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Even Abstract Motion Influences the Understanding of Time

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Many metaphor theorists argue that our mental experience of time is grounded in our understanding of space, including motion through space. Results from recent experiments – in which people think about motion, which in turn influences their thinking about time – support this position. Still, many questions remain about the nature of the metaphorical connection between time and space. Can the mere suggestion of motion influence how people reason about time, and if so, when and how? Three experiments investigated how thinking about "abstract" motion through sequences of numbers or letters would influence reasoning about time. Our results extend earlier psychological work on the link between time and space by showing that even motion in non-physical domains can influence temporal reasoning. The results provide further evidence that metaphorical understanding is grounded in our everyday physical and conceptual experience.

People often use spatial metaphors to describe time, especially metaphors about motion. They talk about time as moving quickly or slowly, as in *"Spring break raced by"* or *"The weekend is taking forever to arrive."* They talk about time as moving in a forward or backward direction, as in *"Let's move the meeting forward to September"* or *"The party was pushed back two hours."* They talk about time in terms of easy or difficult movement, as in *"We blew through final exam week"* or *"We pushed ourselves through the dog days of summer."* People can also take different perspectives when talking about time as motion. They talk about themselves moving through

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time, as in *"We are approaching the holidays,"* or about time moving relative to them, as in *"The holidays are approaching."*

Talking about time in terms of motion is no accident. Nor is it simply a matter of linguistic convention. Rather, it is motivated by our conceptual experience. There is much evidence to show that spatial and temporal representations are linked in everyday reasoning (e.g., Casasanto & Boroditsky, 2008; Xuan, Zhang, He, & Chen, 2007), even in infants (Lourenco & Longo, 2010; Srinivasan & Carey, 2010). There is also evidence to suggest that the conceptual metaphor *"TIME IS MOTION,"* or more generally, *"TIME IS SPACE,"* is universal (Clark, 1973; Evans, 2004; Kövecses, 2005; Radden, 1997; Traugott, 1978). Moreover, it is well established that people readily think about all sorts of things metaphorically. Metaphor allows them to anchor their understanding of relatively abstract domains, such as mathematics (Lakoff & Núñez, 2001), emotions (Kövecses, 2000), and information spaces (Maglio & Matlock, 1999), in terms of concrete, familiar domains (Gibbs, 1994; Lakoff & Johnson, 1980).

The connection between time and space has been studied extensively in linguistics, psychology, philosophy, and other fields, yet many questions remain about the nature of this connection. On one view, time and space are autonomous conceptual domains that both derive structure from a generalized representational template, one that is perhaps the result of evolutionary recycling (see, for instance, Cantlon, Platt, & Brannon, 2009; Jackendoff, 1983; Pinker, 1997; Walsh, 2003). On another view, the conceptual domain of time achieves much of its meaning and coherence from our basic perceptual, motor, and kinesthetic experiences in the physical world (see Clark, 1973; Gibbs, 1994, 2006; Lakoff & Johnson, 1980, 1999).

The goal of this paper is to extend prior psychological work on how people metaphorically conceptualize time. We focus on how the source domain of motion interacts with the target domain of time. In particular, we examine how the direction of motion shapes temporal reasoning, and the extent to which this effect generalizes. We explore the influence of *abstract motion*, which occurs in counting, reciting the alphabet, and other activities that involve mentally "moving" from symbol to symbol in an ordinal sequence (see Langacker, 1986, 1987). Our studies use an ego-moving time perspective, in which people conceptualize motion through time (e.g., *"We are approaching Thanksgiving"*), and a time-moving perspective, in which people conceptualize time moving relative to themselves (e.g., *"Thanksgiving is approaching"*; see Clark, 1973; Gentner, 2001; McGlone & Harding; 1998; but see also Moore, 2006; Núñez, Motz, & Teuscher, 2006). Here we are especially interested in how abstract motion influences temporal reasoning, and what it means for processing everyday spatial metaphors.

ACTUAL MOTION AND TIME

Many researchers have investigated the metaphoric connection between time and motion. The logic is that if time and motion are conceptually linked, then thought about motion should influence thought about time. In pioneering work, McGlone and Harding (1998) asked participants to read a series of statements about time that were phrased in terms of an ego-moving perspective (e.g., *"We passed the deadline two days ago"*) or a time-moving perspective (e.g., *"The deadline passed two days ago"*). For each statement, participants indicated when the event would occur or had already occurred. Critically, the last sentence was ambiguous, as in *"The meeting originally scheduled for next Wednesday has been moved forward two days,"* and thus permitted a Monday and a Friday response. The results showed that participants in the ego-moving condition often interpreted "moved forward" in a manner consistent with the ego-moving perspective (i.e., judged the meeting to be on Friday), but participants in the time-moving condition often interpreted it in a manner consistent with the time-moving perspective (i.e., judged the meeting to be on Monday; see also Boroditsky, 2000).

Boroditsky and Ramscar (2002) further explored how motion influences the understanding of time. In several studies, participants answered the question, "Next Wednesday's meeting has been moved forward two days. What day is the meeting now that it has been rescheduled?" (adapted from McGlone & Harding, 1998), after thinking about movement under various circumstances. In one experiment, participants imagined themselves moving toward a stationary object, or they imagined an object moving toward them before answering the ambiguous "move forward" time question. When they had thought about themselves moving, they were more likely to indicate that the meeting would be held on Friday than Monday, but when they had thought about an object moving toward them, the two responses were about equally likely. The results from Boroditsky and Ramscar (2002) showed that different ways of thinking about physical motion can yield different construals of time. (For related work, see Núñez, Motz, & Teuscher, 2006; Teuscher, McQuire, Collins, & Coulson, 2008.)

FICTIVE MOTION AND TIME

Matlock, Ramscar, and Boroditsky (2005) extended earlier findings on the *"TIME IS MOTION"* metaphor by exploring the effect of fictive motion, a non-literal type of motion implied in statements such as *"The road goes through the desert"* and *"The tattoo runs along his spine"* (Matlock, 2004a; 2004b; Langacker, 1987; Matsumoto, 1996; Talmy, 2000). In one experiment, participants read and visually depicted sentences that did or did not include fictive motion (e.g., *"The tattoo runs along his spine"* versus *"The tattoo is next to his spine"*) before answering the "move forward" question. In brief, sentences with fictive motion led to proportionally more Friday than Monday responses, but sentences without fictive motion yielded no reliable differences. (See also Ramscar, Matlock, & Dye, 2010.)

ABSTRACT MOTION AND TIME

So far, there is good evidence to support the idea that thought about motion, including fictive motion, influences temporal reasoning. Could even subtler forms of motion have a similar influence? Langacker (1986, 1987) argues that *abstract motion* is involved in counting, reciting the alphabet, and other forms of serial processing (see also Matlock, 2010). The idea is that people mentally "move" from one symbol to another when processing symbols in a series. Research on number cognition supports this view. In Western cultures, smaller and larger numbers are associated with left and right sides of space, respectively (Dehaene, Bossini, & Giraux, 1993), suggesting a spatially organized mental number line. And when people are thinking about numbers, they mentally "move" along the number line.[1] For example, when people generate numbers at random, their eye position predicts what number they have in mind. Leftward shifts often precede smaller numbers, and rightward shifts, larger numbers (Loetscher, Bockisch, & Brugger, 2008; see also Fischer, Castel, Dodd, & Pratt, 2003; Loetscher, Bockisch, Nicholls, & Brugger, 2010; Schwarz & Keus, 2004). These results suggest a strong coupling between external physical space and internal mental space, with eye movements along physical trajectories reflecting abstract motion along the mental number line.[2] Abstract motion can also be construed in terms of movement toward or away from a "zero" reference point, consistent with a left–right orientation (see Dehaene, 1997; Lakoff & Núnez, 2001). On this view, when people "move" in ascending order through a series of numbers (e.g., *2*, *3*, *4*), they "go" forward and away from zero. When they "move" in descending order (e.g., *4*, *3*, *2*), they "go" backward and toward zero.

Especially compelling evidence for abstract motion in numerical processing comes from research on *operational momentum*, the spatial "overshooting" that occurs when people engage in mental arithmetic (e.g., McCrink, Dehaene, & Dehaene-Lambertz, 2007; Pinhas & Fischer, 2008; Knops, Viarouge, & Dehaene, 2009). McCrink et al. (2007) presented participants with videos of sets of objects being added or subtracted and asked them to judge whether the depicted outcome was correct. When participants made errors, they often systematically overestimated the result of addition problems and underestimated the result of subtraction problems. The directional nature of these errors suggests that participants "moved" along their mental number line in solving the problems, spontaneously invoking a form of abstract motion. Importantly, abstract motion is not limited to numbers. Many other ordinal sequences, such as letters of the alphabet (Gevers, Reynvoet, & Fias, 2003) and even faces that vary in emotional expression (e.g., less happy to more happy; Holmes & Lourenco, in press) are mentally organized in a linear fashion. So, processing such information may also involve "motion" through non-literal (i.e., mental) space.

In the current work on TIME IS MOTION, three experiments examined direction of abstract motion and how it would influence temporal reasoning. In each experiment, participants first thought about abstract motion in a forward or backward direction (e.g., wrote a sequence of numbers in ascending or descending order) before answering the "move forward" question about next Wednesday's meeting. Because "forward" is ambiguous in the temporal domain, more Friday responses would indicate that participants adopted an ego-moving perspective. We hypothesized that abstract motion in a canonical forward direction (e.g., sequence of numbers going away from zero), like forward motion through physical space (Boroditsky & Ramscar, 2002; Matlock et al., 2005), would be more likely to prompt an ego-moving perspective and bias people toward a Friday response than abstract motion in a backward direction (e.g., sequence of numbers toward zero). In Experiment 1, participants filled in missing numbers in an array of numbers, in either ascending or descending order. In Experiment 2, participants filled in missing letters in an array of letters. In Experiment 3, participants read a

[1]Anecdotal evidence also supports this view. Researchers often use fictive motion language to describe the orientation of the mental number line (e.g., "we represent magnitude information on a mental number line that *runs from left to right* for increasing magnitudes"; Fischer, Dewulf, & Hill, 2005), implicitly suggesting that abstract motion is involved in numerical representation.

[2]These shifts in visual attention are analogous to those in the processing of fictive motion language (Richardson & Matlock, 2007).

narrative about a person doing a countdown, in either ascending or descending order, before an event. In all cases, it was expected that people would "move" forward through time to a greater extent after processing symbols in ascending order than after processing symbols in descending order.

EXPERIMENT 1: NUMBERS AND TIME

How might abstract motion—in this case, "movement" through a sequence of numbers—influence temporal reasoning? Would it be anything like actual motion (Boroditsky & Ramscar, 2002) or fictive motion (Matlock et al., 2005)? Participants completed a task in which they thought about numbers that proceeded in ascending or descending order (either *5* to *17* or *17* to *5*) before answering the ambiguous "move forward" question. In light of the earlier results and given our everyday experience with motion (typically forward, not backward), abstract motion in a canonical direction through numbers (ascending order, away from zero) ought to prompt people to adopt an ego-moving perspective, and yield more Friday responses, than abstract motion in a non-canonical direction (descending order, toward zero).

Method

Eighty-eight Stanford undergraduates participated for partial credit in an introductory psychology course. In this and other experiments reported in this paper, participants completed a survey in a booklet that contained various unrelated tasks, and were randomly assigned to the forward or backward condition. First, participants read, "Fill in the blanks with the missing numbers." Next, they filled in the 11 missing integers between *5* and *17* (forward abstract motion) or between *17* and *5* (backward abstract motion). As reading and writing direction (rightward versus leftward) are known to influence spatial reasoning (e.g., Dobel, Diesendruck, & Bolte, 2007; Fagard & Damen, 2003; Shaki & Fischer, 2008), numbers and blanks were presented vertically. Participants then answered the "move forward" question: *Next Wednesday's meeting has been moved forward two days. What day is the meeting now that it has been rescheduled?* Finally, as a manipulation check to ensure that participants had written numbers down in the correct order, participants were asked to indicate the third number they had written (i.e., *8* in the forward condition, *14* in the backward condition).

Results and Discussion of Experiment 1

Prior to the analysis, six participants' responses were omitted because they had been written down in the wrong order. A total of 82 scores were left in the data set.

The number of Friday and Monday responses was calculated in each condition. As predicted, number order (ascending or descending) influenced responses to the "move forward" question. Of the 44 participants who filled in numbers in a forward order (*5 . . . 17*), 25 percent provided a Monday response and 75 percent provided a Friday response. Of the 38 participants who filled in numbers in a backward order (*17 . . . 5*), 61 percent gave a Monday response and 39 percent gave a Friday response. A chi-square test of independence showed a reliable difference in the proportion of Monday and Friday responses across the two conditions, $\chi^2(1) = 9.19$, $p < .002$. Chi-square goodness-of-fit tests also showed that the proportion of responses differed reliably from chance (i.e., 50% Monday, 50% Friday; see McGlone & Harding, 1998) in the forward condition, $\chi^2(1) = 11.00$, $p < .001$, but not in the backward condition, $\chi^2(1) = 1.68$, $p > .19$.

The results indicated that abstract motion through a sequence of numbers influenced temporal reasoning as predicted. Specifically, ascending number order produced a greater proportion of Friday responses (relative to Monday), while descending number order produced no reliable difference between the proportion of Friday and Monday responses.

On our account, direction of abstract motion is responsible for the results. There were proportionally more Friday responses than Monday responses for ascending order, *5 . . . 17,* but no reliable difference for descending order, *17 . . . 5*, because people are used to engaging in forward movement and far less accustomed to backward movement in their everyday experience with motion. People typically move from one place to another by walking, cycling, driving, and so on in a forward direction, not a backward direction. They also perceive others moving in a forward direction far more often than a backward direction. Similarly, they count forward more often than they count backward. Because forward movement is deeply entrenched in everyday experience, it enabled our participants to take an ego-moving perspective through time and provide a Friday response. Because backward movement is somewhat unfamiliar, it was probably less clear which perspective to take, and hence responses were ultimately mixed.

An alternative explanation, however, is that thinking about numbers in ascending order led to more Friday responses because larger numbers are associated with later dates in the week. That is, the result of processing numbers in ascending order is to arrive at larger numbers, and these numbers could be mapped to later temporal events (e.g., Friday, relative to Monday). Additional experiments are needed to rule out this possibility.

EXPERIMENT 2: LETTERS AND TIME

In Experiment 2 we investigated how abstract motion invoked by other ordered mental activities would influence temporal reasoning. How would processing a non-numerical sequence of symbols, such as letters of the alphabet, affect people's reasoning about time? On the one hand, the effect of abstract motion on temporal reasoning might not be expected to generalize to letters, given some evidence suggesting that spatial organization for letters is not as robust as that for numbers (Casarotti, Michielin, Zorzi, & Umiltà, 2007; Dehaene et al., 1993; Zorzi, Priftis, Meneghello, Marenzi, & Umiltà, 2006; but see Gevers et al., 2003). Hence, people might not invoke motion when processing letters. On the other hand, letters resemble numbers in having a sequence of symbols with a fixed order, providing a representational template along which motion could occur. One way to test these competing views is to examine whether the order in which people recite the alphabet influences their conceptualization of time. If letters do not invoke abstract motion, order should have no effect on temporal reasoning. If, however, reciting the alphabet encourages people to conceptually "move" from one letter to the next (Langacker, 1987), movement direction should influence temporal reasoning. Forward letter direction should encourage an ego-moving perspective, yielding a greater proportion of Friday responses to the "move forward" time question compared to backward letter direction.

Method

Ninety-six Stanford undergraduates volunteered for partial credit in an introductory psychology course. First, participants filled in missing letters between either *G* and *P* (forward abstract motion) or *P* and *G* (backward abstract motion), which were vertically displayed on the page. Next, they answered the "move forward" time question about next Wednesday's meeting. Finally, participants were asked to indicate the third letter they had written (i.e., *J* in the forward condition, *M* in the backward condition).

Results and Discussion of Experiment 2

One participant's response were omitted because they had been written down in the wrong order. This left a total of 95 responses.

As predicted, letter direction influenced people's responses to the "move forward" time question. Of the 50 participants who filled in letters in a forward order, 26 percent provided a Monday response and 74 percent provided a Friday response. Of the 45 participants who filled in letters in a backward order, 53 percent provided a Monday response and 47 percent provided a Friday response. A chi-square test of independence showed a reliable difference in the proportion of Monday and Friday responses across the two conditions, $\chi^2(1) = 6.34$, $p < .012$. In addition, chi-square goodness-of-fit tests showed that the proportion of responses differed reliably from chance in the forward condition, $\chi^2(1) = 11.52$, $p < .0001$, but not in the backward condition, $\chi^2(1) = .20$, $p > .6$.

The results indicate that thinking about a sequence of letters in a particular direction can influence the way time is conceptualized. Specifically, ascending order (*G . . . P*) produced a greater proportion of Friday responses (relative to Monday responses), but descending order (*P . . . G*) did not. These results are important because they show that the effect of abstract motion on time is not limited to sequences of numbers. Indeed, letters provide a particularly strong test because there appear to be notable differences in how numbers and letters are represented (e.g., Zorzi et al., 2006). The finding that these two types of ordered sequences produce similar effects suggests that letters are conceptualized in a manner that is consistent with a mental number line. Moreover, the results also render unlikely the possibility that the effects observed in Experiment 1 resulted from mappings between numbers and dates on a calendar; temporal events are not systematically associated with letters of the alphabet. Based on the results, it appears that abstract motion through a sequence of letters can influence temporal reasoning.

EXPERIMENT 3: GENERALITY OF ABSTRACT MOTION'S INFLUENCE ON TIME

Would the direction of abstract motion influence temporal reasoning even when people are not generating an ordered sequence of symbols themselves? Could reading a story that includes a countdown in ascending or descending order produce similar effects? In this experiment, participants were asked to read a story that included a countdown in ascending or descending order, and then to reason about time by answering the "move forward" time question. The goal was to determine whether the influence of abstract motion on time would generalize to conventionalized situations involving a sequence of symbols in ascending or descending order.

Method

A total of 101 undergraduates at the University of California, Merced, volunteered for extra credit in a psychology or cognitive science course. In the forward condition, participants first read the following passage:

> John is at a school event in the park. He is seated at a table and about to compete in an ice cream eating contest. He is fidgeting and eager to start. He's holding a pint of ice cream with one hand and clutching a spoon with the other. Finally, he hears, "One, two, three, four, five, start!

The last sentence was about a person who called out a countdown that occurred in ascending order. In the backward condition, participants read the same passage, but the last sentence was about a person who called out a countdown in descending order. After reading one of these passages, participants answered the ambiguous "move forward" time question used in the previous experiments.

Results and Discussion of Experiment 3

Six responses were omitted because inappropriate responses were given (e.g., Wednesday, Saturday). This left 95 responses. Of the 46 participants in the forward condition (ascending order), 11 percent gave a Monday response and 89 percent gave a Friday response. Of the 49 participants in the backward condition (descending order), 53 percent provided a Monday response and 47 percent provided a Friday response. A chi-square test of independence showed a reliable difference in the proportion of Monday and Friday responses across the two conditions, $\chi^2(1) = 17.34$, $p < .0001$. Chi-square goodness-of-fit tests showed that the proportion of responses differed reliably from chance in the forward condition, $\chi^2(1) = 28.17$, $p < .0001$, but not in the backward condition, $\chi^2(1) = .18$, $p > .6$.

These results are consistent with those of the first two experiments. They show that even in conventionalized counting situations, in which people are not computing sequences of symbols themselves, ascending order encouraged people to take an ego-moving perspective and "move" through time, but descending order did not.

GENERAL DISCUSSION

Three experiments explored whether and how abstract motion would influence temporal reasoning. Together, the results suggest that abstract motion, "motion" from one symbol to another, can influence the way people reason about time in systematic ways. In all three experiments, direction of abstract motion affected people's judgments about when a meeting that was "moved forward" would be held. In Experiments 1 and 2, thinking about forward abstract motion through sequences of numbers or letters (*5 . . . 17* or *G. . . P*) led to more Friday responses than Monday responses, but thinking about backward abstract motion through sequences of numbers or letters

(*17 . . . 5* or *P . . . G*) did not. In Experiment 3, similar results obtained when people read a story that included a countdown in ascending or descending order.

These results are consistent with earlier work on time and motion, both actual and fictive (Boroditsky & Ramscar, 2002; Matlock et al., 2005). However, in the current experiments, participants were not primed with information about motion through physical space in any way. They were never asked to imagine, for instance, being pulled in a chair toward a distant object (Boroditsky & Ramscar, 2002). Nor were they primed with fictive motion sentences, non-literal language known to evoke simulated motion (Matlock et al., 2005). Instead, our participants simply thought about numbers or letters in ascending or descending order. In doing so, they may have mentally simulated motion from one symbol to the next, and, at least in the case of forward motion, it was sufficient to lead to more Friday responses when reasoning about time. This would be in line with evidence that sequential processing invokes abstract motion along an internal spatial representation of symbols (e.g., Loetscher et al., 2008, 2010; McCrink et al., 2007).

Given that thinking about numbers or letters in ascending order produced reliable effects on temporal reasoning across the three experiments, why did thinking about numbers or letters in descending order not do the same? One possibility is that our ordinary experiences with motion often occur in a canonical forward direction. In everyday life, we walk through rooms, down stairs, and across streets with our bodies facing forward. We drive cars on roads or ride bicycles on paths facing forward. We also watch others moving forward hundreds of times on any given day. Because forward movement is deeply entrenched in our perceptual experience, it is primary in our conceptual system (Clark, 1973; Johnson, 1987; Lakoff & Johnson, 1999; Radden, 1997, 2006). As such, it is readily and persistently recruited in our understanding of time, often through mental simulation metaphorically construed actions (see Gibbs & Matlock, 2008). In contrast, backward movement is relatively rare, and consequently, its conceptualization may be inconsistent or vague.

Our results, which extend earlier work on motion and time, suggest that even abstract motion can influence the conceptualization of time. These findings have implications for research on temporal reasoning, and provide insights into the sequential processing of numbers and other symbols. On one view, thinking about numbers might simply involve calling up a static representation of a series of numbers on a line. In this case, people would think about numbers as static entities and would not simulate motion from one to the next. On another view, however, thinking about numbers evokes a dynamic representation. In the latter case, people would mentally simulate motion from one number to the next. If number X is at location 1 and number Y is at location 2, people might imagine moving from location 1 to location 2 while counting. These views point to different predictions: A static representation would predict no difference for the ambiguous "move forward" time question (because a static numerical sequence should not prime conceptual "movement" through time), but a dynamic representation would predict differences as a function of direction of movement, with canonical forward movement encouraging an ego-moving perspective (as with actual and fictive motion). Our results are consistent with the latter explanation. Moreover, they point to yet another way in which abstract knowledge—in this case, notions of magnitude and ordinality—figures into metaphor understanding and use. The knowledge or experience relegated to the source domain (in this case, MOTION) need not be literal (i.e., thought about actual motion). Indeed, abstract information in the source domain may itself be grounded in image schemas and sensorimotor experience (Lakoff & Johnson, 1980; Lakoff & Nuñez, 1999).

Based on our results, we conclude that abstract motion, “motion” through non-physical domains, can influence the understanding of time. The work adds new insights to the existing body of work on the conceptual relationship between space and time by showing how even very subtle forms of motion can influence temporal reasoning. Follow-up research might disentangle the front–back and left–right spatial axes in the processing of ordinal sequences, as both types of construal are recruited in the conceptualization of time (Fuhrman & Boroditsky, 2008; Torralbo, Santiago, & Lupiáñez, 2006). It would also be informative to study the effect of abstract motion on the understanding of time in languages other than English, for instance, Aymara (see Núñez & Sweetser, 2006) or Wolof (see Moore, 2006). Nevertheless, at this point, we can say with some degree of confidence that even abstract motion influences the understanding of time.

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