felt even in societies in which it is less than ubiquitous. In Fedden and Boroditsky's study of how Mian speakers performed in the Temporal Representation Task (section 39.3.1, section 39.3.3.2), for example, "only the number of years of formal education emerged as a significant predictor of temporal arrangement type. Greater number of years of formal education positively predicted left to right arrangements [$r(7) = 0.61$, $p < 0.05$] and negatively predicted absolute spatial arrangements [$r(7) = -0.65$, $p < 0.05$]" (Fedden and Boroditsky 2012: 7). Ontogenetically, too, it seems that children represent time spatially in alignment with the writing direction they are in the process of acquiring, but only once they are actively producing the written form. Leembruggen, Kelly, and Gaby (~~in press~~), for example, find three- to four-year-old, English-speaking children to eschew spatial representations of time in the Temporal Representation Task (section 39.3.1). But by the time children are established in school and the literacy practices taught there (age 5.5–7), their representations of time are robustly organized from left to right.[2]

As we have seen, however, literacy is not the only force shaping spatial representations of time. Among ethnic Thaayorre in Australia's Cape York Peninsula, for example, monolingual English-speaking participants in the Temporal Representation Task produced uniformly left-to-right timelines, while Kuuk Thaayorre speakers with equivalent levels of literacy produced geo-centric east-to-west and other timelines (in addition to some left-to-right; Gaby 2012). The competition between literacy and spoken metaphors in structuring spatial construals of time is revisited in section 39.4.4 below.

39.4.3 The Importance of Context

One common theme emerging from lab-based and cross-linguistic studies alike is the role context plays in determining which of multiple available spatial construals of time is activated on a particular occasion. Context here should be understood in terms of both the particulars of the speech (or thought) event and the more fine-grained subtype of 'time' under

[2] Cf. also Stites and Ozcaliskan's (2013) study of children's relative comprehension of moving-time, moving-ego, and sequence-as-position metaphors.

consideration. For example, deictic time (e.g. when an event occurred/will occur in relation to the speech/thought time) is represented along a different axis from sequence time (when events occurred/will occur relative to one another) among signers/speakers of American Sign Language (Emmorey 2002), Aymara (Núñez and Sweetser 2006a) and English, for whom signs/gestures along the sagittal axis were more common in referring to deictic time, and gestures along the lateral axis more common in referring to sequence time (cf. section 39.3.2.2). The time scale involved may also plays a role, as Núñez and Cooperrider (2013: 225) observe: "the choice [between alternative spatial construals of time] could be modulated by the temporal granularity required – front-back for coarse-grained material and left-right for fine-grained." The Yupno downhill-to-uphill timeline discussed in section 39.3.3.1, for instance, is for the most part restricted to large timescales (as befits its likely origin in Yupno migration). The Yupno case also illustrates the importance of speech/thought location, since the downhill-to-uphill timeline is supplanted by one locating the past in the direction of the entryway and the future away from it when the speech/thought event takes place indoors (Núñez et al. 2012; cf. section 39.3.3.1).

39.4.4 Lingering Questions

For all the advances in our understanding of how we humans construe time in spatial terms, there remain a number of open questions. One such puzzle is the absence of any linguistic correlate of the left-to-right timeline that so dominates English (and other) speakers' representations of time in gesture, written and cultural artifacts, and problem-solving tasks. Yet in no language (of which we are aware) would an expression like *two years leftwards* be used to refer to two years in the past. One explanation that has been proposed is that while the impact of literacy on structuring timelines is profound, it is also relatively recent. Literacy has become the norm in technologically advanced cultures only within the last century or so, and Western graphical timelines only date back to the eighteenth century (Casasanto and Jasmin 2012, Núñez and Cooperrider 2013: 224). Thus, it may be that time is not "metaphorized laterally in language because the cultural artifacts that provide the experiential basis for people's implicit lateral timelines did not exist – or were not widely used – when our conventions for talking about time were developing" (Casasanto and Jasmin 2012: 669). If this reasoning is correct, we might expect to see left-to-right temporal metaphors emerge in future varieties of English. Alternatively, however, it may be that left-to-right temporal gestures do not really reflect a conceptualization of time as moving along the lateral axis with respect to the gesturer's viewpoint. Instead, they might represent the *forwards* motion of some imagined trajector moving along a left-to-right trajectory. Thus, a rightwards movement can still be construed as forwards with respect to the trajector, depending on whether the motion is framed according to an external or internal perspective.

Much as spoken English lacks lateral axis metaphors for time, spoken Kuuk Thaayorre lacks any absolute (east-to-west) temporal metaphors. No such cardinal direction-based temporal metaphors have been documented in a spoken language, despite the fact that for many Australian Aboriginal languages (Kuuk Thaayorre included), these direction terms are of extremely high frequency and cultural importance. This may of course simply reflect an accidental gap in the data, since we have much still to learn about the metaphorical and metonymic extensions of directional terms in Australian languages.

Lastly, there is much still be learned by combining the two approaches outlined in this chapter, extending the empirical base of lab-based research to include a more culturally and typologically diverse set of languages and speakers. There are unquestionably financial and practical hurdles to be overcome in bringing the lab to the field, but as our technology advances both of these hurdles descend.

39.5 Conclusion

The insights gleaned from the studies reviewed above paint a picture of both unity and diversity in how time is spatially construed. There is unity in the very fact of time being expressed using the vocabulary of space, and conceptualized in terms of space before this vocabulary is even acquired. But there is also considerable diversity in the particulars of how time is spatialized. There is diversity in which axis is recruited for gestural, graphical, and other timelines. There is diversity in which semantic and pragmatic factors condition the choice between multiple available timelines. And there is diversity in how time is differently spatialized in language as opposed to gesture as opposed to cultural artifacts as opposed to nonlinguistic cognition, as evidenced by eye movements, posture, and responses to problem-solving tasks.