Reversing the Direction of Time: Does the Visibility of Spatial Representations of Time Shape Temporal Focus?

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While people around the world mentally represent time in terms of space, there is substantial cross-cultural variability regarding which temporal constructs are mapped onto which parts in space. Do particular spatial layouts of time – as expressed through metaphors in language – shape temporal focus? We trained native English speakers to use spatiotemporal metaphors in a way such that the flow of time is reversed, representing the future behind the body (out of visible space) and the past ahead of the body (within visible space). In a task measuring perceived relevance of past events, people considered past events and present (or immediate past) events to be more relevant after using the reversed metaphors compared to a control group that used canonical metaphors spatializing the past behind and the future ahead of the body (Experiment 1). In a control measure in which temporal information was removed, this effect disappeared (Experiment 2). Taken together, these findings suggest that the degree to which people focus on the past may be shaped by the visibility of the past in spatiotemporal metaphors used in language.

Keywords: metaphor, space-time mappings, temporal focus, language and thought

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By far the greatest impediment and aberration of the human understanding arises from [the fact that]...those things which strike the sense outweigh things which, although they may be more important, do not strike it directly. Hence, contemplation usually ceases with seeing, so much so that little or no attention is paid to things invisible.

– Sir Francis Bacon (1620)

1. Introduction

How do we mentally represent abstract concepts like time, if we can neither see, hear, touch, taste, nor smell it? And how does the way we talk about time relate to the way we think about time? One influential proposal claims that we construct abstract domains through analogical extensions from more concrete, more experience-based domains (e.g., Clark, 1973; Lakoff & Johnson, 1980; 1999). In this view, people talk and think about the abstract domain of time in terms of the more concrete domain of space.

Empirical evidence supports this idea. To represent time people around the world rely on space. People talk about time using spatial language (Clark, 1973; Haspelmath, 1997; but see Sinha, Sinha, Zinken, & Sampaio, 2011). In English, for example, the weekend can be ahead of us and we can enjoy a long conversation. People also think about time using spatial representations. When judging temporal order or duration, people appear to be unable to ignore irrelevant spatial information (Boroditsky, 2000; Núñez, Motz, & Teuscher, 2006; Ramscar & Boroditsky, 2005). For example, estimating the duration of a growing line, people systematically overestimated the duration for lines that are longer in space compared to lines that are shorter in space, even if all the lines had the same average duration (Casasanto & Boroditsky, 2008). Moreover, people appear to implicitly generate spatial representations when thinking about time (Fuhrman & Boroditsky, 2010; Gevers, Reynvoet, & Fias, 2003; Ishihira, Keller, Rossetti, & Prinz, 2008; Miles, Nind, & Macrae, 2010; Santiago, Lupáñez, Pérez, & Funes, 2007; Weger & Pratt, 2008). When thinking about past or future episodes, for example, people correspondingly sway slightly backwards or forwards (Miles et al., 2010). Finally, the spatial nature of temporal cognition also manifests itself in gestures accompanying temporal speech. English speakers, for example, may move a hand backward over their shoulder to refer to the past, point downward to refer to the present, and point forward to refer to the future (Cooperrider & Núñez, 2009; McNeill, 2005). Findings like these suggest that people not only talk but also think about the abstract domain of time in terms of the more concrete domain of space.

While people around the world rely on space to mentally represent time, the way time is laid out in space varies substantially across languages and cultures. In English and many other languages, the past is commonly spatialized behind and the future ahead of the body (Haspelmath, 1997). This future-ahead/past-behind mapping was assumed to be universal for a long time (e.g., Lakoff & Johnson, 1980) but evidence from Aymara – a language spoken in the Andes, South America – changed this assumption. For the Aymara, the reversed pattern is the default. The Aymara talk about the future as being behind them and the past as ahead, and gesture accordingly (Núñez & Sweetser, 2006). In Mandarin Chinese, front/back spatial metaphors of time are also used, but in addition, speakers frequently use vertical metaphors to talk about time (Scott, 1989). In all these languages – English, Aymara, and Mandarin Chinese – people represent time in space with respect to their bodies. An Australian aboriginal community speaking Kuuk Thaayorre, however, arranges time according to cardinal directions – from East to West. That is, the direction in which time flows is not fixed with respect to the body but depends on the direction one is facing (e.g., time flows from left to right when facing south but from right to left when facing north; Boroditsky & Gaby, 2010).

What are the sources of such cross-cultural variations in the spatial layout of time? Different factors have been shown to shape how time is laid out in space, such as patterns in spatiotemporal metaphors (Boroditsky, 2000; 2001; Boroditsky & Fuhrman, 2010; Casasanto & Boroditsky, 2004; McGlone & Harding, 1998), writing direction (Fuhrman & Boroditsky, 2010; Ouellet, Santiago, & Israeli, 2010a; Tversky & Kugelmass, 1991) and the cognitive availability of spatial representations (Boroditsky, 2000; Boroditsky & Gaby, 2010; Boroditsky & Ramscar, 2002; Ramscar & Boroditsky, 2005). For example, in Aymara but not in English people talk about the past as being in front of the body, and these patterns in metaphor influence how their speakers spatialize time in gesture (Núñez & Sweetser, 2006). Further, people who read and write from right to left – as in Hebrew or Arabic – are more likely to arrange time from right to left than people who read and write from left to right – as, for example, in English (Fuhrman & Boroditsky, 2010). Finally, people who habitually navigate through space using cardinal directions – like the Kuuk Thaayorre – are likely to co-opt these absolute

spatial representations for time, because they are the most cognitively available (Boroditsky & Gaby, 2010).

So far, there have been many studies reporting cross-cultural differences in the way people represent time in space – be it from left to right, right to left, horizontally or vertically, from east to west, front to back, back to front, etc. Does the way people spatialize time have implications for temporal cognition? In the present study we explore whether different ways of representing time in space, as expressed through metaphors in language, have differential consequences for the temporal focus of their speakers. Does the way people spatially represent time influence the degree to which they pay attention to the past, present, and future? Specifically, if the past is spatially represented within your visible space – in front, as in Aymara, or above, as in Chinese – do you pay more attention to past information than if the past is spatially represented outside your visible space – e.g., behind you, as in English?

Why should the visibility1 of the spatial representations of time used in language affect your temporal focus? If the past is represented in your visible space, you seem to be confronted with it constantly. While you cannot help but see the things in front of you, things that are behind you are easy to ignore. Neuropsychological evidence from hemineglect patients suggests that front and back space are not only intuitively distinct, they also correspond to separate neural representations in the human brain (Viaud-Delmon, Brugger, & Landis, 2007).

Further, it has been argued that the KNOWLEDGE is VISION metaphor (Lakoff, 1993; Lakoff & Johnson, 1980) may underlie the rare pattern of the past-ahead/future-behind mapping of the Aymara. According to Miracle & Yapita (1981), Aymara speakers may map a known period of time onto the space in front of the body, because it is a visually accessible physical area. In Aymara, nayra pacha, "eye/front/sight time" is commonly used to refer to the past and qhipa pacha, "back/behind time" to refer to the future (Núñez & Sweetser, 2006). The past is known, and the space in front of the speaker is visible; the future is unknown and the space behind the speaker is not visible.

Neuropsychological evidence from hemispatial neglect patients supports the idea that visibility of spatial representations of time can affect temporal processing. Hemispatial neglect patients typically have right inferior parietal lesions preventing them from attending to anything in their contralesional visual field (e.g., Heilman & Valenstein, 1979; Bisiach & Luzatti, 2000). In a study by Saj, Vuillemier, Fuhrman, & Boroditsky (submitted), French speaking neglect patients performed a memory task in which they learned about different events that were described either as having taken place in the past or as going to take place in the future. In a subsequent recall phase, neglect patients showed impaired memory for past events compared to future events. In a healthy control group, however, people equally remembered past and future events. Since past information is spatially represented on the left of the mental time line in French speakers (following the reading and writing directionality; cf. Fuhrman & Boroditsky, 2010), these results suggest that neglect patients not only neglect the left side of their visual space but also the left side of time. This finding supports the idea that the visibility of spatial representations of the past – within versus out of the visible space – can affect processing of past information.

Cross-cultural studies have shown considerable differences in temporal focus. Comparing people from collectivistic versus individualistic cultures has revealed differences in causal attribution and in the perception and representation of past information. East Asians, for example, seem to encode deeper causal chains; that is, they are more aware of the indirect, distal consequences of events compared to North Americans (Maddux & Yuki, 2006). These results reflect cross-cultural differences in temporal focus, since being aware of temporally more distal consequences requires a comparatively strong focus on the future. Further, compared to Canadians, Chinese have been shown to consider past information as more relevant, to recall greater detail about past events and to perceive past events as being closer to the present (Ji, Guo, Zhang, & Messervey, 2009). What mechanisms may underlie such cross-cultural differences in temporal focus? It could be that it is merely a cultural difference independent of the languages spoken. For example, it has been speculated that these findings might be based on different philosophical heritage: Confucian versus Aristotelian (Ji et al., 2009). Part of the explanation, however, could be that spatiotemporal metaphors used in language may shape the temporal focus of their speakers. In contrast with English speakers who tend to represent the past out of the visible space, that is, behind – Mandarin Chinese speakers also commonly spatialize the past (or anteriority) within a more visible space, that is, above (e.g., Fuhrman & Boroditsky, 2010). These patterns in spatiotemporal metaphors used in language may

make a temporal construct – such as the past – more visible and thus more likely to form the temporal locus of mental activity.

Based on the studies reviewed above, we hypothesize that the way people spatially represent time, as expressed through metaphors in language, may influence the degree to which they pay attention to the past, present and future. Specifically, we expect people to pay more attention to the temporal construct they spatially represent within their visible, attentionally more accessible space than to the temporal construct spatially represented out of their visible, less attentionally accessible space.

This paper describes two experiments exploring effects of visibility of spatial representations of time on temporal focus. To test our hypothesis, we trained native English speakers to use spatiotemporal metaphors in a way such that the flow of time is reversed, with the future being behind, out of visible space, and the past being ahead, within visible space. Participants were trained by filling in blanks in sentences, such as in In August, September is behind us. In the control condition, people did the same linguistic training but using the canonical spatiotemporal metaphors, with the future being ahead and the past being behind, such as in In August, September is ahead of us. After the linguistic training, the two groups were compared on a temporal focus measure. We reasoned that if the visibility of spatial representations of time influences temporal focus, people who did the non-canonical training that spatializes the past within the visible space should pay more attention to past (but not more to present) events compared to people who did the canonical training that spatializes the past out of the visible space. In contrast, if the visibility of spatial representations of time does not influence temporal focus, then results from the temporal focus measure should not differ across training conditions.

2. Experiment 1: Perceived Relevance of Past Events

In Experiment 1, participants were trained by completing fill-in-the-blank sentences. Their task was to make temporal order judgments and to type in the correct form such as in On Monday, Tuesday is _____ (ahead of/behind) us. Which of the two forms was the correct one differed depending on the condition they were randomly assigned to. In the canonical condition, people filled in the forms using spatial metaphors of time that were familiar to them being native English speakers, spatializing the future in front of the body and the past behind the body (e.g., On Monday, Tuesday is ahead of us.). After this linguistic training, all participants performed a second task measuring perceived relevance of past events. They read a description of a theft scenario. Then, they were asked to imagine being the detective solving the theft case and to judge various clues in terms of their relevance for solving the theft case. The clues were based on suspects' behaviors that either occurred in the remote past, in the recent past, or on the same day.

2.1 Methods

2.1.1 Participants

One hundred ninety-two native English speakers (*M* (age) = 36.36, *SD* (age) = 12.63) were recruited online from Amazon's Mechanical Turk and randomly assigned to different training conditions. On Mechanical Turk, we restricted participation to "Turkers" in the United States with a 95% or better performance record to ensure high quality participants in our sample. We prevented "Turkers" from participating repeatedly in our study by having Mechanical Turk track their IP addresses. In addition, participants were excluded from the data analysis if they did not pass a screening (see Appendix), which tested whether people read instructions carefully. Each participant was paid $7 and the study took approximately 30 minutes to complete.

2.1.2 Materials

Training. For the linguistic training, 90 fill-in-the-blank sentences were constructed (see Appendix). Each sentence described two points in time and their temporal relation, such as in On Monday, Tuesday is _____ (ahead of/behind) us. Crucially, the spatiotemporal metaphors establishing the temporal relation of the two points in time were left blank. The types of temporal sequence descriptions varied in time scale (e.g., days, months, decades) and content (e.g., meals, weekdays, historical events, life events). Moreover, each sentence always occurred in two versions. For example, if there was a sentence On Monday, Tuesday is _____ (ahead of/behind) us., the reversed version On Tuesday, Monday is _____ (ahead of/behind) us. was always part of the training as well.

Spatial metaphors of time vary, not only across languages, but also within languages. To see how general possible effects may be across different

types of talking about time in terms of space in English, we varied some of these types across three different linguistic frames (see Table 1). All three linguistic frames used different subtypes of the Time Orientation Metaphor, which spatializes the future in front of the ego and the past behind the ego (Lakoff & Johnson, 1999). Frame 1 and frame 2 were based on a dynamic, moving-ego spatial metaphor of time. In the moving-ego metaphor, the observer is conceptualized as moving over a landscape from stationary temporal events in the past to stationary temporal events in the future (e.g., Christmas is ahead of us.). This moving-ego metaphor can be distinguished from the moving-time metaphor, in which temporal events are seen as moving with respect to the stationary observer (e.g., Christmas is approaching.). In contrast with the moving-ego metaphor used in frame 1 and frame 2, a static spatial metaphor of time was used in frame 3. While spatial words like 'ahead' (frame 1) or 'forward' (frame 2) imply motion, 'front' (frame 3) does not (e.g., The computer screen can be in 'front' of you but not 'ahead' of you, if you are not moving forward along a path). Also, while frame 1 and frame 2 were familiar ways of talking about time for native English speakers (Clark, 1973), frame 3 was not. Frame 3 was loosely translated from Aymara, in which 'front time' (nayra pacha, "eye/front/sight time") is commonly used to refer to the past and 'back time' (qhipa pacha, "back/behind time") to refer to the future (Núñez & Sweetser, 2006). What distinguished frame 3 from frame 1 and 2 – in addition to the non-familiarity for native English speakers and the use of a static spatial model of time – is that there was no information provided for whom or what time Y was front or back time. Finally, frame 1 and frame 2 differed in terms of their spatiotemporal ambiguity of the verb - adverb constructions. While the combination of 'to be + ahead of/behind' (frame 1) can have spatial and temporal meaning, the combination of 'to think + forward/back' can only have temporal meaning, or it is at least more removed from the spatial meaning.

If we found differences in temporal focus according to the visibility of time in space as used in metaphors during the linguistic training, how general would they be across different types of talking about time in terms of space in English? Would it be only the orientation of the spatiotemporal metaphor that shaped temporal focus? Or would it matter whether the frame was familiar, one in which the ego was moving (frame 1 and 2) or non-familiar, in which the ego was stationary and non-referenced (frame 3)? And would it make a difference whether the verb-adverb construction was spatiotemporally ambiguous (frame 1) or unambiguously temporal (frame 2)?

Measure. We measured perceived relevance of past events using the task from Ji et al.'s (2009) study 1. This task consisted of a short description of a theft scenario, 66 behavioral information items, and an 8-point relevance scale ranging from not relevant at all to extremely relevant for each item (see Appendix).

There was a total of 66 behavioral information items. These 66 items were grouped into 22 sets of three items based on the type of behavioral information (e.g., if they had to do with money). Within each set, the three items were randomly associated with one of three time frames: (1) remote past (a long time ago), (2) recent past (relatively recent compared to the remote past), and (3) present/immediate past (on the day of the theft or concurrent).

Two different random associations of items with time frames were used (see Appendix). Most items (46 out of 66) that were associated with one time frame in one randomization (e.g., Last year, one student smoked.) were associated with one of the other time frames in the other randomization (e.g., Two weeks ago, one student smoked. or This morning, one student smoked.). Participants were randomly assigned to one of the two randomizations. The study was implemented in Qualtrics, a web-based survey software (Qualtrics Labs Inc., Provo, UT).

2.1.3 Design

The experiment used a 2 (Canonicality: whether participants used canonical or non-canonical

Table 1. Linguistic Frames.

Linguistic frame	Example	Response options
1. At time X, time Y is _____ us.	On Monday, Tuesday is _____ us.	ahead of or behind
2. At time X, I think _____ to time Y.	On Monday, I think _____ to Tuesday.	forward or back
3. At time X, time Y is _____ time.	On Monday, Tuesday is _____ time.	front or back

metaphors during linguistic training) x 3 (Linguistic frame: frame 1, frame 2, frame 3) x 3 (Time: present events, recent past events, remote past events) mixed design, with Canonicality and Linguistic frame as between-participant variables and Time as a within-participant variable. This design allowed for the presentation of each item only once to each participant and responses to different time frames could be compared within participants. The independent variables were Canonicality, Linguistic frame, and Time. The dependent variable was Mean Relevance Ratings of the behavioral information items. Participants were randomly assigned to one of the six training conditions, such that any given participant was trained using either canonical or non-canonical metaphors in one out of the three linguistic frames before rating the relevance of the behavioral information items.

2.1.4 Procedure

Participants were told they would participate in two independent studies, a "Verbal Abilities Test" and a "Detective Skills Test". In reality, the "Verbal Abilities Test" formed the training phase and the "Detective Skills Test" formed the measure phase. Before starting with the "Verbal Abilities Test" all participants answered a small screening question (see Appendix) checking whether they would read our instructions carefully enough.

Training. During the training phase, participants completed 90 fill-in-the-blank sentences. Their task was to make temporal order judgments and to type in the correct form such as in On Monday, Tuesday is _____ (ahead of/behind) us. Which of the two forms was the correct one differed depending on the condition they were randomly assigned to. In the canonical condition, people filled in the forms using spatial metaphors of time familiar to them as native English speakers, spatializing the future in front of the body and the past behind the body (e.g., On Monday, Tuesday is ahead of us.). In the non-canonical condition, people filled in the forms using spatial metaphors of time as if the direction of time was reversed, spatializing the future behind the body and the past ahead of the body (e.g., On Monday, Tuesday is behind us.). The correct spatial metaphor of time (future-ahead/past-behind versus future-behind/past-ahead), was not explained explicitly to the participants but had to be inferred from three correctly completed sample sentences. That is, the instructions and the stimuli were the same across conditions; only the required responses differed. Sentences were presented individually and the order of presentation was randomized for each participant. Participants could only proceed to the next sentence after giving the correct response according to the condition they were in. In case of incorrect responses, participants received feedback informing them they had made a mistake and asking them to reconsider their response.

Measure. After the training, all participants performed a second task, the "Detective Skills Test", measuring perceived relevance of past events (Ji et al., 2009, Study 1). They read a description of a theft scenario and were then asked to imagine being the detective solving this theft case and to judge the 66 behavioral information items in terms of their relevance for solving the theft case (see Materials).

We reasoned that if the visibility of spatial representations of time – as people used them during the training – indeed shapes their temporal focus, they should judge past behaviors to be more relevant for solving the case after non-canonical training (spatializing the past in front of the body, making the past "visible") than after canonical training (spatializing the past out of the visible space, leaving the past "invisible").

Further, we reasoned that if the present is spatially represented at the location of the observer (e.g., Lakoff & Johnson, 1999), that is, neither in front of nor behind the observer, reversing the direction of time in metaphor should not affect the visibility of spatial representations of the present. Accordingly, the linguistic training should not affect judgments of present events.

Finally, if temporally more distant events – such as remote past events – are conceptualized as spatially more distant objects and temporally more proximal events – such as recent past events – as spatially more proximal objects (e.g., Lakoff & Johnson, 1999), one may expect differences in relevance judgments of these events depending on their visibility. One possibility is that distant objects are more visible than proximal objects (e.g., if the proximal ones are too close, right in front of the eyes) and therefore the visibility manipulation in metaphor may affect judgments of remote past events more than judgments of recent past events. Another possibility is that representing recent past events in more proximal space may occlude, may reduce the visibility of spatial representations of remote past events. Accordingly, one may expect that the visibility manipulation in metaphor may affect the judgments of recent past events more than the judgments of remote past events.

2.2 Results

Figure 1 gives an overview of the results of Experiment 1. We submitted the mean relevance ratings to a by-items 2 x 3 x 3 repeated measures ANOVA, with Canonicality (canonical training, non-canonical training), Linguistic frame (frame 1, frame 2, frame 3) as within-item variables and Time (present, recent past, remote past) as a between-item variable. We also conducted a by-participant 2 x 3 x 3 mixed ANOVA, with Canonicality and Linguistic frame as between-participant factors and Time as a within-participant factor.

2.2.1 Results: overview

As predicted, participants considered past information to be more relevant for solving the theft case after non-canonical training than after canonical training. The main effect of Canonicality was significant in the by-items analysis ($F(1,120) = 118.923$, $p < .001$, $\eta^2 = .5$) and marginally significant in the by-participant analysis ($F(1,186) = 3.66$, $p = .06$, $\eta^2 = .02$). Overall, participants considered present information as more relevant than recent past information, and recent past information as more relevant than remote past information, as confirmed by a significant main effect of time ($F(2 \text{ or } 2,120) = 74.08$, $p <= .001$, $\eta^2 = .55$ by items; $F(2,372) = 349.51$, $p < .001$, $\eta^2 = .65$ by participants). There was no significant interaction between Canonicality and Time ($F(2,120) = .76$, $p = .47$, $\eta^2 = .013$ by items; $F(2,372) = .325$ $p = .73$, $\eta^2 = .002$ by participants), that is, the canonicality effect did not significantly differ across time frames.

2.2.2 Results: Linguistic frames

Figure 2 shows the canonicality effect plotted by Time and Linguistic frame. There was no significant interaction between Canonicality, Time and Linguistic frame ($F(4,240) = .41$, $p = .80$, $\eta^2 = .01$ by items; $F(4,372) = .20$, $p = .94$, $\eta^2 = .002$ by participants), that is, participants considered information as more relevant after non-canonical training than after canonical training, independent of time and also independent of the linguistic frame they used during the training.

2.2.3 Results: Effects of relevance

Some behavioral information items were considered to be more relevant for solving the case than others. To assess whether the canonicality effect co-varied with the relevance attributed to the items, we split the items into four groups at the quartiles of their mean relevance ratings (see Figure 3). We then conducted a by-items 2 (Canonicality) x 3 (Linguistic Frame) x 3 (Time) repeated measures ANOVA with Relevance (not relevant, slightly relevant, moderately relevant, highly relevant) added as a between-items

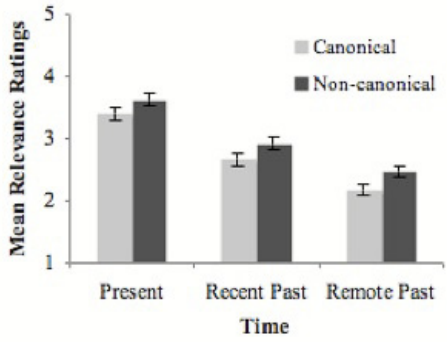

Fig. 1 Mean ratings of relevance given by participants after canonical versus non-canonical training in Experiment 1 ($N = 192$). The error bars represent between-participants standard error.

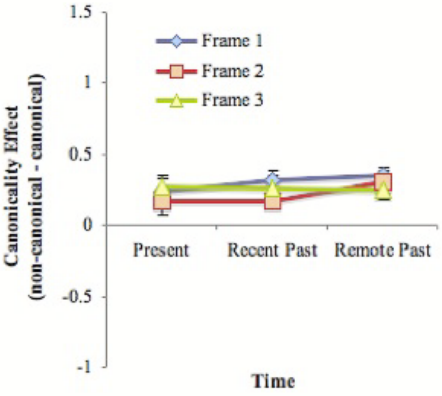

Fig. 2 Canonicality effect (non-canonical – canonical relevance ratings) in Experiment 1 ($N = 192$) plotted by Time and Linguistic frame. The error bars represent between-participants standard error.

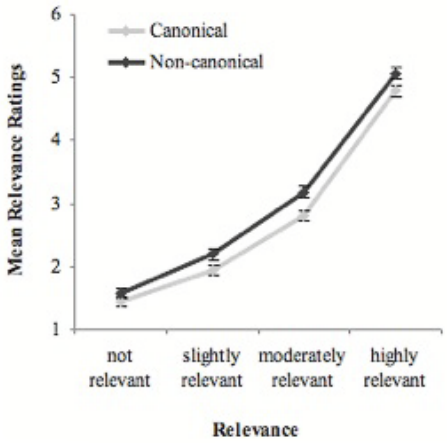

Fig. 3 Mean ratings of relevance plotted by Canonicality and Relevance (quartile-split) in Experiment 1 ($N = 192$).

variable. There was a significant interaction between Canonicality and Relevance ($F(3,120) = 4.44$, $p < .01$, $\eta^2 = .10$). That is, the canonicality effect increased with relevance from 'not relevant' over 'slightly relevant' to 'moderately relevant' items but then decreased again for 'highly relevant' items (see Figure 3). This pattern indicates that participants' relevance judgments were particularly susceptible to our manipulation between the extreme ends of the scale, a phenomenon also referred to as scale-attenuation (or floor- and ceiling) effects (Kantowitz, Roediger & Elmes, 2009, p. 268). One explanation for this pattern may be that some items were so obviously irrelevant or so obviously relevant for solving the case that their relevance judgments could not be modulated by our manipulation, or that our measurement scale was too restricted to measure any differences that may have existed between the conditions.

2.3 Discussion

The results of Experiment 1 show that people considered past information to be more relevant after non-canonical training than after canonical training, independent of the linguistic frame used during the training. However, the absence of a Canonicality x Time interaction effect indicates that people generally considered clues as more relevant after non-canonical training than after canonical training, independent of the time frame as well. If the canonicality effect indeed reflects a shift in temporal focus toward the past, why would people also consider present information to be more relevant after non-canonical training than after canonical training?

One explanation could be based on differences in task difficulty. The non-canonical training was cognitively more demanding than the canonical training, because the required responses were counterintuitive (using past-ahead/future-behind metaphors). The difference in task difficulty may have been accompanied by a difference in factors like arousal or fatigue, potentially introducing a bias driving the main canonicality effect.

Alternatively, the canonicality effect may indeed reflect a shift in temporal focus as predicted by the visibility of the past in the spatiotemporal metaphors used during prior linguistic training. Supporting this view, one could argue that people in the non-canonical condition also considered present information to be more relevant than people in the canonical condition because the majority of the present information items actually referred to the past as well. In fact, 13 out of 22 present information items contained temporal adverbs referring to the past (e.g., "This morning"). Accordingly, the "present" time frame may more appropriately be labeled "immediate past". Processing past information in general – be it remote, recent, or immediate past – may have been equally affected by our manipulation, that is, by orienting either to the front or back of the body when processing past information during the linguistic training.

In short, the results of Experiment 1 do not distinguish between an account of a shifted temporal focus toward the past based on enhanced visibility of the spatial representation of the past and one based on differential task difficulty. Experiment 2 sets the temporal and non-temporal explanations against each other.

3. Experiment 2: Perceived Relevance of Continuous Events

To distinguish between temporal and non-temporal explanations of the results of Experiment 1, we designed a control experiment in which we used the same detective task, but we reduced the temporal nature of the task. We used a subset of the original items, removed temporal adverbs (e.g., Three years ago) and changed the tense from past to present. By doing so, items in the control task referred to students' more general characteristics or habitual behaviors (e.g., One student smokes.) rather than to students' behaviors at specific points in time (e.g., Three years ago, one student smoked.) as in the original task. If differences related to task difficulty rather than to temporal focus gave rise to the canonicality effect in the original task, we should find the same canonicality effect for the control task. However, if a shift in temporal focus drives the canonicality effect, removing references to the past in the control task should result in a diminished or absent canonicality effect.

3.1 Method

3.1.1 Participants

Ninety-six participants (M (age) = 34.16, SD(age) = 11.28) were recruited online from Amazon's Mechanical Turk. The recruitment procedure and the inclusion criteria were the same as in Experiment 1. Participants were randomly assigned to one of the

six training conditions and subsequently to either the original task (N = 48) or the control task (N = 48).

3.1.2 Materials

The materials were the same as in Experiment 1 except for the behavioral items of the detective task. We used a subset of the original items (52 out of 66), removed the temporal adverbs (e.g., Three years ago) and changed the tense from past to present (see Appendix). By doing so, items in the control task referred to students' more general characteristics or habitual behaviors (e.g., One student smokes.) rather than to students' behaviors at specific points in time (e.g., Three years ago, one student smoked.) as in the original task.

3.1.3 Design

The design was the same as in Experiment 1 except for a 2-level between-participant factor Task (original, control), which was added to be able to compare the results of the original versus the control task. Participants were randomly assigned to one of the six training conditions and subsequently to either the original task or the control task. That is, a given participant used either canonical or non-canonical metaphors in one out of the three linguistic frames and then performed either the original task or the control task.

3.1.4 Procedure

The procedure was the same as in Experiment 1 except that after the training participants were randomly assigned to either the original task measuring perceived relevance of past events or to the control task measuring perceived relevance of continuous events.

3.2 Results

The main results of interest are plotted in Figure 4. To summarize, there was no canonicality effect in the control task measuring perceived relevance of continuous events and the canonicality effect was replicated in the original task measuring perceived relevance of past events.

For the data analysis, we proceeded as follows. To examine whether the results of the original task of Experiment 1 (N = 192) could be replicated in Experiment 2 (N = 48), we compared both data sets in a by-items 2 (Canonicality) x 3 (Linguistic frame) x 3 (Time) repeated measures ANOVA and added Run (first run vs. second run) as a within-item variable. We also conducted a by-participants 2 (Canonicality) x 3 (Linguistic frame) x 3 (Time) repeated measures ANOVA and added Run (first run vs. second run) as a between-participant factor.

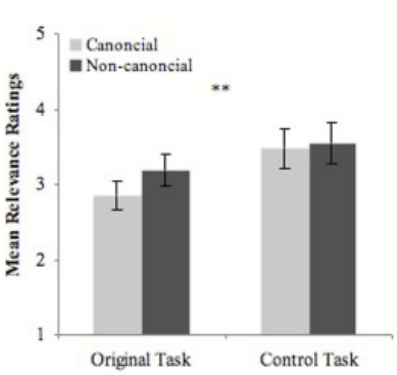

Fig. 4 Mean ratings of relevance by Canonicality and Task in Experiment 2 (N = 96). The error bars represent between-participants standard error.

Further, we analyzed the data of the control task (N = 48) separately by submitting the mean relevance judgments of the continuous events to a by-items 2 (Canonicality) x 3 (Linguistic frame) repeated measures ANOVA using both Canonicality and Linguistic frame as within-items variables. We also conducted a by-participant 2 (Canonicality) x 3 (Linguistic frame) ANOVA using both Canonicality and Linguistic frame as between-participant factors.

To examine potential interactions of Canonicality and Task and their manifestation across linguistic frames, we conducted a by-items 2 (Canonicality) x 3 (Linguistic Frame) x 2 (Task: original vs. control) repeated measures ANOVA on the mean relevance judgments. We also conducted a by-participants 2 (Canonicality) x 3 (Linguistic Frame) x 2 (Task: original vs. control) ANOVA. We compared the relevance ratings of the subset of items of the original task (e.g., Three years ago, one student smoked.) with their continuous equivalents of the control task (e.g., One student smokes.).

3.2.1 Results: Replicated Results of Experiment 1 (Original Task)

The main effects of Canonicality and Time were replicated (see Figure 5). There were no significant interactions of Canonicality x Run (F(1,129) = 1.23, p = .27, η^2 = .01 by items; F(1,228) = .051, p = .82, η^2 = .000 by participants) nor of Time x Run (F(2,129) = .54, p = .59, η^2 = .01 by items; F(2,456) = .24, p = .79, η^2 = .001 by participants).

One result that was not replicated was the non-

significant Canonicality x Time interaction; the Canonicality x Time x Run interaction was significant in the by-items analysis ($F(2,129) = 4.21$, $p = .02$, $\eta^2 = .06$) but not in the by-participant analysis ($F(2,456) = 2.34$, $p = .10$, $\eta^2 = .010$ by participants). That is, based on the by-items analysis, the canonicality effect was bigger for the present and recent past time frames than for the remote past time frame in Experiment 2 but not in Experiment 1.

This decreased canonicality effect for clues from the remote past could be interpreted in terms of temporal distance. Clues from the remote past were generally considered to be the least relevant for solving the case. They may have been so obviously irrelevant that their relevance judgments were not susceptible to our manipulation, or our measurement scale was too restricted to measure differences that may have existed between the conditions. Another possibility is that this variability of the canonicality effect across time frames in Experiment 2 was due to the relatively small number of participants ($N = 48$), compared to Experiment 1 ($N = 192$).

In the by-items analysis, the non-significant effects of Linguistic frame and of the Canonicality x Linguistic frame interaction in Experiment 1 were not replicated in Experiment 2 (see Figure 6); there were significant interactions of Linguistic frame x Run ($F(2,258) = 3.50$, $p = .03$, $\eta^2 = .03$ by items) and Canonicality x Linguistic frame x Run ($F(1,258) = 31.47$, $p < .001$, $\eta^2 = .20$ by items). One explanation for this variability across different linguistic frames may be the relatively small number of participants in each linguistic frame in Experiment 2 ($N = 8$), compared to Experiment 1 ($N = 32$).

3.2.2 Results: Control Task

As predicted, there was no significant main effect of Canonicality for the control task (see Figure 4; $F(1,51) = 1.31$, $p = .26$, $\eta^2 = .03$ by items; $F(1,42) = .09$, $p = .76$, $\eta^2 = .002$ by participants). However, the main effect of Linguistic frame was significant in the by-items analysis ($F(2,102) = 7.92$, $p < .01$, $\eta^2 = .13$ by items; $F(2,42) = .51$, $p = .60$, $\eta^2 = .02$ by participants) and the interaction between Canonicality and Linguistic frame was significant in the by-items analysis ($F(2,102) = 31.35$, $p < .001$, $\eta^2 = .38$) and marginally significant in the by-participants analysis ($F(2,42) = 2.97$, $p = .06$, $\eta^2 = .12$). That is, people considered information to be more relevant after non-canonical training than after canonical training, and to a similar extent across frame 1 and frame 2. In frame 3, the canonicality effect was reversed; people considered information to be more relevant after canonical training than after non-canonical training (see Figure 7).

One explanation for this deviant result pattern in frame 3 could be the fact that this linguistic frame differed from frame 1 and frame 2 in the sense that it used a static spatial model of time, that the ego was not explicitly referenced, and that it was the only non-familiar frame for English speakers. However, if this explanation was true for the control task, one may have expected a similarly deviant pattern of frame 3 in the original task as well. Another reason for this variability across linguistic frames may be the relatively small number of participants in each linguistic frame ($N = 8$).

3.2.3 Results: Original Task vs. Control Task

We conducted a by-items 2 (Canonicality) x 3 (Linguistic Frame) x 2 (Task: original vs. control) repeated measures ANOVA on the mean relevance

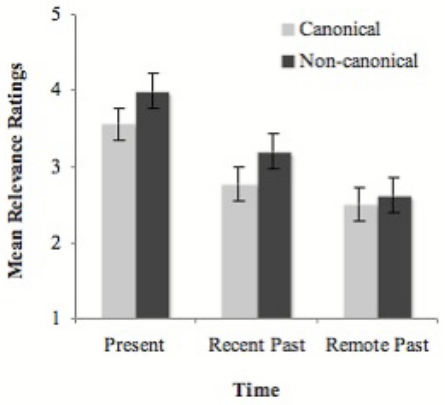

Fig. 5 Mean ratings of relevance given by participants after canonical versus non-canonical training in the original task ($N = 48$) of Experiment 2. The error bars represent between-participants standard error.

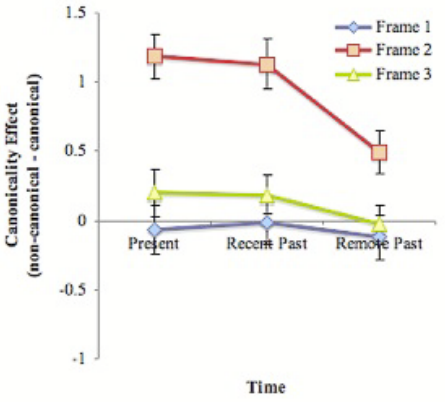

Fig. 6 Canonicality effect (non-canonical – canonical relevance ratings) by Time and Linguistic frame in the original task ($N = 48$) of Experiment 2. The error bars represent between-participants standard error.

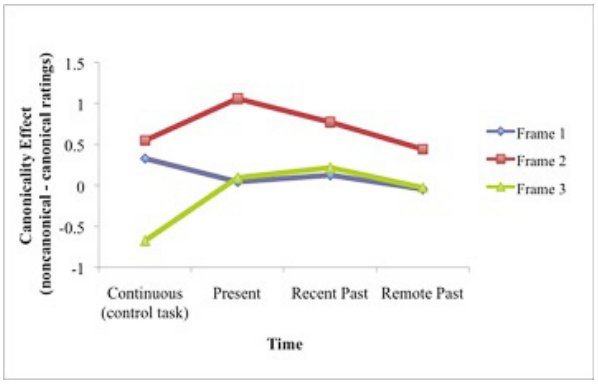

Fig. 7 Canonicality effect (non-canonical – canonical relevance ratings) by Time and Linguistic frame in Experiment 2 (N = 96).

judgments, using Canonicality, Linguistic Frame and Task as within-item variables. We also conducted a by-participants 2 (Canonicality) x 3 (Linguistic Frame) x 2 (Task: original vs. control) ANOVA, using Canonicality, Linguistic Frame and Task as between-subject factors.

Canonicality Effect. In the by-items analysis, the canonicality effect was significantly smaller in the control task measuring perceived relevance of continuous events compared to the original task measuring perceived relevance of past events. This observation was confirmed by a significant interaction between Canonicality and Task (F(1,51) = 9.70, p < .01, η^2 = .16). This interaction, however, was not significant in the by-participants analysis (F(1,84) = .61, p = .44, η^2 = .01).

Canonicality Effect by Linguistic Frame. Examining the canonicality effect across linguistic frames we can see variability (see Figure 6). In the by-items analysis, there was a significant interaction between Canonicality, Linguistic frame, and Task (F(1,102) = 10.73, p < .001, η^2 = .17). That is, the canonicality effect was reduced in frame 2 and frame 3, but increased in frame 1. This interaction, however, was not significant in the by-participants analysis (F(2,84) = .79, p = .46, η^2 = .02).

One explanation for the variability of the canonicality effect across linguistic frames (and across analyses) may be the relatively small number of participant in each linguistic frame in Experiment 2 (N = 8), compared to Experiment 1 (N = 32).

3.3 Discussion

As predicted, the overall canonicality effect was replicated in the original task measuring perceived relevance of past events but absent in the control task measuring perceived relevance of continuous events, favoring a temporal focus account of the canonicality effect over one based on differences in task difficulty.

However, examining the results in more detail, we found considerable variability of the canonicality effect across linguistic frames in the control task as well as in the original task. One reason for this variability may be the relatively small number of participants in each task of Experiment 2 (N = 48) compared to Experiment 1 (N = 192).

4. General Discussion

Previous work has shown that the way people talk about time in spatial terms can shape the way they think about time spatially (e.g., Boroditsky, 2000; 2001; Boroditsky & Fuhrman, 2010; Casasanto & Boroditsky, 2004; McGlone & Harding, 1998; Sweetser, 2006). In this study, we found evidence suggesting that the way people map time onto space in spatiotemporal metaphors cannot only rearrange spatial layouts of time, but that it may also shape the temporal focus of the language user. People considered past events and present (or immediate past) events to be more relevant after using new metaphors that spatialized the past in front and the future behind the body compared to people that used canonical metaphors that spatialized the past behind and the future in front of the body (Experiment 1). People seemed to have paid more attention to a temporal construct if they spatially represented it within their visible space than if they spatially represented it out of their visible space, suggesting that the visibility of spatial representations of time may shape temporal focus.

Since using reversed metaphors seems cognitively more demanding than using canonical metaphors, one may argue that the canonicality effect could have been driven by differences in factors related to task difficulty, such as fatigue, rather than to differences in temporal focus. In fact, there is evidence suggesting that fatigue can influence temporal focus. For example, people with low blood glucose levels (one aspect of fatigue) have been shown to focus more on the present in decision making than people with high blood glucose levels (Wang & Dvorak, 2010). There are at least two reasons, however, why a fatigue account of our finding is implausible. First, if fatigue indeed induces an increased focus on the present, one would expect a decreased focus on past events after using the more fatiguing new metaphors, not an increased focus on past events. Second, and more importantly, if differences in fatigue would have driven the canonicality effect,

one would expect to find the same effect on any relevance judgment, even if the items to be judged are not anchored to past reference points. However, when judging the relevance of continuous events with removed references to the past, the canonicality effect disappeared (Experiment 2). Whether people used visible or non-visible spatial metaphors of the past did not affect relevance judgments of continuous events, weakening possible alternative explanations of the canonicality effect based on task difficulty.

What mechanism could underlie our findings? If temporal constructs are implicitly associated with different parts of the peripersonal space (Fuhrman et al., 2011; Ouellet, Santiago, Funes, & Lupiáñez, 2010b; Torralbo et al., 2006; Torralbo, Santiago, & Lupiañez, 2006), then using spatiotemporal metaphors that reassociate the past to more visible parts of that space (ahead of the body instead of behind) may induce privileged access to information temporally referenced in the past. This privileged access, in turn, may have increased participants' likelihood of including past information in an imagined chain of causal antecedents preceding the theft when judging the clues in the detective task.

In the control task measuring perceived relevance of continuous events, relevance judgments of clues were not affected by the visibility manipulation. What may explain the disappearance of the effect in this task? One possibility is that judgments of continuous events were less susceptible to the visibility manipulation because representing continuous events may involve different spatial representation of time than representing past events. Representing continuous events may involve spatial representations of past instances as well as spatial representations of future instances. Making the past visible in metaphor may have induced facilitated access to past instances, while making the future invisible may have induced inhibited access to future instances. The two potentially present effects may have cancelled each other out. Another possibility is that representations of continuous temporal events were not as strongly associated with locations in space as representations of temporal events that were explicitly referenced to the past. As a consequence, relevance judgments of continuous events may have been less susceptible to reassociations of temporal constructs with more or less visible parts of space.

Our findings suggest that people pay more attention to the temporal construct they spatially represented in front of the body than to the temporal construct spatially represented behind the body. So far, we have interpreted this finding in terms of the visibility of spatial representations of the past. However, alternative interpretations seem possible. The space in front is in general more attentionally accessible than the space behind, not only visually. In addition to vision, other senses seem also oriented toward the front (e.g., hearing, olfaction), which may be part of the reason we call it "the front" of the body in the first place. The space in front may not necessarily (or not exclusively) be attentionally more accessible because it is visible space. For example, it may also be more attentionally accessible, because the front is the space where we typically perform motor action. In fact, evidence from neglect patients suggests that the motor versus non-motor distinction may be a crucial aspect of the attentional division between front and back space (Saj & Vuilleumier, 2007).

Future research should address the question whether our findings are only based on the visibility of a temporal construct represented in space or whether other modalities play a role as well. First, one could try alternative ways to manipulate the degree of visibility of temporal constructs in spatiotemporal metaphors – for example, by using vertical metaphors, as in Mandarin Chinese, during the linguistic training – and see whether one finds similar results following visibility patterns. Second, one could examine whether actual visibility shapes temporal focus, for example, by comparing near- vs. far-sighted people without correction (or people in fog with high vs. low visibility) on a measure of temporal focus. Third, to test the relative importance of different modalities for the effect, one could test whether attentional deficits associated to specific modalities (e.g., visual vs. motor or auditory neglect) have differential implications for temporal cognition (cf., Saj, Vuillemier, Fuhrman, & Boroditsky, submitted).

Further, it would be interesting to explore the generalizability of our findings. For example, we have shown that reversing the direction of time in metaphors can increase attention to the past, but does it also decrease attention to the future? To address this question one could use the same linguistic training but using a subsequent task measuring past and future orientation, such as the Zimbardo Time Perspective Inventory (Zimbardo & Boyd, 1999), or an inter-temporal choice task (e.g., Frederick, Loewenstein, & O'donoghue, 2002; Yi, Gatchalian, & Bickel, 2006). And how generalizable is our finding across time scales? The detective task we used measured temporal focus on a relatively large time scale (Ji et al., 2009). Would our manipulation also affect temporal focus of people judging events

on a small time scale (e.g., ranging from milliseconds to minutes), such as during causal inferences (e.g., Majid, Sanford, & Pickering, 2007)? And would our manipulation affect peoples' temporal focus during actual behavior (that is, measured non-linguistically)?

The results reported in this paper may also inspire future research on cross-cultural differences in cognition. Could the visibility (or attentional accessibility) of space-time mappings as used in spatiotemporal metaphors be a causal factor underlying cross-cultural differences in temporal focus? If reversing the direction of time in language for about twenty minutes (approximate duration of our linguistic training) can shift the temporal focus of the language user, it seems plausible to assume that habitually using more visible spatiotemporal metaphors could shape whole time perspectives of a linguistic community (Zimbardo & Boyd, 1999). In the context of the Aymara, questions have been raised regarding the origin of this peculiar front-past/behind-future mapping. For example, Núñez & Sweetser (2006) speculated whether it was their particular time perspective (rather neglecting the future) that gave rise to their particular use of metaphors or whether the metaphors gave rise to their particular time perspective. Our findings suggest that metaphors in language can in principle – and at least transiently – cause a shift in temporal focus. This indicates that Aymara's metaphors could indeed be a causal factor underlying and maintaining Aymara's time perspective. Analogous to the Aymara case, patterns in spatiotemporal metaphors of Mandarin Chinese may also foster the particular past orientation of their speakers (cf., Ji et al., 2009). In short, the more visible spatial representations of the past used in language – above as in Chinese or ahead, as in Aymara – may be causally involved in shaping their relatively strong past orientation.

5. Conclusion

Previous work has shown that mental representations of time differ across cultures and groups. The degree to which people focus on the past, present, and future, has been shown to have important consequences for education (e.g., learning from past mistakes), and for mental and physical wellbeing (Lewin, 1942; McFadden & Atchley, 2006; Petry & Bickel, 1998; Zimbardo & Boyd, 2009). In this paper we presented evidence suggesting that the degree to which people focus on the past may be shaped by the visibility of the past in spatiotemporal metaphors used in language.

Footnotes

[1]The term "visibility" can have various meanings. Here we are not referring to visibility in the strict perceptual sense where light hits the retina, etc., but rather to visibility in an imagined space. That is, if spatial representations of temporal constructs were actual objects located in space, one could either see them – if ahead of the observer – or not – if behind the observer.

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References

Bacon, F. (1620) *Novum organum*, ed. and trans. P. Urbach and J. Gibson (1620; Chicago: Open Court, 1994), 60.

Boroditsky, L. (2000). Metaphoric structuring: Understanding time through spatial metaphors. *Cognition, 75*(1), 1–28.

Boroditsky, L. (2001). Does Language Shape Thought?: Mandarin and English Speakers' Conceptions of Time. *Cognitive psychology, 43*(1), 1–22.

Boroditsky, L., & Fuhrman, O. (2010). Do English and Mandarin speakers think about time differently? *Cognition*.

Boroditsky, L., & Gaby, A. (2010). Remembrances of Times East: Absolute Spatial Representations of Time in an Australian Aboriginal Community. *Psychological Science, 21*(11), 1635–1639.

Boroditsky, L., & Ramscar, M. (2002). The roles of body and mind in abstract thought. *Psychological Science, 13*(2), 185.

Buhrmester, M., Kwang, T., & Gosling, S. (2011). Amazon's Mechanical Turk. *Perspectives on Psychological Science, 6*(1), 3.

Casasanto, D., & Boroditsky, L. (2004). How deep are effects of language on thought? Time estimation in speakers of English, Indonesian, Greek, and Spanish. *Proceedings of the 26th Annual Meeting of the Cognitive Science Society. Chicago, IL.*

Casasanto, D., & Boroditsky, L. (2008). Time in the mind: Using space to think about time. *Cognition, 106*(2), 579–593.

Clark, H. (1973). Space, time, semantics, and the child.

Cooperrider, K., & Núñez, R. (2009). Across time, across the body Transversal temporal gestures. *Gesture, 9*(2), 181–206.

Frederick, S., Loewenstein, G., & O'Donoghue, T. (2002). Time discounting and time preference: A critical review. *Journal of economic literature, 40*(2), 351–401.

Fuhrman, O., & Boroditsky, L. (2010). Cross-Cultural

Differences in Mental Representations of Time: Evidence From an Implicit Nonlinguistic Task. *Cognitive Science, 34*(8), 1430–1451. doi:10.1111/j.1551-6709.2010.01105.x

Fuhrman, O., McCormick, K., Chen, E., Jiang, H., Shu, D., Mao, S., & Boroditsky, L. (2011). How Linguistic and Cultural Forces Shape Conceptions of Time: English and Mandarin Time in 3D. *Cognitive Science, 35*(7), 1305–1328. Blackwell Publishing Ltd. doi:10.1111/j.1551-6709.2011.01193.x

Gevers, W., Reynvoet, B., & Fias, W. (2003). The mental representation of ordinal sequences is spatially organized. *Cognition, 87*(3), B87–B95. doi:10.1016/S0010-0277(02)00234-2

Haspelmath, M. (1997). *From space to time. temporal adverbials in the world's languages* (p. 181).

Ishihara, M., Keller, P., Rossetti, Y., & Prinz, W. (2008). Horizontal spatial representations of time: Evidence for the STEARC effect. *Cortex, 44*(4), 454–461. doi:10.1016/j.cortex.2007.08.010

Ji, L., Guo, T., Zhang, Z., & Messervey, D. (2009). Looking into the past: Cultural differences in perception and representation of past information. *Journal of Personality and Social Psychology, 96*(4), 761.

Kantowitz, B. H., Roediger, H. L., & Elmes, D. G. (2009) *Experimental Psychology: Understanding Psychological Research* (9th ed.). Belmont, Calif.: Wadsworth, 2009.

Lakoff, G. (1993). *The contemporary theory of metaphor. Metaphor and thought*.

Lakoff, G., & Johnson, M. (1980). *Metaphors we live by* (Vol. 111).

Lakoff, G., & Johnson, M. (1999). *Philosophy in the Flesh* (Vol. 77).

Lewin, K. (1942). *Time perspective and morale*.

Maddux, W., & Yuki, M. (2006). The "ripple effect": Cultural differences in perceptions of the consequences of events. Personality and Social *Psychology Bulletin, 32*(5), 669.

Majid, A., Sanford, A. J., Pickering, M. J. (2007). The linguistic description of minimal social scenarios affects the extent of causal inference making. *Journal of Experimental Social Psychology, 43,* 918-932.

McFadden, S. H., & Atchley, R. C. (2006). *Aging and the meaning of time. a multidisciplinary exploration* (p. 280). Springer Pub Co.

McGlone, M., & Harding, J. (1998). Back (or forward?) to the future: The role of perscpective in temporal language comprehension. *Journal of Experimental Psychology*

McNeill, D. (2005). *Gesture and thought* (p. 318). University Of Chicago Press.

Miles, L., Nind, L., & Macrae, C. (2010). Moving through time. *Psychological Science, 21*(2), 222.

Miracle, A., & Yapita, J. D. (1981). *Time and space in Aymara.* In M. J. Hardman (Ed.), The Aymara language in its social and cultural context (pp. 33–56). Gainesville: University Presses of Florida.

Núñez, R., & Sweetser, E. (2006). With the future behind them: Convergent evidence from Aymara language and gesture in the crosslinguistic comparison of spatial construals of time. *Cognitive Science: A Multidisciplinary Journal, 30*(3), 401–450.

Núñez, R., Motz, B., & Teuscher, U. (2006). Time after time: The psychological reality of the ego-and time-reference-point distinction in metaphorical construals of time. *Metaphor and Symbol, 21*(3), 133.

Ouellet, M., Santiago, J., & Israeli, Z. (2010a). Is the future the right time?. *Experimental psychology.*

Ouellet, M., Santiago, J., Funes, M., & Lupiáñez, J. (2010b). Thinking about the future moves attention to the right. Journal of Experimental Psychology: *Human Perception and Performance, 36*(1), 17.

Petry, N., & Bickel, W. (1998). Shortened time horizons and insensitivity to future consequences in heroin addicts. *Addiction.*

Ramscar, M., & Boroditsky, L. (2005). On the experiential link between spatial and temporal language. *Cognitive Science.*

Saj, A., & Vuilleumier, P. (2007). Neglect: Remembering the space left behind. *Current Biology, 17*(24), R1060–R1062.

Saj, A., Vuillemier, P., Fuhrman, O., Boroditsky, L. (2012). *Patients with left spatial neglect neglect the left side of time too.* Manuscript submitted for publication.

Santiago, J., Lupáñez, J., Pérez, E., & Funes, M. J. (2007). Time (also) flies from left to right. *Psychonomic Bulletin & Review, 14*(3), 512–516. doi:10.3758/BF03194099

Scott, A. (1989). The vertical dimension and time in Mandarin. *Australian Journal of Linguistics, 9*, 295–314.

Sinha, C., Sinha, V., Zinken, J., & Sampaio, W. (2011). When time is not space: The social and linguistic construction of time intervals and temporal event relations in an Amazonian culture. *Language and Cognition, 3*(1), 137–169.

Sweetser, E. (2006). With the future behind them: Convergent evidence from Aymara language and gesture in the crosslinguistic comparison of spatial construals of time. *Cognitive Science, 30*(3), 401–450.

Torralbo, A., Santiago, J., & Lupiañez, J. (2006). Flexible conceptual projection of time onto spatial frames of reference. *Cognitive Science, 30*(4), 745–757.

Tversky, B., & Kugelmass, S. (1991). Cross-cultural and developmental trends in graphic productions. *Cognitive psychology.*

Viaud-Delmon, I., Brugger, P., & Landis, T. (2007). Hemineglect: take a look at the back space. *Annals of Neurology, 62*(4), 418–421.

Wang, X., & Dvorak, R. D. (2010). Sweet Future: Fluctuating Blood Glucose Levels Affect Future Discounting. *Psychological Science, 21*(2), 183–188. doi:10.1177/0956797609358096

Weger, U. W., & Pratt, J. (2008). Time flies like an arrow: Space-time compatibility effects suggest the use of a mental timeline. *Psychonomic Bulletin & Review, 15*(2), 426–430. doi:10.3758/PBR.15.2.426

Yi, R., Gatchalian, K. M., & Bickel, W. K. (2006). Discounting of Past Outcomes. *Experimental and Clinical Psychopharmacology, 14*(3), 311–317.

doi:10.1037/1064-1297.14.3.311

Zimbardo, P. G., & Boyd, J. (2009). *The Time Paradox. The New Psychology of Time That Will Change Your Life (*p. 378). Free Pr.

Zimbardo, P., & Boyd, J. (1999). Putting time in perspective: A valid, reliable individual-differences metric. *Journal of Personality and Social Psychology, 77*(6), 1271–1288.