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# 40

# Conceptualizing Time in Terms of Space: Experimental Evidence

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## 40.1 Introduction

Do space–time metaphors in language reflect how space and time are related in speakers' minds? People often use spatial expressions to talk about time (H. Clark 1973, Lakoff and Johnson 1980a). For instance, you can fall *behind* on a deadline, go to sleep *before* midnight, or look *forward* to a *long* vacation. Based on these patterns in language, metaphor theorists have argued that space and time are metaphorically related in thought: people use space to talk about time because they use space to think about time (Lakoff and Johnson 1980a, 1999).

Skeptics have pointed out, however, that linguistic data alone, are not sufficient to support the claim that people think metaphorically (Murphy 1996) – only that they talk metaphorically. Linguistic analyses of space–time metaphors can help to identify *possible* ways in which people could think about time. Finding out whether people actually think about time in corresponding ways requires the use of nonlinguistic methods, motivating collaboration between linguists and researchers in allied areas of the cognitive sciences (Casasanto 2008b).

Performing experimental tests of nonlinguistic space–time mappings in people's minds is not just a formality to satisfy skeptics, nor an exercise in confirming what linguistic analyses have already made clear. Experiments allow researchers to discover relationships between space and time in the mind that cannot be predicted or explained by language. In this chapter we review evidence for four different relationships between people's linguistic metaphors and their mental metaphors[1] that link space and time: some linguistic metaphors accurately reflect nonlinguistic mental metaphors

[1] To disambiguate between metaphors in language and in thought, we use the term 'linguistic metaphor' to refer to metaphoric expressions in language and 'mental metaphor' to refer to associative mappings between nonlinguistic mental representations in metaphorical source and target domains (see Casasanto 2009, 2013 for discussion). This

(section 40.2); additionally, in some cases, linguistic metaphors not only reflect the way people think but can also play a causal role in determining which mental metaphors people use (section 40.3); by contrast, people use some mental metaphors that are not reflected in spoken language at all (section 40.4); finally, people use some mental metaphors that directly contradict the conventional metaphors in their spoken languages (section 40.5). Together, this growing body of experimental research suggests that space–time metaphors in language provide a rich set of hypotheses about people's spatial conceptions of time, but that understanding the full range of space–time mappings in our minds, and determining which mental metaphors people may be using at any moment, requires looking beyond language.

## 40.2 When Temporal Language Reflects Temporal Thinking

### 40.2.1 A Sagittal Mental Timeline

Across many languages, temporal sequences are described as unfolding along the sagittal (front–back) axis. People *look forward* to their retirement, *think back* to their first kiss, or *plan ahead* for the arrival of a new baby. In each of these examples, time is described as a line that runs through the speaker's body with the future being in front of the speaker and the past being in the back. On one proposal, this mapping arises from the universal experience of moving forward through space: when people walk somewhere, places they have already passed lie behind them, and places they have yet to reach lie in front of them (H. Clark 1973).

The results from psycholinguistic studies suggest that when people process language about temporal sequences, they activate front–back spatial schemas, at least in certain contexts. In one study, people read sentences describing spatial and temporal sequences with two possible frames of reference. Some sentences described sequences of objects or events as if the reader was moving through space or time (e.g. *The flower is in front of me; In March, May is ahead of us*). Other sentences described sequences of objects or events moving relative to each other (e.g. *The hatbox is in front of the Kleenex; March comes before May*). Participants were faster to process temporal sentences after reading spatial sentences with matching as opposed to mismatching frames of reference (Boroditsky 2000; see also Boroditsky and Ramscar 2002, Duffy and Feist 2014). In another study, participants judged whether verbs described past or future events. Participants were faster to make 'future' judgments if the verb appeared in front of a silhouette of a face, rather than behind it, whereas 'past'

distinction becomes particularly important here as we discuss multiple dissociations between linguistic metaphors and mental metaphors.

judgments showed the opposite pattern (Torralbo, Santiago, and Lupiáñez 2006, Sell and Kaschak 2011, Ulrich et al. 2012).

Two studies from Miles and colleagues suggest that implicitly activating a sagittal mental timeline can affect people's spontaneous thoughts and motor actions. In one study, participants were given the perceptual illusion of moving forwards or backwards through space by watching dots move toward or away from the center of the screen. Participants who experienced illusory forward motion were more likely to report daydreaming about future events whereas participants who experienced illusory backward motion were more likely to report daydreaming about the past (Miles et al. 2010). In a second study, participants stood in the middle of a room with a motion-tracking device attached to their knee. Half of the participants were asked to imagine a typical day in the past, and the other half were asked to imagine a typical day in the future. Participants who were assigned to think about the past tended to lean backwards, whereas participants assigned to think about the future tended to lean forwards (Miles, Nind, and Macrae 2010).

These results suggest that people not only talk but also think about time as being mapped onto a front–back continuum. As we will describe below, however, this is not the only axis people use to think about time – it may not even be the dominant way in which English speakers think about time.

### 40.2.2 Asymmetric Use of Space to Think about Time

Space and time are asymmetrically related in language: people use spatial expressions to talk about time more than vice versa. For instance, English speakers often talk about *short* careers or *extended* relationships, but using time to talk about space is much less common. Are nonlinguistic representations of space and time also asymmetrically related?

#### 40.2.2.1 Space–time Asymmetry in Adults

Adults use space to think about time, more so than vice versa, as shown by psycholinguistic studies (Boroditsky 2000, Bottini and Casasanto 2010) and nonlinguistic studies (Casasanto and Boroditsky 2008). In a series of nonlinguistic psychophysical experiments, people saw stimuli that varied in their spatial and temporal extents, and estimated either the spatial or temporal magnitude of each stimulus. For example, in some experiments participants saw lines of different lengths 'growing' across the screen for different durations. The durations and lengths of the lines were fully crossed, so their temporal and spatial properties were not correlated. On each trial, participants reproduced either the line's length or its duration. When people reproduced the durations of the lines, they were consistently influenced by task-irrelevant spatial information. The farther the line traveled across the screen, the longer people estimated its duration to be, even though on average all lines had the same duration. However, people's space estimates were not influenced by task-irrelevant temporal information: the time it took for a line to grow across the screen did not affect people's length estimates. This pattern of asymmetric interference persisted across experiments that changed the attentional, mnemonic, and perceptual demands of the task: space influences time more than vice versa, even when people are not using language (Casasanto and Boroditsky 2008, Bottini and Casasanto 2010, Gijssels et al. 2013).

In contrast to human adults, space and time appear to be symmetrically related in monkeys. In another psychophysical study, human subjects and rhesus macaques saw lines of different durations and lengths. Participants saw a line and then judged either its duration or its length. As predicted, human subjects showed the standard space–time asymmetry: when judging durations, people had more difficulty ignoring task-irrelevant spatial information than vice versa. Monkeys, however, showed a symmetrical pattern of interference: when judging durations, they were influenced by task-irrelevant variation in space, as much as vice versa (Merritt, Casasanto, and Brannon 2010). Do these results show that language is a prerequisite for having a space-time asymmetry? Not necessarily. Humans and monkeys differ in many more ways than just their linguistic abilities. Yet these results raise the possibility that the asymmetric mapping between spatial and temporal representations may be uniquely human (Merritt, Casasanto, and Brannon 2010).

A space–time asymmetry has now been shown in numerous behavioral studies that were designed expressly to test for it, and to control for factors that could give rise to this pattern spuriously (Boroditsky 2000, Casasanto and Boroditsky 2008, Bottini and Casasanto, 2010, Casasanto, Fotakopolou, and Boroditsky 2010, Bottini and Casasanto 2013, Gijssels et al. 2013, Magnani, Oliveri, and Frassinetti 2014, Open Science Collaboration 2015). In all of these studies, participants judged visually presented stimuli. One study, however, used haptic (i.e. tactile) stimuli, and reported a reversal of the usual space–time asymmetry (Cai and Connell 2015). In one version of the task, based loosely on Casasanto and Boroditsky's (2008), participants held sticks of varying lengths between their fingertips, while their hands were occluded from view. From the moment they touched the ends of the stick, the experimenter played a tone for a given duration, and participants were instructed to remove their fingers from the stick when the tone stopped. They then reproduced either the spatial length of the stick by holding their hands out and pushing them against a board, or reproduced the duration of the tone by holding down a button. Results showed that the duration of a tone influenced participants' estimates of how long the stick was, but not vice versa.

Although an exception to the usual space–time asymmetry could be of theoretical interest, there are several reasons to question the interpretability of these results. First, in Casasanto and Boroditsky's (2008) tasks, participants were asked to estimate the spatial and temporal dimensions of a single stimulus: temporal and spatial information were conveyed by the same percept of the same physical event (e.g. a line). In Cai and Connell's task, however, participants estimated the spatial and temporal dimensions of *different* stimuli (i.e. a stick, a tone), which are difficult, if not impossible, to equate perceptually. Second, in a valid test of a cross-domain asymmetry, the perceptible input should be matched across the domains (e.g. space, time) in every way possible; there should be no asymmetries built into the stimuli. This was not the case in Cai and Connell's design. In the task described above, spatial information was available via one sensory modality: touch. By contrast, temporal information was available via two sensory modalities: touch and sound. As such, when participants were encoding the stimuli into memory there were two sources of temporal interference (haptic, auditory), but only one source of spatial interference (haptic). Likewise, when reproducing the spatial length of a stick, participants were susceptible to temporal interference from the duration for which they held the stick; but there was no equivalent source of spatial interference when they were reproducing the duration of the tone, since tones have no spatial extent. These asymmetries built into the stimuli and responses could be responsible for the observed 'backward' time–space asymmetry. Thus, it remains an open question whether the space–time asymmetry found in experiments with visual stimuli extends to stimuli in other sensory modalities.

#### **40.2.2.2** Space–time Asymmetry in Children

By kindergarten, children already show an asymmetric space–time mapping in the mind. In one study, four- to ten-year-olds saw two snails travel across the screen for different distances and durations. Children either judged which snail traveled farther in space (while ignoring duration) or which snail traveled for a longer time (while ignoring distance). Like adults, children showed an asymmetric pattern of space–time interference: children were better at making spatial judgments in the presence of irrelevant temporal information than they were at making temporal judgments in the presence of irrelevant spatial information (Casasanto, Fotakopoulou, and Boroditsky 2010; see Bottini and Casasanto 2013 for similar results in Dutch and Brazilian children).

How are space and time related in children's minds before they acquire language? Prelinguistic children may already have some expectations that spatial and temporal magnitudes should correspond. In two looking time studies, infants differentiated between stimuli that were matched in size and duration and those that were not matched, suggesting that they expect bigger objects and longer durations to go together (Srinivasan and Carey 2010, de Hevia et al. 2014).

Is the space–time mapping in these young children already asymmetric? One study raised this question in infants, and the data were interpreted as suggesting that space and time are symmetrically related in their minds. Children were trained to associate a visual feature of the stimuli (e.g. black versus white color) with either greater or lesser magnitude, in one domain (e.g. space). After training, they transferred the association between color and magnitude to another domain (e.g. time). The strength of this transfer effect was similar no matter whether the infants were trained on space and tested on time, or vice versa (Lourenco and Longo 2010). These results show that babies can generalize magnitude mappings from one domain to another. Yet they do not provide a clear answer as to whether space and time are asymmetrically related in infants' minds for several reasons, the simplest of which is that the lack of a difference between conditions constitutes a null effect (see Bottini and Casasanto 2013 for further discussion).

In sum, studies in preschoolers show the same space–time asymmetry as has been found in adults. Studies in infants are less conclusive. They show that space and time are already related in the infant mind, but these data do not provide a clear answer as to whether this mapping is symmetric or asymmetric. It is possible that humans' earliest conceptions of space and time are symmetric, like monkeys', and only become asymmetric over the course of cognitive development (Merritt, Casasanto, and Brannon 2010). Srinivasan and Carey (2010) have suggested that using metaphors in language gives rise to the conceptual asymmetry. However, this possibility is difficult to reconcile with the language acquisition data. In general, children appear to use spatial words before they use their temporal equivalents. For instance, they use the preposition *in* spatially (e.g. *in a box*) more frequently than temporally (e.g. *in a minute*; H. Clark 1973). Young children also sometimes misinterpret temporal expressions as having spatial meanings. After seeing scenarios like a toy doll petting a dog, children were asked temporal questions about the events. When asked questions like '*When did the boy pat the dog?*,' some children responded by giving spatial answers, like '*over there*' (E. Clark 1971). Finally, children produce spatial uses of words like '*long*' and '*short*' earlier than temporal uses of the same words, even though temporal uses are more frequent in the adult input that children receive (Casasanto 2016a, 2016b). The most natural explanation for these patterns is that space is conceptually more fundamental than time from early childhood, and this conceptual space–time asymmetry guides language acquisition.

#### 40.2.2.3 Experimental Evidence for a Space–time Asymmetry: Summary and Implications

Together, data from children and adults indicates that the space–time asymmetry found in linguistic metaphors is also found in people's more basic, nonlinguistic mental representations: across many contexts, people use space to think about time, more than vice versa. This asymmetric relationship is consistent with metaphor theory, but conflicts with the predictions made by an influential neurocognitive model of spatial and temporal magnitude representation. According to A Theory of Magnitude (ATOM), space, time, and other prothetic domains (i.e. domains that can be experienced as 'more' or 'less' in magnitude) are represented in the mind by a common, analog magnitude metric (Walsh 2003). If this model is correct and space and time rely on the same representations, then there is no a priori reason to assume that these domains should affect each other asymmetrically (Casasanto, Fotakopoulou, and Boroditsky 2010). Yet the behavioral evidence reviewed here argues against this possibility: whereas monkeys show a symmetric space–time relationship that is consistent with ATOM, human children and adults do not. Rather, people mentally represent space and time asymmetrically, as predicted on the basis of their linguistic metaphors.

### 40.2.3 Cross-linguistic Differences in Linguistic Space–time Metaphors Predict Corresponding Differences in Mental Metaphors

The studies reviewed so far suggest that people think about time the way they talk about it in their native language. Yet not all languages use the same kinds of space–time metaphors. Do people who use different space–time metaphors in language use correspondingly different mental metaphors for time?

#### 40.2.3.1 Cross-linguistic Differences in Talking and Thinking about the Past and Future

Even when languages agree that temporal sequences unfold along a sagittal axis, they may differ in how they map the past and future onto the front and back ends of the sagittal continuum. In contrast to English and many other Western languages, Aymara talks about the past as being in front of the speaker and the future as being behind: *nayra mara* 'front year' means last year, whereas *qhipa marana* 'back year' means next year. This mapping conflicts with the universal experience of moving forward through space, but corresponds to another universal experience: people can *see* what is in front of them but not what is behind them. Metaphorically, we can see what has happened in the past, but not what is going to happen in the future. Accordingly, the Aymara word *nayra* is used to mean both *front* and *eye* (Núñez and Sweetser 2006b).

Do the Aymara think about the past as being in front? The results from one gesture study suggest they do. Aymara speakers were more likely to produce forward gestures when talking about the past, and more likely to produce backward gestures when talking about the future (Núñez and Sweetser 2006b; see also Núñez et al. 2012).

In addition to using the sagittal axis, some languages also use the vertical axis to talk about temporal sequences. Like English, Mandarin frequently maps temporal sequences onto a front–back axis, using words like *qián* 'front' and *hòu* 'back' to refer to future and past events. However, Mandarin also commonly uses vertical spatial terms to talk about temporal sequences: earlier and later events are referred to as *shàng* 'up' and *xià* 'down' (Scott 1989, Boroditsky 2001).

To test whether English and Mandarin speakers also think about temporal sequences differently, one study primed speakers of these languages with sagittal and vertical spatial scenarios, and then asked participants to judge temporal sentences (e.g. *August comes later than June*). After seeing a sagittal spatial scenario, English speakers responded faster to sentences describing temporal events, whereas Mandarin speakers responded faster to the same sentences after seeing a vertical spatial scenario (Boroditsky 2001; see also Boroditsky, Fuhrman, and McCormick 2011; but see Chen 2007, January and Kako 2007). Similarly, Mandarin speakers (but not English speakers) were faster to judge whether pictures depicted earlier or later events by pressing a top button for "earlier" responses and a bottom button for "later" responses, rather than the opposite mapping (Boroditsky, Fuhrman, and McCormick 2011; see also Miles et al. 2011).

#### 40.2.3.2 Cross-linguistic Differences in Talking and Thinking about Duration

Previous cross-linguistic experiments either required participants to use language overtly or allowed them to use it covertly in ways that could, in principle, give rise to the observed behavioral results. Do people who talk about time in different ways still think about time differently when they are not using language? One study addressed this question by comparing how Greek and English speakers think about duration. Like many other languages, English tends to describe duration in terms of one-dimensional spatial length (e.g. a *long* time, like a *long* rope; Alverson 1994, Evans 2004). This unidimensional mapping has been assumed to be universal: a consequence of the unidirectional flight of time's arrow, and of universal aspects of our bodily interactions with the environment (Clark 1973). In contrast with English speakers, however, Greek speakers tend to express duration in terms of three-dimensional volume or amount, such as *poli ora* 'a lot of time' and *poli nero* 'a lot of water.' Rather than 'a long night,' Greek speakers would say 'a big night' (*megali nychta*) to indicate that the night seemed to last a long time. Greek speakers can express duration in terms of linear extent, just as English speakers can make use of volume or amount expressions, but volume metaphors are more frequent and productive in Greek, whereas linear extent metaphors are more frequent and productive in English (Casasanto et al. 2004, Casasanto 2008b, 2010).

To test whether Greek and English speakers think about duration differently, speakers of these languages performed a pair of psychophysical duration estimation tasks, with two types of spatial interference. In the distance interference condition, participants saw lines of various durations and lengths travel across the screen. After each line had disappeared, participants reproduced its duration (as in Casasanto and Boroditsky 2008; see section 40.2.2.1). In the amount interference condition, participants saw animations of an empty container 'filling up' with liquid to different levels for different durations. After the container disappeared, participants estimated its duration.

The experimenters predicted that, if English and Greek speakers tend to think about duration the way they talk about it, using spatial schemas of different dimensionalities, then they should show different patterns of spatial interference in their time estimates: English speakers should show greater interference from irrelevant length information, whereas Greek speakers should show greater interference from irrelevant amount information. Importantly, in both tasks, the spatial extents or amounts were fully crossed with the temporal durations of the stimuli; that is, there was no correlation between the spatial and temporal aspects of the stimuli. This feature of the tasks is critical for supporting the inference that the predicted pattern is not due to participants verbally labeling the relevant dimension of the stimuli during the task: because the lengths and durations of the stimuli were uncorrelated, labeling long-duration lines as 'long' and short-duration lines as 'short' could only wipe out the predicted spatial interference effect, rather than creating or enhancing it.

Results showed that task-irrelevant distance information interfered with English speakers' duration estimates (more than Greek speakers'): the farther the line traveled across the screen, the longer English speakers estimated its duration to be. By contrast, task-irrelevant amount information interfered with Greek speakers' duration estimates (more than English speakers'): the fuller a container, the longer Greek speakers estimated its duration to be. Greek and English speakers, who use different spatial metaphors to talk about duration, think about duration in correspondingly different ways, even when they are performing low-level, nonlinguistic tasks (Casasanto et al. 2004).

## 40.3 When Temporal Language Shapes Temporal Thinking

If people who talk about time differently also think about it differently, using different spatial metaphors, does this mean that using space–time metaphors in language influences their mental metaphors for time? Not necessarily. In principle, nonlinguistic factors could cause members of different groups to conceptualize time differently – and therefore to talk about it differently. That is, cross-linguistic differences in verbal metaphors could be either a *cause* or an *effect* of cross-group differences in spatial conceptions of time.

All of the cross-linguistic data reviewed so far come from *quasi-experiments*: studies in which participants were already members of one group or another (e.g. English versus Greek speakers), prior to the experiment. Quasi-experiments (which, perhaps surprisingly, constitute the majority of the 'experiments' in the cognitive sciences) are capable of showing correlations – for example, correlations between the way people talk and the way they think – but they are not capable of establishing causal relationships. In order to determine whether linguistic metaphors can have a causal influence on people's mental metaphors, it is necessary to perform an experimental intervention in which participants from a single population are randomly assigned to different 'treatment' groups (i.e. a randomized-controlled trial [RCT] design).

Casasanto and colleagues (2008b, 2010) followed their cross-linguistic tests of distance-duration and amount-duration metaphors in language and thought with an RCT experiment. English speakers were assigned to talk about duration using either distance or amount metaphors. Participants completed a fill-in-the-blank questionnaire comparing the durations of events using either distance words (e.g. a meeting is *longer* than a sneeze) or amount words (e.g. a meeting is *more* than a sneeze), and then performed the nonlinguistic filling container task from Casasanto et al. (2004). If using space–time metaphors in language is sufficient to influence how people think about time, then training English speakers to talk about duration like Greek speakers should also make them think about duration like Greek speakers. As predicted, English speakers who were trained to talk about duration in terms of amount were affected by task-irrelevant variation in a container's fullness when estimating its duration, like native Greek speakers. After distance training, however, task-irrelevant amount information did not influence English speakers' duration estimates (Casasanto 2008b, 2010; see Boroditsky 2001 for compatible results in a psycholinguistic task).

Using space–time metaphors in language can influence which mental metaphors people use, causing them to activate spatial schemas of one dimensionality or another to conceptualize duration. These results raise the question: is language creating these space–time mappings, or is linguistic experience modifying pre-linguistic mental metaphors? Pre-linguistic infants appear to intuit links between duration and distance (Srinivasan and Carey 2010) and between duration and size (Lourenco and Longo 2010). Thus, both the one-dimensional mapping that is evident in English and the three-dimensional mapping that is evident in Greek may be present in infants' minds pre-linguistically. Using linguistic metaphors, then, appears to influence temporal thinking by strengthening one of these pre-linguistic space–time associations, and at the same time weakening the alternative association (though not extinguishing it). The presence (and persistence) of both mental metaphors in the same individuals may explain how people are able to switch between them

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rapidly, on the basis of brief but intense exposure to a dispreferred linguistic metaphor in the laboratory (Casasanto 2008b, 2014, Gijssels and Casasanto this volume Ch. 40, Casasanto and Bottini 2014).

Somewhat paradoxically, this training study, which was designed to test whether language influences the way people conceptualize time when they are *not* using language, yields insights into the way people process verbal space–time metaphors when they are using language. In principle, what appear to be verbal space–time metaphors could instead be instances of polysemy. For instance, people could be processing phrases like *long time* or *more time* as having a purely temporal meaning, without activating any spatial representations. Yet the results from the training study rule out this possibility. For English speakers to show the predicted interference effect from spatial amount on their duration estimates, the linguistic stimuli must have caused readers to activate representations of three-dimensional space when comparing event durations, demonstrating that the spatial language was being interpreted metaphorically (i.e. causing source-domain representations to be activated online, during language use).

## 40.4 Space-time Mappings in the Mind That are Absent from Language: Lateral Mental Timelines

No known spoken language talks about time as being organized laterally (left–right). English speakers can say that "July comes *before* August" but not "July comes *to the left* of August" (Cienki 1998). Yet people consistently represent temporal sequences on a lateral axis. When talking about the order of events, English speakers produce gestures that follow a mental timeline running from left to right: earlier events are more likely to be accompanied by leftwards gestures, whereas later events are accompanied by rightwards gestures (Cooperrider and Núñez 2009, Casasanto and Jasmin 2012). This lateral space–time mapping may even be stronger than the sagittal one: English speakers' spontaneous co-speech gestures mainly follow a left-to-right mapping, even when they are explicitly using sagittal (front–back) metaphors in language (e.g. gesturing left while saying 'even farther *back* [in the past]'; Casasanto and Jasmin 2012).

Even when people are not gesturing, they still represent the order of events along a left–right timeline. In several experiments, people were faster to judge the relative temporal order of stimuli if the left–right locations of the responses or stimuli was consistent with the direction of their mental timeline (Gevers, Reynvoet, and Fias 2003, Torralbo, Santiago, and Lupiáñez 2006, Santiago et al. 2007). In one experiment, English speakers decided whether famous people became celebrities before or after participants were born. People were faster to respond 'before' and 'after' when responses were mapped to the left and right than with the opposite mapping, as predicted on the direction of their mental timeline (Weger and Pratt 2008).

### 40.4.1 What Gives Rise to thIs Lateral Space–time Mapping?

Where does the lateral mapping of temporal sequences come from? Across cultures, the direction of people's mental timeline correlates with the direction in which they read and write. In one experiment, children and adults recreated the order of temporal events (e.g. meals of the day) by placing stickers relative to a reference sticker (e.g. lunch). English speakers, who write from left to right, preferentially placed breakfast to the left of lunch and dinner to the right. Arabic speakers, who write from right to left, showed the opposite pattern: they placed breakfast to the right of lunch and dinner to the left (Tversky, Kugelmass, and Winter 1991). Reaction time studies comparing English and Hebrew speakers (Fuhrman and Boroditsky 2010) and Spanish and Hebrew speakers (Ouellet et al. 2010) find similar results: people who read from left to right map later events to the right, whereas people who read from right to left map later events to the left.

Does writing direction play a causal role in shaping the mental timeline? The correlational evidence reviewed above do not support this inference. In principle, a writing system could emerge with one directionality or another as a consequence of culture-specific conceptions of time – not the other way around. Furthermore, groups who write from left to right also tend to spatialize time from left to right on calendars and graphs (Tversky, Kugelmass, and Winter 1991). This covariation leaves open a host of possible scenarios according to which orthography could either play a primary causal role, a mediating role, or no causal role at all in determining the direction of the mental timeline.

To find out whether reading experience is sufficient to determine the direction of the mental timeline, Casasanto and Bottini (2014) trained Dutch participants to read in different directions while they judged whether phrases referred to past or future events. For participants in the standard orthography condition, all instructions and stimuli appeared in the usual left-to-right Dutch orthography. However, for participants in the mirror-orthography condition, all instructions and stimuli were mirror-reversed, forcing them to read from right to left. Whereas people in the standard orthography condition responded faster when the locations of the response keys matched a left-to-right mental timeline, this effect reversed for the people in the mirror-reversed condition. After about five minutes of training, people who had read from right to left responded faster when 'earlier' was mapped to the right button and 'later' to the left button, compared to the opposite mapping. Further experiments showed that Dutch speakers could be trained to conceptualize events in time as flowing upward (after reading upward orthography) or downward (after reading downward orthography). A few minutes of training with a new orthography can redirect the mental timeline, demonstrating a causal role for reading experience.

Why does reading experience influence the organization of the mental timeline? For each line of text that people read or write, they move their attention gradually from the left to the right side of the page or the computer screen. Therefore, moving rightward in space is tightly correlated with 'moving' later in time, strengthening an association of earlier times with the left side of space and later times with the right (Casasanto and Bottini 2014). Although reading experience alone is sufficient to determine the direction of the mental timeline in the laboratory, beyond the lab it is likely that other culture-specific experiences (e.g. using calendars, lateral gestures for time) also contribute to the way people mentally spatialize sequences of events on the lateral axis.

### 40.4.2 Why is That Lateral Space–time Mapping Absent from Spoken Language?

There is now abundant evidence that people think about sequences of events as unfolding along a lateral axis – so why do they not talk about them using lateral space–time metaphors in language? One possible reason is that spatial metaphors in languages like English developed generations before the age of mass literacy, and of ubiquitous calendars and graphs. Time may not be 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).

If this proposal is correct, then cultures that strongly rely on printed text and on graphical left–right representations of time should start talking about time in lateral spatial terms. One anecdotal example comes from the US army, where the daily schedules for soldiers are shown on a chart with twenty-four columns: one column for each hour of the day, starting with 0000 on the left and ending with 2300 on the right. Each day, the timing of a team's shift (i.e. the period for which they are assigned to work) is indicated by a laterally oriented rectangle displayed on top of the chart (e.g. a six-hour shift is indicated by a rectangle covering six columns). If a shift gets moved, the rectangle is moved accordingly. One informant reports that when a shift is moved to an earlier slot, people often say they are being 'shifted left,' whereas when a shift gets moved to a later slot they are being 'shifted right' (Casasanto and Jasmin 2012). Now that many people within language communities share the same experience of reading and writing, and of lateral space–time mappings in graphic conventions, these lateral mappings could begin to infiltrate spoken language.

## 40.5 Space–time Mappings in the Mind That Contradict Mappings in Language: The Temporal Focus Hypothesis

The lateral mental timeline illustrates a mental metaphor that is not conventionalized in any known spoken language. A mental metaphor in speakers of Darija, a dialect of Modern Standard Arabic, departs even farther from expectations based on linguistic metaphors. In Arabic, as in many languages, the future is *ahead* and the past is *behind*. Yet a study by de la Fuente et al. (2014) suggests that some Arabic speakers' conceptualize the past as ahead and the future as behind them.

To probe Spanish and Moroccan Arabic speakers' conceptions of time, participants were shown a diagram of a cartoon figure, viewed from the top, with one box in front of him and another box behind him, and asked to indicate which box corresponded to the future and which to the past. Even though both Arabic and Spanish speakers talk about the future as being in front, the groups showed opposite mappings in the diagram task: Spanish speakers tended to put the future event in front and the past event behind, whereas Moroccan Arabic speakers put the past event in front and the future event behind (de la Fuente et al. 2014).

Why do Moroccan Arabs think about the past as in front and the future behind them? There is no plausible explanation based on metaphors in the Arabic language, which encodes the opposite space–time mapping. There is also no explanation based on the universal experience of moving forward through space and time as we walk (or ride, drive, etc.; H. Clark 1973). In the absence of any explanation based on language or bodily experience, de la Fuente et al. turned to aspects of Moroccan culture. Compared to many Europeans and Americans, Moroccans tend to focus more on past times and older generations, they are more observant of ancient rituals, and they place more value on tradition, rather than focusing on future-related concerns like technological development and globalization (Mateo 2010). De la Fuente et al. hypothesized that this cross-cultural difference in attitudes toward the past and future was responsible for the observed differences in spatial mappings of time. According to the Temporal Focus Hypothesis, people who 'focus' on the past metaphorically (i.e. who devote attention to it) should tend to place the past in front of them, in the location where they could focus on the past literally with their eyes if past events were physical objects that could be seen; by contrast, people who 'focus' on the future metaphorically should place the future in front of their eyes.

De la Fuente et al. (2014) confirmed that Morrocans and Spaniards tended to focus more on the past and future, respectively, as indicated by their agreement with past-focused statements (e.g. *The young people must preserve the traditions*) versus future-focused statements (e.g. *Technological and economic advances are good for society*) on a questionnaire. Individuals' degree of past- or future-focus, as indexed by their responses on this questionnaire, predicted whether they would place the past or future in front of them in the cartoon diagram task. To determine whether temporal focus plays a causal role in people's front–back mappings of time, de la Fuente et al. (2014) experimentally manipulated whether participants were focusing their attention on the past or future, using a writing exercise. People who were assigned to write about past events were subsequently more likely to place the past in front on the cartoon diagram task, whereas people who wrote about future events were more likely to place the future in front.

These results show that cultural attitudes toward the past and future can determine how people spatialize time in their minds, and that mental metaphors for time can vary independently of linguistic metaphors.

## 40.6 Are There People Who Do Not Have Any Space–time Mappings in Language or Thought?

In contrast to most other languages that have been attested, Amondawa does not use spatial metaphors to talk about temporal sequences. Even though this Western Amazonian language has a range of temporal expressions to refer to the past and future, to parts of the day, and to seasonal cycles, these expressions do not show any overlap with how Amondawa talks about space (Sinha et al. 2011).

Does the absence of linguistic metaphors for temporal sequences mean that the Amondawa do not use space to conceptualize time? Not necessarily. Traditionally, the Amondawa people have not been exposed to cultural artifacts that influence space–time mappings in other populations, like calendars or a writing system. Yet, when asked to visually represent temporal sequences, they still produced a timeline, which was roughly lateral. In two separate tasks, Amondawa speakers were asked to arrange a set of plates on the ground to represent the different parts of the year and the day. For both tasks, participants arranged the plates on a slightly curved line that either ran from left-to-right or right-to-left (Sinha et al. 2011). Therefore, even though the Amondawa do not have any linguistic or cultural conventions for spatializing temporal sequences, they still appear to use space systematically to think about time – at least when prompted to create a spatial diagram.

Turning from spatial mappings of temporal succession to mappings of duration, there is preliminary evidence that not all kinds of space–time metaphor are absent from the Amondawa language. In one elicitation task, members of the Amondawa tribe who were bilingual in Amondawa and Portuguese translated Portuguese phrases into Amondawa. The original Portuguese stimuli consisted of spatial phrases describing the length or size of objects (e.g. *uma corda comprida* 'a long rope'), and temporal phrases describing the duration of events (e.g. *uma cantiga comprida* 'a long song'). In their translations, these informants used the same Amondawa words to refer to both spatial length and duration. For instance, the word *-puku* 'long' was used to talk about a long rope as well as to talk about a long conversation (Bottini 2011). Although these data suggest that the Amondawa may use space–time metaphors to talk about duration, these findings should be treated as preliminary. As Bottini (2011) points out, the original Portuguese phrases contained space–time metaphors, which may have biased participants to use Amondawa words for spatial extent to talk about duration. Still, it is notable that when Amondawa informants were asked whether they could use literal translations of Portuguese spatial/ motion metaphors for temporal sequences (e.g. the *coming* year) in Amondawa, the informants rejected this possibility (Sinha et al. 2011).

In sum, although the Amondawa appear not to use space–time metaphors to talk about temporal sequences, they produce roughly linear diagrams upon request, suggesting that they may conceptualize temporal sequences spatially. It remains an open question whether the Amondawa systematically talk and think about duration in terms of spatial length.

## 40.7 Separating Influences of Language and Culture on Temporal Cognition

Researchers sometime question whether 'language' and 'culture' can ever truly be separated; indeed, language is one highly systematic aspect of human culture. Is it possible to know whether language or nonlinguistic cultural factors are influencing people's thoughts? Although language and culture may appear inextricable in the world, the previous sections illustrate how these different strands of human experience can be disentangled in the laboratory, for the purpose of identifying the experiential determinants of our thoughts.

One strategy for disentangling language and culture is to elicit behavior that is only consistent with one strand of experience, and not with the other. For instance, de la Fuente et al. (2014) showed that Moroccan participants' spatial conceptions of past and future were incompatible with conventional space–time metaphors in their language. Similarly, numerous studies have shown that people conceptualize time according to a left–right mental timeline that is absent from language. Linguistic experience, therefore, is not a potential basis for these conceptions to time, but cultural attitudes and practices provide potential explanations.

In order to determine whether such potential explanations are sufficient to account for a pattern of behavior, a second strategy is needed: performing true experimental interventions, in which participants are drawn from a single population and randomly assigned to 'treatment' conditions. For instance, Casasanto and Bottini (2014) manipulated reading direction to show that this cultural practice is sufficient to shape the direction of people's lateral mental timeline, even if their language remains unchanged. Conversely, Boroditsky (2001) and Casasanto et al. (2004) exposed people to new verbal metaphors to show that linguistic experience can shape conceptions of time, while ruling out any nonlinguistic, cultural explanations. Note that this kind of novel metaphor treatment is different from randomly assigning bilinguals to use one of their languages or another; switching languages may also cause bilinguals to switch *mindsets*. Real, known languages are embedded in cultures, and using them may cause bilinguals to activate culture-specific ways of thinking, even if they have been randomly assigned to use one language or the other. By assigning people from the same population to novel linguistic or cultural treatments, however, it is possible to isolate the influence of factor of interest, and to rule out the contribution of other confounding factors.

## **40.8** Conclusions

Space and time are closely related in both language and thought. Yet the space–time relationships found in linguistic metaphors are not always the same as those found in people's nonlinguistic mental metaphors. The spatial metaphors people use to talk about time can reveal how they use space to think about time. In some cases, spatiotemporal language not only reflects the structure of people's thoughts, but also actively shapes nonlinguistic mental representations of time, causing people to conceptualize temporal sequences using spatial schemas with different orientations (horizontal versus vertical), and to conceptualize duration using spatial schemas of different dimensionalities (one-dimensional versus three-dimensional).

Yet language is not the only force that shapes mental metaphors. Cultural practices and artifacts can influence whether people conceptualize events as unfolding along left-to-right or right-to-left mental timelines, neither of which is conventionalized in any known spoken language. Cultural attitudes can influence whether people conceptualize the future as in front of them or as behind them, even though the latter mental metaphor may directly contradict the sagittal mapping of time encoded in a speaker's language.

The emerging body of experimental research on nonlinguistic space–time mappings has taken inspiration from the larger body of descriptive research on space–time metaphors within and across languages. Cognitive linguistics, in particular, has highlighted the centrality of space in language about time, and by inference in temporal thinking. Importantly, however, only some experiments confirm predictions based on linguistic analyses. Other experiments reveal space–time mappings in people's minds that are absent from language, or at odds with their linguistic metaphors. This is good news. It suggests these experiments are serving their most important scientific function, which is not to confirm what we already believed, but rather to challenge those beliefs and generate new insights.

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