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The spatial alignment of time: Differences in alignment of deictic and sequence time along the sagittal and lateral axes

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ABSTRACT

People use space in a variety of ways to structure their thoughts about time. The present report focuses on the different ways that space is employed when reasoning about deictic (past/future relationships) and sequence (earlier/later relationships) time. In the first study, we show that deictic and sequence time are aligned along the lateral axis in a manner consistent with previous work, with past and earlier events associated with left space and future and later events associated with right space. However, the alignment of time with space is different along the sagittal axis. Participants associated future events and earlier events—not later events—with the space in front of their body and past and later events with the space behind, consistent with the sagittal spatial terms (e.g., ahead, in front of) that we use to talk about deictic and sequence time. In the second study, we show that these associations between sequence time and sagittal space are sensitive to person-perspective. This suggests that the particular space-time associations observed in English speakers are influenced by a variety of different spatial properties, including spatial location and perspective.

1. Introduction

Space and time are intricately linked in the human mind. Systematic associations between time and space regularly show up not only in how we talk about time (e.g., *I'm looking**forward**to the weekend*), but also in co-speech gesture (Cooperrider & Núñez, 2009), in a variety of cultural artifacts (e.g., calendars, timelines), and even in how we reason about time (e.g., Boroditsky, 2000). These associations are complex and multifaceted, as both space and time are rich concepts (for a review, see Núñez & Cooperrider, 2013). Dimensions of spatial cognition include extent, perspective, and motion. And similarly, temporal cognition includes duration, past and future, and sequential order. While we know that space and time tend to be associated, less is known about the particulars of how (and whether) different spatial concepts are associated with how we think about time.

The present paper will focus on two different types of *relationships* between temporal events (Núñez & Cooperrider, 2013). The first, *deictic time*, captures temporal relationships that are referenced relative to the present moment, reflecting past/future relationships. The second, *sequence time*, captures temporal relationships that are referenced relative to another moment in time, reflecting earlier/later relationships, regardless of the present moment. For instance, whether the discovery of Mars happened *earlier* or *later* than the discovery of Jupiter (Evans, 2003; Moore, 2006; Tenbrink, 2011; Traugott, 1978; Núñez & Cooperrider, 2013). While both refer to a series of temporal events, they differ in that deictic time is always anchored to a deictic center (e.g., the present), while sequence time does not rely on this deictic center (i.e., there is not necessarily a "past" or "future" in sequence time). Both deictic and sequence time are spatialized in systematic ways in speech, gesture, and thought, as documented in a variety of data from linguistics (e.g., Traugott, 1978; Evans, 2003), gesture research (Cooperrider & Núñez, 2009; Casasanto & Jasmin, 2012), and cognitive psychology (e.g., Torralbo, Santiago, & Lupiáñez, 2006; Weger & Pratt, 2008; Fuhrman & Boroditsky, 2010).

One prominent way that people in many Western cultures spatialize both deictic and sequence time is along a lateral (left-right) spatial axis. Across a variety of studies that vary in response mode, type of stimulus, and language of study, it has been demonstrated that people who read and write from left to right associate past and earlier events with the left side of space and future and later events with the right side of space (e.g., Torralbo et al., 2006; Santiago, Lupáñez, Pérez, & Funes, 2007; Weger & Pratt, 2008; Ulrich & Maienborn, 2010; Ouellet, Santiago, Funes, & Lupiánez, 2010; Fuhrman & Boroditsky, 2010). This pattern is reversed for those who read and write from right to left (e.g., Tversky, Kugelmass, & Winter, 1991; Fuhrman & Boroditsky, 2010). Furthermore, when talking about various events in time, English speakers often gesture along a left to right "timeline", with leftward gestures co-produced with speech about past or earlier events and rightward

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gestures co-produced with speech about future or later events (Cooperrider & Núñez, 2009; Casasanto & Jasmin, 2012; Walker & Cooperrider, 2016). Such patterns are likely shaped by a lifetime of cultural experiences, including reading and writing in a particular direction (e.g., Tversky et al., 1991; Bergen & Lau, 2012; Winter, Matlock, Shaki, & Fischer, 2015).

An additional way that deictic and sequence time are spatialized is apparent in how we talk about time. English speakers often employ *sagittal* (front-back) language to talk about deictic time (e.g., The future *ahead* looks bright) and sequence time (e.g., Christmas always falls *ahead* of New Years). For deictic time, future times lie *ahead* of the speaker with past times lying *behind* the speaker; while for sequence time, earlier times lie *ahead* of later times. A closer look at these linguistic examples reveals that deictic and sequence time are aligned along the sagittal axis in a different manner than how they are aligned along the lateral axis, which is not used in the English language to talk about time. That is, in language, future and earlier events, rather than future and later events, are aligned with the front while past and later events, rather than past and earlier events, are aligned with the back. For example, we conducted a brief analysis of 100 randomly sampled instances of the word "ahead" from the Corpus of Contemporary American English (COCA) (Davies, 2008). These tokens contained 32 examples of the word "ahead" used temporally. Eight of those instances were used to communicate an earlier time in a sequence (e.g., "On Wednesday investors turned cautious *ahead* of next week's Fed meeting") and 24 were used to talk about future times (e.g. "And I think we're going to build on that in the weeks *ahead*"). Not a single example was used to talk about a later time in a sequence or about a time in the past.

This alignment of future with earlier contrasts with behavioral and gestural evidence of how deictic and sequence time are aligned along the lateral axis, where future and later events are aligned with right space and past and earlier events are aligned with left space. What implications do these differences in alignment have for how people think about these temporal concepts? Are these differences simply due to the use of different tasks for the different axes (e.g., comparing linguistic patterns with behavioral and gestural tasks along the lateral axis)? If so, are the patterns used in language simply conventions that people use to talk about time, or do they reflect something deeper about how people might associate deictic and sequence time with the sagittal axis?

Research using a variety of different methods suggests that people reliably associate deictic time with the sagittal axis (Sell & Kaschak, 2011; Kranjec & McDonough, 2011; Miles, Nind, & Macrae, 2010; Miles, Karpinska, Lumsden, Macrae & Gilbert, 2010; Hartmann & Mast, 2012; Koch, Glawe, & Holt, 2011; Sullivan & Barth, 2012; Eikmeier, Schröter, Maienborn, Alex-Ruf, & Ulrich, 2013). For instance, Hartmann and Mast (2012) found that future events were categorized more quickly when the participants were physically displaced forwards in a moving chair rather than backwards. However, few psychological studies have examined the association between *sequence* time and the sagittal axis, and the ones that do often fail to find effects (e.g., Kranjec & McDonough, 2011; Fuhrman et al., 2011; Casasanto & Jasmin, 2012). Thus, perhaps people simply do not associate sequence time with the sagittal axis. However, an alternate explanation is that previous experiments may not have been designed in a way that would capture any associations that might exist. For instance, Kranjec and McDonough (2011) did not present related stimuli in sequential order (e.g., a series of pictures of a caterpillar transforming into a butterfly would be intermixed with a variety of unrelated images). This may have made it difficult for participants to interpret the events as part of a sequence. However, if people could associate sequence time with the sagittal axis, what would such associations look like?

One possibility is that deictic and sequence time will be aligned along the sagittal axis much like they are aligned along the lateral axis, where past and earlier events are associated with the left and future and later events are associated with the right. As we know that people associate future events (i.e., events that are *later than now*) with the space in front of them, under this "polarity correspondence" hypothesis (Proctor & Cho, 2006), one would expect later events in a sequence to also be associated with the space in front of the speaker while both past and earlier events would be associated with the space behind the speaker. The "polarity correspondence" hypothesis (Proctor & Cho, 2006) aims to account for many of the observed compatibility effects across a variety of domains (e.g., time, number, valence). It proposes that for binary classification tasks, the stimuli and response alternatives are both coded in terms of positive or negative polarity and when the two polarities match, response selection is faster. In the present case, as deictic events, events in a sequence, and the sagittal and lateral axes each can be categorized in terms of two poles (earlier vs later, past vs future, front vs back, left vs right), responses may be the most efficient when the poles of the different categories are aligned (Proctor & Cho, 2006). We know how the poles are likely to be aligned based on the results along the lateral axis (where for English speakers, earlier and past align with left space and later and future align with right space). So, the polarity correspondence hypothesis predicts that we should see similar patterns of alignment along the sagittal axis. In contrast, associations between deictic and sequence time and sagittal space could be based on the words we use to talk about them. Under this "lexical association" hypothesis, while past events lie behind the speaker and future events ahead of the speaker, earlier events should lie ahead of, or in front of, later events, consistent with linguistic patterns.

Recent findings provide support for this latter hypothesis. Walker, Bergen, and Núñez (2014) had participants listen to stimuli presented auditorily either along the sagittal axis (from speakers placed in front of or behind their body) or along the lateral axis (from speakers to the left or to the right of the body). Participants then, reporting verbally, made either deictic judgments (e.g., Is high school graduation in the past or in the future?) or sequence judgments (e.g., Is high school graduation earlier or later than college graduation?). While the expected effects emerged for deictic and sequence judgments along the lateral axis (participants were faster to make "past" and "earlier" judgments presented to the left and "future" and "later" events presented to the right), results along the sagittal axis were mixed. For sequence judgments, they found that participants were faster to make "later" judgments when the stimuli were presented *behind* the participant and "earlier" judgments when the stimuli were presented *in front of the* participant. This pattern of compatibility effects mirrors how English speakers talk about temporal sequences, where earlier events lie in front of later events. However, with this paradigm they found no evidence of an association between deictic time and the sagittal axis. This pattern of results was unexpected because typically, if any space-time associations are observed along the sagittal axis, they are for deictic judgments, with future events associated with the space in front of the body and past events behind the body (e.g., Kranjec & McDonough, 2011).

These findings are seemingly at odds with a series of studies conducted by Eikmeier and colleagues (Eikmeier et al., 2013; Eikmeier, Alex-Ruf, Maienborn, & Ulrich, 2015). They found stronger associations between space and time for deictic judgments along the sagittal axis (Eikmeier et al., 2013) than along the lateral axis (Eikmeier et al., 2015). As a result, they propose that the left-right axis is more weakly represented than the front-back axis, and that the sagittal axis "may have a privileged cognitive status when people think about past and future" (Eikmeier et al., 2015, p. 5). However, a closer look at their experimental design suggests that there are nuanced (yet important) differences between their paradigm and the one used by Walker et al. (2014). Eikmeier et al. measured whether simple tones presented in different spatial locations (in front of or behind the participant, Eikmeier et al., 2013; or to the left or to the right of the participant, Eikmeier et al., 2015) primed participants to vocally respond "past" or