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As time goes by: Evidence for two systems in processing space→time metaphors

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Temporal language is often couched in spatial metaphors. English has been claimed to have two space→time metaphoric systems: the *ego-moving* metaphor, wherein the observer's context progresses along the time-line towards the future, and the *time-moving* metaphor, wherein time is conceived of as a river or conveyor belt on which events are moving from the future to the past. In three experiments, we investigated the psychological status of these metaphors by asking subjects to carry out temporal inferences stated in terms of spatial metaphors. In Experiment 1, we found that subjects were slowed in their processing when the assertions shifted from one spatial metaphoric system to the other. In Experiment 2, we determined that this cost of shifting could not be attributed to local lexical factors. In Experiment 3, we again found this metaphor consistency effect in a naturalistic version of the study in which we asked commonsense time questions of passengers at an airport. The results of the three studies provide converging evidence that people use spatial metaphors in temporal reasoning. Implications for the status of metaphoric systems are discussed.

INTRODUCTION

We often talk about time in terms of space. Spatial representations of time are also pervasive across cultures in artifacts such as clocks, time-lines, drawings, and musical notation. Whether we are looking *forward* to a

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TABLE 1
Space-time correspondences in language

Space	*Time*
at the corner	*at* noon
from here *to* there	*from* two o'clock *to* four o'clock
through the tunnel	*through* the night
He stood *before* the house	it happened *before* evening
He was running *ahead* of me	He arrived *ahead* of me

brighter tomorrow, proposing theories *ahead* of our time, or falling *behind* schedule, we are relying on terms from the domain of *space* to talk about *time*. Many researchers have pointed out that there is an orderly and systematic correspondence between the domains of *time* and *space* in language (Bennett, 1975; Bierwisch, 1996; Clark, 1973; Lehrer, 1990; Traugott, 1975, 1978). Our purpose here is to investigate the psychological status of the correspondence between these two domains.

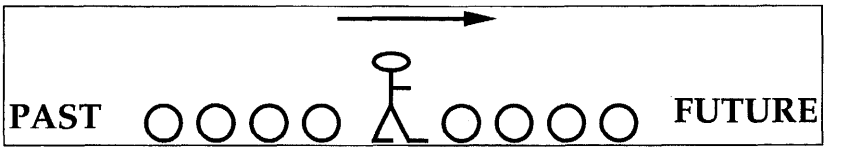
Language in the *time* domain can be roughly divided into three components: tense, sequencing, and aspect (Traugott, 1978). Our concern here is with sequencing, the system whereby events are temporally ordered with respect to each other and to the speaker (e.g., "The worst is behind us." or "Thursday is before Saturday.") Table 1 shows some space→time correspondence in English (taken from Lehrer, 1990). There appear to be some universal properties in importing language about *space* to describe *time* (Clark, 1973; Traugott, 1978). First, since *time* is usually conceived as one-dimensional, the spatial terms that are borrowed are uni-dimensional terms (e.g., *front/back, up/down*) rather than terms that are usually applied to two- or three-dimensional entities (e.g., *narrow/wide* or *tall/short*). Second, to capture the sequential order of events, the time-line has to be directional. Thus, ordered terms such as *front/back* and *before/after* are used, rather than symmetric terms such as *right/left*. Overall, spatial terms referring to front/back relations are the ones most widely borrowed into the *time* domain cross-linguistically.

Two systems for sequencing events

Within English, it has been pointed out that there are actually two space→time metaphoric systems.[1] The first system can be termed the *ego-*

[1] Having two different systems for sequencing events is not peculiar to English. Many languages have one system in which front" is assigned to the future, and another system in which front is assigned to the past. When front is assigned to the future, time is represented as an observer travelling along a time-line, or through a landscape. When front is assigned to the past, the observer is stationary and time is moving past. It could also be rationalised that the past is in front because the observer already knows what is in the past. The future is in back because one can not see the future, just as one cannot see behind one's back.

Ego-Moving Metaphor



Time-Moving Metaphor

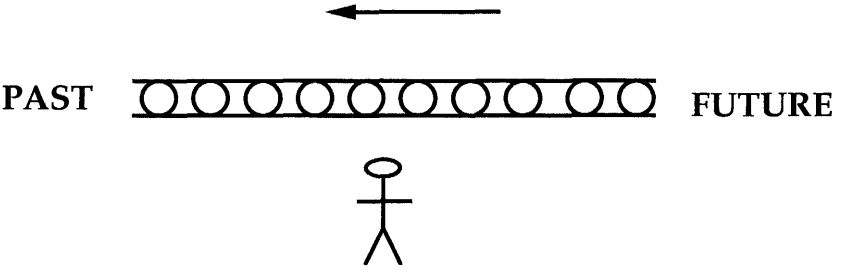


Figure 1. Time-moving and ego-moving metaphors.

moving metaphor, where EGO or the observer's context progresses along the time-line towards the future. The second system is the *time-moving* metaphor. In this metaphor, a time-line is conceived of as a river or conveyor belt on which events are moving from the future to the past (see Figure 1). These two systems lead to different assignments of front/back to a time-line (Clark, 1973; Fillmore, 1971; Lakoff & Johnson, 1980; Traugott, 1978). For example, in the ego-moving system, front is assigned to the future (later) event (e.g., "The war is *behind* us." or "His whole future is *before* him."). In the time-moving system, in contrast, front is assigned to a past (earlier) event. (e.g., "I will see you *before* 4 o'clock." or "The reception *after* the talk.")[2]

[2] Here "after" means "behind". "After" is derived from the spatial term "aft" which is the end part of a ship.

Space and *time* are only one example of a large set of domain pairs that seem to have systematic correspondence in language. Lakoff and his colleagues have pointed out the presence of many large-scale systems of conventional conceptual metaphors: language from one domain that is habitually used in other domains (Lakoff & Johnson, 1980; Lakoff & Kovecses, 1987; Turner, 1987). These metaphors can often be characterised as originating in one or more abstract schemas in the base (or source) domain: e.g., "Anger is heat/fire", "Argument is war". For example, conventional expressions reflecting the "Anger is fire" schema (from Lakoff & Kovecses, 1987) include:

> Those are *inflammatory* remarks.
> She was doing a *slow burn.*
> He was breathing *fire.*
> Your insincere apology just *added fuel to the fire.*

Such linguistic patterns suggest that many conceptual domains can be described and organised systematically in terms of more tangible and familiar domains. The abstract domain of *time*, for instance, can be organised and structured in terms of the more familiar and readily observable domain of *space* according to the "Time is a path along which we travel", (ego-moving) and "Time is a moving stream" (time-moving) schemas. However, whether these large-scale schemas are psychologically real conceptual systems, or post-hoc theoretical constructs, remains an open question.

The systematicity and coherence of the ego-moving and time-moving systems in language compels one to wonder whether these two metaphoric systems are psychologically real: that is, are there two separate conceptual systems underlying the two different ways of talking about time? Do the ego-moving and time-moving systems exist as two distinct globally consistent metaphoric systems, and are they used on-line to process temporal expressions?

It would be rash to assume that any apparent metaphoric system in language necessarily functions as a psychologically real mapping. The perils of relying solely on one's intuitions in formulating accounts of metaphorical processing are well illustrated in a recent study of illusory transparency of idioms done by Keysar and Bly (1995). They found that the perceived transparency of an idiomatic expression (the perceived connection between the expression and its meaning) increases with repeated use of an expression, and is largely independent of whether such a connection is conceptually motivated. A priori, it is not clear that global conceptual systems are necessary for processing metaphoric expressions. A simpler, more parsimonious hypothesis may be that a metaphoric meaning

is stored as a secondary meaning in the lexical entry of the base term. In the case of space→time metaphors, a word like "ahead" would have (at least) two word senses associated with it: "in front of spatially" and "in front of temporally". There would be no global domain-mapping, only a series of local polysemies. In this case the posited ego-moving and time-moving conceptual systems may be informative about the history of language, but not about current processing. In order to establish the psychological reality of space→time metaphors, then, we must be able to empirically distinguish between the above two possibilities.

Evidence for conceptual metaphors: The metaphor consistency effect

There is evidence regarding the existence of large-scale conceptual metaphoric systems. Gentner and Boronat (1991) devised a paradigm which allows us to test whether a statement that appears to be metaphoric is processed through a local process such as direct lexical look-up, or as part of a globally coherent metaphorical system (Gentner, 1992; Gentner et al., 2001). Gentner and Boronat presented a series of conceptual metaphors from a single coherent source domain in a connected text in order to establish a global mapping which served as a setting for the final test sentence. In the consistent mapping condition, the same metaphor was maintained throughout, e.g.,

> "Anna was boiling mad when you saw her.
> //Later she was doing a slow simmer."

In the inconsistent mapping condition, the metaphor is changed between the initial passage and the final sentence, e.g.,

> "Anna was a raging beast when you saw her.
> //Later she was doing a slow simmer."

In all cases the same meaning in the target domain was maintained. Using this technique, Gentner and Boronat (1991) found that subject's reading time for the final sentence was longer following a shift from one metaphor to another. A lexical control condition established that this *metaphoric consistency* effect was not due simply to lexical associations. This cost in comprehension time for a shift in global metaphor suggests that the individual assertions were processed as part of global metaphoric systems. This Metaphoric Consistency effect can be used as a diagnostic tool for distinguishing whether a given metaphor is processed at a local

lexical level, or is tied to a large-scale conceptual system. Other evidence for the existence of global conceptual metaphors has been reported by Albritton, McKoon, and Gerrig (1995) who found that large-scale conceptual metaphor schemas facilitated recognition judgements for schema-related sentences in text (see also Gibbs, 1990, 1994; Keysar et al., 2000); but see Glucksberg, Brown, & McGlone, 1993 for contradictory evidence).

We now return to space→time metaphors and to the question of their "Winter comes before Spring" psychological status. Are temporal event sequencing expressions processed as part of global space→time conceptual systems? There is reason to doubt this. First, Gentner and Boronat obtained evidence for domain mappings only when conceptual metaphors were relatively novel; tests using highly conventional metaphors (such as "get this topic across") did not reveal a significant cost for re-mapping. Further, there is evidence that in processing such conventional metaphors and idioms as "lose one's cool," the posited "anger is heat" metaphor is never accessed (Glucksberg et al., 1993). The space→time metaphors are highly conventional; indeed, the expressions reflecting the two metaphoric systems are almost invisible; people rarely notice that there are two different *space-time* mapping systems in their everyday language. It could be that the two mapping metaphors were alive in the history of language, but now are only stored as alternate word-senses of the spatial terms (Bowdle & Gentner, 1995; Gentner & Bowdle, in press; Gentner et al., 2001; Gentner & Wolff, 2000; Wolff & Gentner, 2000). If this is the case, we would not expect to see a Metaphoric Consistency effect when space→time metaphors are used.

A second reason we might not expect to see a global system mapping effect is that the contrast between metaphors here is quite subtle, since they both apply between the same two domains of *space* and *time*. In the materials used by Gentner and Boronat, two metaphors from different base domains (e.g., Heat and Dangerous animal) were applied to the same target (Anger). In the present case, however, we have two conceptual systems from the same base domain, *space*, to the same target domain, *time*. For this reason, we will call these mappings *system mappings* rather than *domain-mappings*. Evidence that these two space→time metaphors are psychologically distinct would be particularly interesting, since it would suggest considerable representational specificity in metaphoric systems.

In order to assess the psychological status of space→time metaphors, we used the basic logic of the Gentner and Boronat (1991) paradigm. We asked whether participants are faster to process assertions based on a space→time metaphor when the preceding sentences are in the consistent metaphor than when they are in the inconsistent metaphor. That is, is there a processing cost for shifting metaphors. However, whereas Gentner and

Boronat used a simple reading-time measure (that is, they recorded participants' time to read sentences and found that reading time was elevated after a shift in metaphors), we used a more demanding task. Because space→time metaphors are often highly conventional, we feared that a simple comprehension task might not fully capture the phenomenon. Subjects could gloss over the familiar expressions without fully processing the sequential relations between events. To ensure that subjects fully processed the sentences, we made the task more interactive by asking subjects to place an event on a time line.

The general method was very similar to that of the Gentner and Boronat study (Gentner, 2001; Gentner et al., 2001; Gentner & Imai, 1992). A test sentence describing a temporal relation between E1 and E2 was preceded by three setting sentences. In the consistent mapping condition, the setting sentences and the test sentence used the same metaphoric system – either ego-moving or time-moving. In the inconsistent mapping condition, the setting sentences belonged to a different metaphoric system from that in the test sentence. According to the domain-mapping hypothesis, there should be a metaphoric consistency effect (that is, processing should be faster in the consistent mapping condition than in the inconsistent mapping condition). This is because in the consistent condition, subjects can continue to build on the same systematic mapping as they progress from the setting sentences to the test sentence, but in the inconsistent condition, to understand the test sentence subjects must discard their existing mapping and set up a new one.

The alternative possibility is that people process space→time metaphors at a local lexical level, with the temporal meanings as alternate word senses, so that a systematic mapping does not take place. In this case, we should find no effect of metaphoric consistency – that is, no difference in response time to process a series of space→time assertions whether they use the same metaphor single system or intermix the two different metaphoric systems. Three experiments have been conducted to examine this question.

EXPERIMENT 1

Method

Participants. Participants were 112 Northwestern University students who received course credit for their participation.

Materials. The materials consisted of 30 setting sentences and 10 test sentences. Fifteen of the setting sentences used the time-moving metaphor, and the other fifteen used the ego-moving metaphor. Likewise, five of the test sentences used the time-moving metaphor, and the other five used the ego-moving metaphor. A sample set of stimuli appears in Appendix 1.

Design. The design was a 2 (Metaphor Type) × 2 (Consistency) between-subject design. There were four between-subject conditions, consisting of the four possible combinations of setting sentence and test sentence: Condition 1: time-moving setting – time-moving test; Condition 2: ego-moving setting – time-moving test; Condition 3: ego-moving setting – ego-moving test; and Condition 4: time-moving setting – ego-moving test.

Procedure. Subjects saw three setting sentences followed by a test sentence, each sentence one at a time on the computer screen, with a time line below as depicted in Figure 2. They were instructed to respond by pressing one of two keys to indicate whether the first event (E1) in the sentence takes place in the past or future relative to the second event (E2). The *reference* event (E2, the event mentioned in the second place) was located on a time line as shown in Figure 2.

There were five such blocks of three setting sentences from the same metaphoric system, followed by a test sentence that was either from the same metaphor (consistent) or from the other metaphor as the setting sentences (inconsistent). (From the subjects' point of view, there was nothing to distinguish test sentences from setting sentences; all sentences required the same kind of time-line placement response.) The organisation of setting sentences within blocks and the presentation order of the test sentences were randomised. Thus, subjects in the two consistent conditions (conditions 1 and 3) saw all 20 sentences from a single mapping system (either ego-moving or time-moving). For subjects in the two inconsistent conditions, the metaphoric system was switched in every fourth sentence. Response time and accuracy were recorded.

Results and Discussion

The results of Experiment 1 are summarised in Tables 2a and 2b. As predicted by the global mapping hypothesis, subjects in the consistent

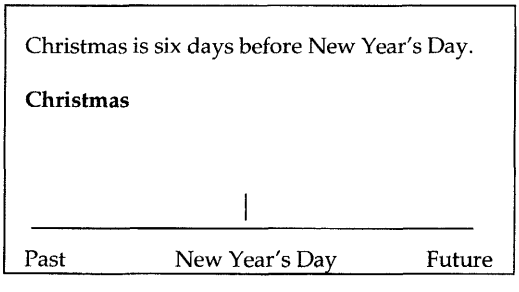


Figure 2. An example of material in Experiments 1 and 2.

TABLE 2a
Experiment 1. Mean reaction times (and *SD*s) for consistent and inconsistent conditions (ms)

	Consistent	*Inconsistent*	*Total*
Time-moving Test	4766.9 (1256)	5100.8 (1592)	4933.9 (1432)
Ego-moving Test	3689.1 (1136)	4496.5 (1137)	4092.8 (1295)
Total	4228.0 (1306)	4798.7 (1488)	

TABLE 2b
Experiment 1:. Accuracy for consistent and inconsistent conditions (% correct)

	Consistent	*Inconsistent*	*Total*
Time-moving Test	95.2	93.8	94.5
Ego-moving Test	93.2	89.7	91.5
Total	94.2	91.8	93.0

conditions responded faster ($M = 4228.0$ ms) than those in the inconsistent conditions ($M = 4798.7$ ms). The overall accuracy rate was 93.0 %, and errors were evenly distributed across the four conditions. A 2 (Consistency) × 2 (Metaphor type) ANOVA on the response times for test sentences with erroneous responses removed revealed a main effect of consistency, $F(1, 108) = 5.074$, $p < .05$. There was a marginal main effect of metaphor type, with responses to test sentences in the time-moving metaphor taking longer than responses to those in the ego-moving metaphor, $F(1, 108) = 2.842$, $p < .10$ (we return to this effect later in the discussion). There was no interaction between consistency and metaphor type.

The fact that subjects were faster to make inferences when the test sentences continued the same metaphoric system as the setting sentences is consistent with the system mapping hypothesis.[3] This pattern suggests that people understand these metaphors via a systematic mapping from the domain of *space* to the domain of *time*, so that processing further

[3] We should note, however, that statements that belonged to the same metaphoric system were also similar in grammatical structure: Time-moving sentences attribute motion to an event, whereas ego-moving sentences attribute motion to an entity. This is a potential confound in the present study, as a "grammatical consistency effect" could have inflated the reaction-time differences attributed to the effects of metaphoric consistency. However, later studies have shown effects of metaphorical consistency while using dependent measures such as sentence interpretation that avoid this possible confound (Boroditsky, 2000; McGlone & Harding, 1998). See the General Discussion for details. We thank Matt McGlone for pointing out this potential confound.

metaphors belonging to the same system is facilitated relative to shifting to metaphors belonging to a different system.

However, because of our randomisation procedures, we were concerned that local effects might have inflated the effect for consistency. For example, certain terms might have been particularly associated with one metaphoric system or the other. The most important of these was the possibility of lexical priming when the same spatio-temporal term was used in a setting sentence and the adjacent test sentence (e.g., *before-before*). Such local juxtapositions could have resulted in faster response times through purely lexical association processes. Obviously this kind of facilitation, if it occurred, should not count as evidence for the global metaphoric system hypothesis. In Experiment 1, the probability of such same-word repetition was low but not zero. We were also concerned about the possibility of response bias in cases when the same response occurred in the last setting sentence and in the test sentence (e.g., past/past).

Experiment 2 was designed to control those local factors strictly. In Experiment 2, the test sentences utilised only three terms: *ahead, before* and *behind.* These have the convenient property of being used in both of the space→time mapping systems, but with different temporal consequences. For example, compare the following two sentences:

(1) Christmas is six days *ahead* of New Year's Day.
(2) The holiday season is just *ahead* of us.

Let us denote the figure event (the event first mentioned in each sentence) as E1 and the reference event (the second event) as E2. Then the two time-lines in Figure 3 show how E1 and E2 are placed in the time-line. The past and future of E1 relative to E2 is reversed between (1′) and (2′), even though the same term "ahead of" is used to describe both temporal relations.

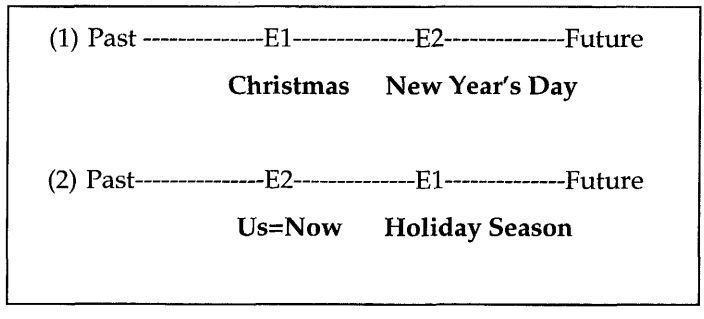


Figure 3. Sequencing two events. In (1) Christmas is six days *ahead* of New Year's Day (time-moving) and (2) the holiday season is just *ahead* of us (ego-moving).

In order to separate global mapping effects from possible local effects, we manipulated the setting sentences just prior to the test sentences. In both the consistent and inconsistent mapping conditions, the test sentences were preceded equally often by setting sentences containing the following three context-word types: Same term (e.g., *before* in setting and *before* in test); opposite term (e.g., *after-before*); and neutral term (e.g., *preceding-before*). The neutral terms were terms that were part of the metaphoric system in question, but not strongly lexically connected to the test word. If the advantage for the consistent conditions obtained in Experiment 1 was merely due to local lexical priming and response bias effects, then there will be no metaphor consistency effect, but merely a difference between same-word conditions over neutral and opposite-word conditions. If, however, there is a genuine effect of metaphoric systems on the comprehension process, then we should see an overall consistency effect as in Experiment 1. We might also expect that the difference between consistent and inconsistent mappings will be greatest in the same-word case, when the preceding setting sentence uses the same term as the test. However, if the consistency effect were to occur *only* in the same-word case, this would not constitute evidence for a true metaphoric consistency effect (because such a pattern could arise simply from the processing cost associated with having to shift the lexical interpretation of the same word). In sum, the global mapping hypothesis predicts an overall metaphoric consistency effect that is not restricted to same-word items.

EXPERIMENT 2

Method

Participants. The participants were 72 students at Northwestern University who received course credit for their participation.

Design and materials. The design included three fully crossed within-subject factors: metaphor type (ego-moving or time-moving), consistency (consistent or inconsistent), and setting word type (same, neutral, or opposite). There was also a between-subject assignment group factor with three levels (see Figure 4 for a schematic diagram of the design). Each subject saw 12 blocks, where each block consisted of three setting sentences and a test sentence – a total of 48 sentences, of which 12 were test sentences. Of the 12 test sentences, six contained temporal relations reflecting the ego-moving metaphor; the other six reflected the time-moving metaphor. Of these, within each metaphor type, three were in the consistent condition (i.e., setting and test sentences in the same metaphor system) and the other three were in the inconsistent condition. The setting sentences appearing prior to a test sentence included one of the following

setting word types: (1) same (e.g., *before/before*); (2) opposite (e.g., *after/before*); (3) neutral (e.g., *preceding/before*). Thus, each of the 12 blocks reflected each combination of two metaphor types, two consistency conditions and three setting word types (see Figure 4).

One aspect of the design was a bit complex. As mentioned earlier, we restricted ourselves to *ahead*, *before*, and *behind* as the test words. To avoid carryover effects, we needed to ensure that participants experienced each of these test words in only one condition. We have three test words in the two mapping metaphors, yielding six item sets. We divided these six item sets into three between-subject assignment groups as follows (see

consistency / metaphor	**Consistent**			**Inconsistent**		
Ego-moving	same	opposite	neutral	same	opposite	neutral
Time-moving	same	opposite	neutral	same	opposite	neutral

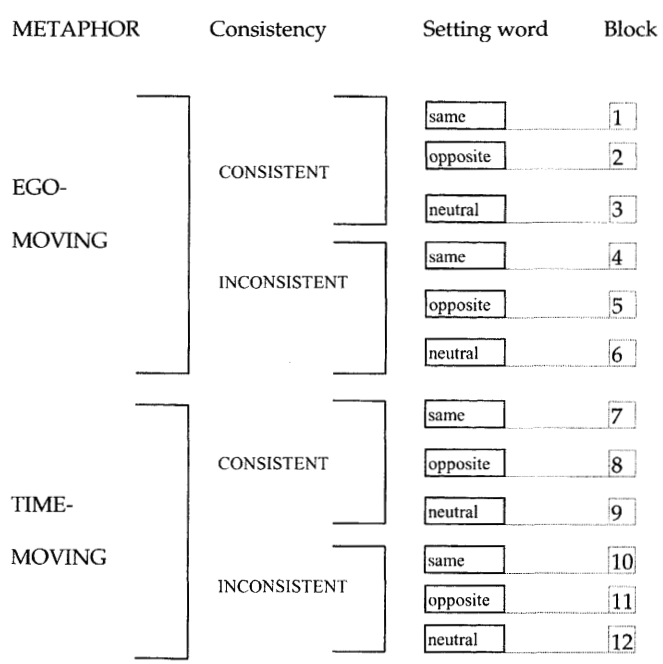


Figure 4. Experiment 2 design. The top part shows the within-subject conditions and the bottom part shows the between-subject assignment group conditions.

Figure 4): group 1 contained *before* – ego-moving test sentences, and *ahead* – time-moving test sentences; group 2 contained *behind* – ego-moving test sentences, and *before* – time-moving test sentences; group 3 contained *ahead* – ego-moving test sentences and *behind* – time-moving test sentences. Each of these six item sets had six test sentences, formed by crossing setting word type (same, opposite, and neutral) with consistency, as discussed above. The overall design of the experiment was 3 (Assignment group) × 2 (Metaphor type) × 2 (Consistency) × 3 (Setting word). A sample stimulus set is given in Appendix 2.

Procedure. The method of stimulus presentation and response was the same as in Experiment 1. The 12 blocks reflecting the 12 within-subject conditions were randomised. Subjects saw each test sentence only once, and each test sentence was assigned to the consistent and inconsistent conditions in each context word type an equal number of times across subjects.

Results and Discussion

The results are summarised in Tables 3 and 4 and in Figure 5. A 3 (Assignment group) × 2 (Consistency) × 2 (Metaphor type) × 3 (Setting word) mixed-measures ANOVA revealed a marginally significant effect of consistency, $F(1, 69) = 3.743$, $p = .057$. As predicted by the global mapping hypothesis, response times were shorter in the consistent ($M = 4525.3$)

TABLE 3
Experiment 2. Mean response times (ms)

		Ego-moving		*Time-moving*	
	Context word	*Consistent*	*Inconsistent*	*Consistent*	*Inconsistent*
Ahead					
	Same	3163.9	3731.3	4757.6	5287.6
	Opposite	3055.9	3495.9	6060.0	5069.2
	Neutral	3037.5	2889.0	5154.5	6805.8
Before					
	Same	3401.2	4638.4	4182.3	4578.4
	Opposite	4578.2	4945.2	3762.2	4734.3
	Neutral	4175.8	5712.0	4314.0	4373.1
Behind					
	Same	3107.0	3109.5	8971.1	6556.2
	Opposite	2825.5	3825.4	7372.3	5952.8
	Neutral	2888.2	2927.3	6647.4	7214.1

TABLE 4
Experiment 2. Accuracy for consistent and inconsistent conditions by setting word type (% correct)

	Time-moving		*Ego-moving*	
	Consistent	*Inconsistent*	*Consistent*	*Inconsistent*
Ahead	91.7	83.3	100	98.6
Before	95.8	93.1	95.8	94.4
Behind	81.9	68.1	100	100
Total	89.8	81.5	98.6	97.7

than in the inconsistent condition ($M = 4769.1$). There was a main effect of Metaphor type, $F(1, 69) = 223.991$, $p < .001$: subjects were faster to process statements that used the ego-moving metaphor ($M = 3639.3$) than statements that used the time-moving metaphor ($M = 5655.2$). We will address this effect in detail later in the discussion. There was also a main effect of Assignment group, $F(2, 69) = 7.387$, $p = .001$, as well as a 3-way

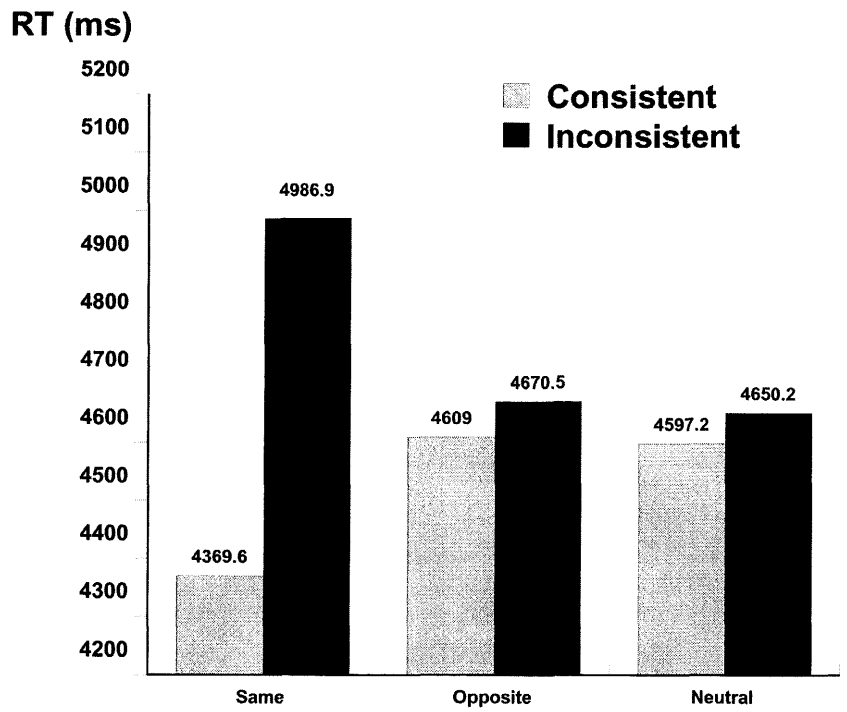


Figure 5. Experiment 2 results. Response times for metaphorically consistent and inconsistent metaphors across different context conditions.

interaction between consistency, setting word, and group, $F(2, 69) = 3.593$, $p = .033$, and a 3-way interaction between metaphor type, consistency and setting word, $F(1, 69) = 4.994$, $p = .029$. These effects presumably are due in part to variable properties of the items, as well as to one item set that behaved differently from the others, as discussed below.

A central goal in this study was to test whether there are true metaphoric consistency effects, or whether the apparent effect of metaphoric consistency in Experiment 1 can be accounted for in terms of local priming effects. Experiment 2 yielded evidence for global consistency effects in that subjects were faster in the consistent condition than in the inconsistent condition at all levels of setting word (same, opposite, and neutral) (see Figure 5). No significant main effect for setting word nor interaction between consistency and setting word was found. However, as would be predicted by the consistency hypothesis, the consistency effect is particularly pronounced in the same setting word condition (see Figure 5).

In order to be completely satisfied that there are global consistency effects when the setting word was neutral or opposite (that is, where there is no possibility for local priming), we conducted an ANOVA excluding the same setting word condition. The consistency effect was significant, $F(1, 46) = 5.452$, $p < .05$. This means that the metaphoric consistency effect we observed was not an artifact of lexical priming between identical words. Of course, these findings do not rule out the presence of lexical priming; but they establish that there is a global metaphoric consistency effect over and above such local priming. We also found no evidence for a response-priming effect: item sets that required the same response in the test sentence (e.g., *future-future*) as in the setting sentence were no faster on average than those that required different responses. Thus the results do not appear to result from local effects, but rather from system-level facilitation within the two metaphoric systems.

One puzzling result was the interaction found in the main ANOVA between consistency and metaphor type, $F(1, 69) = 5.114$, $p = .027$. For the ego-moving metaphor, as predicted, response times in the inconsistent condition (M = 3919.3) were considerably longer than those in the consistent condition (M = 3303.7). However, for the time-moving metaphor, response times were no longer (indeed, non-significantly shorter) in the inconsistent condition ($M = 5619.0$) than in the consistent condition ($M = 5691.2$). In addition, there was an interaction between group and metaphor type, $F(2, 69) = 46.247$, $p < .01$. Although all three assignment groups show faster response times for ego-moving metaphors than time-moving metaphors, this difference was far larger for assignment group 3 ($M = 3228.9$ and $M = 7119.0$, respectively) than for Group 1 ($M = 4575.1$ and $M = 5522.5$, respectively) and Group 2 ($M = 3113.8$ and

M = 4324.1, respectively). Finally, there was an interaction between consistency and assignment group, $F(2, 69) = 5.963$, $p < .01$. Participants were faster to respond in the consistent condition than in the inconsistent condition (the predicted pattern) in assignment group 1 (M = 4687.9 and M = 5409.7, respectively) and assignment group 2 (M = 3513.2 and M = 3924.7, respectively). Assignment group 3, however, showed an opposite effect – participants were slower in the consistent (M = 5374.7) than in the inconsistent condition (M = 4973.2).

Upon closer examination of the data set, we discovered that there was a speed–accuracy trade-off in the *behind*-time-moving condition. As shown in Table 4, the pattern without the *behind*-time-moving item set was as in Experiment 1: a high accuracy rate (95.3%) with no significant difference in accuracy between the consistent and inconsistent conditions. In contrast, accuracy in the *behind*-time-moving set was 75.0% overall, with the inconsistent condition at 68.1% and the consistent condition at 81.9%, marginally significant at $t = 2.00$, $p = .057$. It appears that for time-moving items involving *behind*, the metaphoric consistency effect was manifest as lower accuracy rather than longer response times.[4]

In order to remove contamination from the *behind*-time-moving item set, we repeated all the pertinent response time analyses excluding assignment group 3, which contained the *behind*-time-moving item set. A 2 (Group) × 2 (Consistency) × 2 (Metaphor type) × 3 (Setting word type) mixed-measures ANOVA revealed a main effect of consistency, $F(1, 46) = 12.714$, $p < .01$. No significant Consistency × Group or Consistency × Metaphor effects were found. With this exclusion, both time-moving and ego-moving conditions showed the predicted effect: consistent metaphors were faster to process than inconsistent metaphors throughout. No significant main effect for setting word nor interaction between consistency and setting word was found.

The results of Experiment 2 replicated the results obtained in Experiment 1. The metaphoric consistency effect was obtained when the possible local factors were strictly controlled by the manipulation of the setting word. The results of these studies suggest that spatio-temporal expressions are processed as belonging to large-scale conceptual systems, and not as isolated lexical entries. These findings strongly indicate that global systems are in play when people make inferences about temporal relations.

In Experiment 3 we turned to the larger question of whether space→time metaphoric systems have force in real life. It is important to check whether results found in the laboratory are characteristic of

[4] The *behind*-time-moving set was also slower overall than the other item sets, leading to the Group × Metaphor type interaction.

natural temporal processing, and not the result of some deliberative strategy on the part of the subject. Perhaps people in a natural setting can process temporal event-sequencing expressions without accessing the underlying spatial metaphor. This study also allowed us to address a possibility pointed out by McGlone and Harding (1998): namely, that the use of a time-line in Experiments 1 and 2 may have overemphasised the spatial dimension of the task. Perhaps subjects in our study made use of the spatial ego-moving and time-moving metaphors simply because the time-line task required them to transfer temporal information into a spatial format. To address this concern, a purely temporal task is needed. Therefore our third experiment was a purely temporal task conducted in a natural setting.

Experiment 3 was based on the same rationale as Experiments 1 and 2. If temporal event-sequencing statements are processed as domain-mappings from space, then metaphoric consistency should have an effect on reaction time. If the ego-moving and time-moving metaphors are switched, processing time should increase. Experiment 3, however, radically differed in methodology from the first two experiments. The experimenter (LB) went to the airport and asked people seemingly innocent questions about the time in other cities. The key manipulation was whether the questions asked used the same spatial metaphor throughout or shifted from one metaphor to the other. The prediction was that people would take longer to answer in the latter (inconsistent) case.

EXPERIMENT 3

Method

Participants. The participants were 40 passengers at Chicago's O'Hare airport chosen at random, and balanced for gender across conditions. Participants were not aware of being in a psychological study.

Materials and design. The design was 2 × 2 between-subjects design shown in Figure 4. The two manipulations were (1) metaphor consistency and (2) order of presentation. The metaphor consistency manipulation had two conditions; consistent: both the setting question and the test question used the ego-moving metaphor; and inconsistent: the setting question adopted the same perspective as the time-moving metaphor,[5] and the test question used the ego-moving metaphor. We also varied the order of

[5] We used the purely temporal terms *earlier/later* because it proved impossible to construct a short, natural query using the spatial-temporal terms *before/after* or *ahead/behind.* The terms *earlier/later* impose the same temporal perspective as the time-moving metaphor.

presentation of the two possible choices within the setting question such that half of the subjects heard the correct possibility first, and half heard the incorrect possibility first. Thus the materials consisted of an introductory sentence, four possible setting questions (two ego-moving and two time-moving), and a test question (ego-moving).

Procedure. Participants were approached individually by an experimenter at Chicago's O'Hare airport. The experimenter greeted the participant with the introductory sentence, and then asked the participant one of the four possible setting questions (shown in Figure 6). Once the participant had responded, the experimenter asked the test question. The response time to the test question was timed with a digital wristwatch equipped with a stopwatch. The stopwatch was started at the end of the test question and stopped as soon as the subjects began to answer. As the questions dealt with adjusting a watch to match a time-zone change, the participants did not suspect that they were being timed. All responses were written down by the experimenter immediately following the exchange.

	Consistent	Inconsistent
	Intro: Hello, I'm on my way to Boston.	
Order 1	**Setting:** Is Boston <u>ahead</u> or behind us time-wise?	**Setting:** Is it <u>later</u> or earlier in Boston than it is here?
Order 2	**Setting:** Is Boston behind or <u>ahead</u> of us time-wise?	**Setting:** Is it earlier or <u>later</u> in Boston than it is here?
	Test: So should I turn my watch <u>forward</u> or back?	

<u>Note.</u> The correct answer to each question is underlined.

Figure 6. The design of Experiment 3.

Participants were thanked for their assistance with adjusting the watch, but were not told that they were participating in a psychological experiment.

An example exchange was as follows:

E: "Hello, I'm on my way to Boston" (intro)
"Is it later or earlier in Boston than it is here?" (setting question) [TM]
S: "It's later there"
E: "So should I turn my watch forward or back?" (test question) [EM]
S: "Forward" (response timed from end of test question)
E: "Great, thank you!"

Results and discussion

As predicted, subjects in the consistent condition ($M = 1445$ ms, $SD = 649$ ms) responded significantly faster than subjects in the inconsistent condition ($M = 2722$ ms, $SD = 1454$ ms), $t(36) = 2.449$, $p < .05$. There were three error responses which were excluded from the analyses. Neither order of presentation nor gender had any significant effect on response times.

Upon closer examination of the actual responses given by subjects, we found an interesting split between responses within the inconsistent condition. Many of the subjects given the time-moving setting question (i.e., those in the inconsistent condition) converted the question to an ego-moving framework. Thus, responses to the setting question in the inconsistent condition followed two general patterns: *converted* and *non-converted.* e.g.,

E: "Is it earlier or later in Boston than it is here?"
S: *Converted*: "Well, they are ahead of us, so it is later"
Non-Converted: "It is later"

Sixty per cent of the participants in the inconsistent condition converted to the ego-moving metaphor when answering the setting question (which was posed in the time-moving metaphor). No subjects in the consistent condition showed such a conversion pattern. There was a difference in response times to the test question which followed this division within the inconsistent condition. Subjects who followed the Conversion pattern of response ($M = 1912$ ms, $SD = 758$ ms) were faster on the test question than those who did not convert ($M = 3938$ ms, $SD = 1500$ ms) $t(18) = 4$, $p < .01$. This secondary finding is also in line with predictions made by the domain-mapping hypothesis. Subjects who converted had already performed an ego-moving mapping, and thus when presented with the test question (ego-moving) had no need to re-map and as a result produced

shorter response times. Subjects who did not convert, however, needed to abandon their old structure, and set up a new one which reflected in their long response times. The effect of conversion was sufficiently strong that the response times of subjects who followed the conversion pattern varied only marginally from those of subjects in the consistent condition $t(27) = 1.914$, $p = .066$.

Overall, our finding of a metaphoric consistency effect in Experiment 3 is consistent with the findings of Experiments 1 and 2, and corroborates the psychological reality of global spatio-temporal metaphoric systems. The fact that processing took longer in the inconsistent mapping condition than in the consistent condition provides strong evidence that large-scale conceptual systems underlie the processing of spatio-temporal metaphors on-line.

GENERAL DISCUSSION

The results obtained from the three experiments are evidence for two distinct psychological systems used in processing event-sequencing statements. The two metaphoric systems discussed in this paper are highly conventional and are rarely noticed in everyday language. Yet our experiments showed that when people make inferences about temporal relations in text, they process more fluently if the sequence of metaphors belongs to the same global metaphor system. This held even when local lexical effects were strictly controlled (Experiment 2). Further, we observed the same effect in a purely temporal, oral task conducted in an airport – a highly natural context for temporal concerns (Experiment 3). These findings make it very unlikely that spatio-temporal metaphors are processed by direct lexical look-up, or that temporal meanings of spatial terms are simply stored as local secondary meanings in the lexical store. For if this were true, we would not have observed a processing time cost for switching between metaphoric systems (the Metaphoric Consistency effect) in our experiments.

Further evidence for the psychological reality of space-time metaphors comes from a study by McGlone and Harding (1998). McGlone and Harding developed an ingenious metaphor disambiguation technique for assessing the force of metaphoric systems. They primed subjects with either an ego-moving or a time-moving context and then asked them to disambiguate spatio-temporal expressions such as "Next Wednesday's meeting has been advanced by two days". Subjects showed a strong tendency to interpret such ambiguous statements in a manner consistent with the space-time mapping provided. McGlone and Harding concluded that the two systems are real conceptual metaphors, and not simply etymological relics.

Overall, there is strong evidence for two psychologically distinct global conceptual systems. Thus we can rule out an account based on purely local word senses. This opens up two further questions. First, how do such metaphors originate; and second, what is the processing mechanism.

How do space→time metaphors originate?

One prominent account is that spatial representations are the source of temporal representations. Abstract domains such as time receive their structure through metaphorical mappings from more concrete experiential domains like space; that is, metaphors create similarity (Fauconnier, 1990; Gibbs, 1994; Lakoff & Johnson, 1980; Turner, 1987). The second account, at the opposite extreme, is structural parallelism (Murphy, 1996). Due to inherent similarities in the referent domains of *space* and *time*, parallel sequencing systems evolved independently in the two domains. Then, because of the structural similarity of the representations, the two conceptual domains became aligned with common abstractions receiving the same linguistic label. In this case the same set of terms might be used in both domains without one domain's having been structured by the other. The third possibility, structure-mapping, has commonalities with both the other two. In structure-mapping, the first step in a metaphor or analogy is discovering existing common structure. Once the representational structures of the domains – here, space and time – are aligned, further inferences connected to the base system (within *space*) are projected to the target domain (*time*) (Gentner, 1983, 2001; Gentner & Markman, 1997). Thus, parallels between space and time are partly discovered and partly imported.

How are space→time metaphors processed?

There are four possible accounts of the mechanism, loosely related to the three 'origins' accounts above. First, on the *constitutive metaphors* account (that metaphors create similarity), space→time metaphors might be processed entirely by mapping the statements to the spatial domain, processing them and then mapping the inferences back to the temporal domain. As noted by Boroditsky (2000) this is what should occur if temporal representations derive their meanings from spatial representations. Second, in the opposite direction, the *structural parallelism* account holds that space-time metaphors are processed entirely independently of the spatial domain. The third possibility is that metaphors are processed as online domain-mappings, roughly like extended analogies (Allbritton, McKoon, & Gerrig, 1995; Gentner et al., 2001; Gentner, Falkenhainer, & Skorstad, 1988). The representational structures of *space* and *time* are aligned, and structured inferences drawn from *space* (the base domain) to

time (the target domain). On this account, an existing domain-mapping can facilitate future consistent mappings via an incremental mapping process. In incremental mapping, an existing system of correspondences is extended by introducing new structure into the base and computing new correspondences and inferences consistent with the existing mapping (Keane & Bradshaw, 1988; Forbus, Ferguson, & Gentner, 1994). A fourth account is *cognitive archaelogy*: space→time metaphors were originally directional mappings from space to time, but now simply express relational systems that are entrenched in both domains.

On the *constitutive metaphors* view, processing space→time metaphors requires recourse to the spatial domain. On both the *cognitive archaeology* and the *structural parallelism* accounts, there is no current reliance on spatial representations in temporal reasoning. Space may have had a special role in initially deriving temporal representations (as in the cognitive archaeology view) or not (as in the structural parallelism view), but there is no current directionality between space and time. Finally, the *domain-mapping* view would predict that although highly conventionalised space→time systems can be processed without direct recourse to space, these metaphors can be incrementally extended in generative mappings from space to time. (Structure-mapping theory allows for both an initial structural alignment and later inferences, which are directed from the well-structured domain to the less-structured domain (e.g., Gentner, 1983; Gentner & Wolff, 2000; Wolff & Gentner, 2000.) Thus a modification of Murphy's proposal is that an initial partial alignment between two domains may be followed by further inferences by which the well-structured domain amplifies the structure of the weaker domain.)

Our findings and those of McGlone and Harding (1998) do not tell us whether the space→time metaphors are processed directionally in real time. However, recent research by Boroditsky (2000, 2001; Boroditsky & Ramscar, in press) lends weight to the interpretation that the two systems are indeed domain mappings from space to time, rather than simply two coherent systems. In one set of studies, participants were slowed in their processing of temporal statements when they were primed with an inconsistent spatial schema, relative to a consistent spatial schema. The reverse was not true: Temporal metaphors did not interfere with the priming of inconsistent spatial metaphors. A further finding was that people were influenced by spatial perspective when reasoning about events in time. These results are consistent with a directional structure-mapping from space to time, rather than with a purely symmetric structural similarity relationship.

Another set of studies showed that metaphoric relationships between domains are in large part shaped by language – if spatio-temporal metaphors differ, so do people's conceptions of time (Boroditsky, 2001).

English and Mandarin speakers use different spatial metaphors for time – English speakers predominantly talk about time as if it were horizontal, while Mandarin speakers commonly use both horizontal and vertical metaphors to talk about time. This difference between the two languages was reflected in the way their speakers think about time. For example, Mandarin speakers were faster to confirm that March comes earlier than April if they had just seen a vertical array of objects than if they had just seen a horizontal array, and the reverse was true for English speakers. These results suggest that Mandarin speakers tend to think about time vertically, and interestingly, this pattern held even when the task was conducted in English. These results lend support to the metaphorical mapping claim. Together with the present results, they suggest that our representation of time is structured in part by on-line structural analogies with the more concrete and experiential domain of space.

Are time-moving metaphors more difficult than ego-moving metaphors?

In Experiment 3 we observed spontaneous conversion from the time-moving to the ego-moving metaphor. It is noteworthy that such conversions never occurred in the reverse direction, despite an equal number of opportunities. This suggests that the O'Hare participants preferred to reason with the ego-moving metaphor. This observation is in line with our findings in Experiments 1 and 2, in which subjects took longer to respond to items that used the time-moving metaphor than to those that used the ego-moving metaphor. These results seem to suggest that the ego-moving metaphor is somehow easier or more natural for English speakers. Why might this be the case?

First, statements in the ego-moving metaphor capture the temporal relationship between an event and an observer (e.g., "Boston is ahead of us in time.") and therefore contain only two points which can be placed on a time-line (e.g. [Past..... US..... Boston..... Future]). Statements using the time-moving metaphor, in contrast, usually capture the temporal relationship between two events (e.g., "It is later in Boston than it is in Chicago."), with the observer as a third point on a time line. Thus, the time-moving metaphor is typically a three-term relation whereas the ego-moving metaphor is typically a two-term relation. This may explain the greater processing difficulty of time-moving metaphors.

We can draw a second explanation for the apparent relative difficulty of time-moving metaphors from recent work on temporal reasoning by Schaeken, Johnson-Laird, and d'Ydewalle (1996). Because, as discussed above, the relative temporal location of an observer is not specified in the time-moving metaphor, the observer can occur as a third point anywhere

on the time-line. For example, the statement "John arrives ahead of Mary" can produce the following three time-lines:

1. [Past ..... Obs..... John ..... Mary..... Future]
2. [Past ..... John ..... Obs..... Mary..... Future]
3. [Past ..... John ..... Mary..... Obs..... Future]

Schaeken et al. (1996) found that subjects take longer to reason about temporal sequences when more than one sequence can be constructed from the available information (as in the example above). Therefore, if subjects in our experiments were trying to place an observer on a time-moving time-line, they would incur a processing time cost that may give rise to the main effects for metaphor type found in Experiments 1 and 2. Such effects of multiple mental models might contribute to the greater difficulty of time-moving metaphors.[6]

Beyond two systems

Clearly, much remains to be done. The ego-moving and time-moving metaphors that we have discussed so far are only two of a larger set of temporal metaphors. Lakoff and colleagues have reported seven metaphors for *time* in English including time as a resource ("We're almost out of time.") and time as a container ("He did it in three minutes.") (U. C. Berkeley Metaphor Website). Fraser (1987) lays out a number of historical models and metaphors for time. Some temporal metaphors are said to be widespread cross-linguistically. Alverson (1994) has reported that a consistent set of five *time* metaphors (two of which are ego-moving and time-moving) is commonly used across languages as diverse as English, Mandarin, Hindi, and Sesotho. However, the psychological status of these metaphors is yet to be determined.

Global consistency and conventionality

A striking aspect of this research is that we found system-level consistency effects for space→time metaphors that are highly conventional. This runs contrary to prior findings of metaphoric consistency effects for novel but not conventional metaphors (Gentner & Boronat, 1991; Gentner & Wolff, 2000; Gentner et al., 2001; Glucksberg et al., 1993; Keysar et al., 2000). Indeed, it has been suggested that conventional metaphors may be encoded and processed simply as alternate lexical entries, rather than as

[6] Another possibility that should be investigated is whether the ego-moving metaphor simply occurs more frequently in discourse than the time-moving metaphor. But even if this turned out to be the case, it would not be clear whether such a frequency differential was itself causal or was an effect of other factors.

part of large-scale domain mappings (Blank, 1988; Gentner & Bowdle, in press; Cacciari & Tabossi, 1988; Gibbs, 1994; Gentner & Wolff, 1997).

There are at least three interrelated reasons that space→time metaphors should act as domain mappings, unlike other conventional metaphors. First, as discussed above, space→time metaphors may in part be constitutive of temporal representational structure (Langacker, 1986; Talmy, 1985, 1987). Combining structure-mapping processes with Murphy's parallel-structure account, we would expect the use of spatial language to be crucial in the explicit and extended articulation of temporal structure. Second, these metaphors are used in relational reasoning, in contrast to many other conventional metaphors, such as "He blew his stack", that convey both local sensory properties and relational information. Third, unlike many conventional metaphors – e.g., "Anger is a raging beast" or "Music is food for the soul" – that convey some sensory attributive properties, these spatio-temporal metaphoric systems are entirely relational. The spatial terms, in closed-class fashion, derive their meanings entirely from their positions within their respective relational systems. For example, *after* is inherently the opposite of *before*, and so on. (As noted above, a term like *after* can take opposite readings in the two spatial systems and therefore in the two temporal metaphors, but in either case it will maintain its antonymic relation with *before*.) Such a term cannot be interpreted outside of its relational system. Possibly it is the degree of interdependency amongst the meanings of these terms that enforces system-level consistency in these conventional metaphors. If so, then considerations of the relationality of the base system and the constitutivity of the metaphor in the target may be clues to deciding, in Ortony's (1975) words, when metaphors are necessary and not just nice.

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APPENDIX 1

Sample Stimuli for Experiment 1a

Condition 1 – Consistent time-moving

Setting sentences – time-moving:

I will take the Math exam before the English exam.
My birthday is ahead of John's birthday.
I will take two months vacation after graduation.

Test sentence – time-moving:

Dinner will be served preceding the session.

Condition 2 – Inconsistent time-moving

Setting sentences – ego-moving:

I am looking forward to the concert.
In the weeks ahead of him, he wanted to finish this project.
We are coming into troubled times.

Test sentence – time-moving:

Dinner will be served preceding the session.

Note. Conditions 3 and 4 were parallel to conditions 1 and 2, respectively, but with ego-moving test sentences. Thus four conditions were run between-subjects.

APPENDIX 2

Experiment 2. Sample stimulus set – Assignment Group 1

Six **ahead**-time-moving blocks

	Consistent	Inconsistent
Same	*S3:* Christmas is six days ahead of New Year. *Test:* Transistors came ahead of microprocessors.	*S3:* The final exam lies ahead of us. *Test:* The parade is ahead of the festival.
Opposite	*S3:* Adulthood falls behind puberty. *Test:* The physics exam is ahead of the English exam.	*S3:* We are happy that the war is behind us. *Test:* The newscast is ahead of the late night movie.
Neutral	*S3:* The most productive years are still to come. *Test:* I will arrive in Tokyo three days ahead of you.	*S3:* We met each other ten years back. *Test:* John's graduation is ahead of my graduation.

Six **before**-ego-moving blocks

	Consistent	Inconsistent
Same	*S3:* He has many exciting years before him. *Test:* The deadline for the proposal is right before us.	*S3:* I will bring the book before Thursday. *Test:* He has an oral exam right before him.
Opposite	*S3:* It seems the recession is behind us. *Test:* Mike thinks about the years before him when he retires.	*S3:* I want to do some shopping after the concert. *Test:* A serious recession is before us.
Neutral	*S3:* John has many years to go to complete the program. *Test:* Eva is dreading the operation before her.	*S3:* Heavy rain followed the thunder. *Test:* Jane has been dreaming about the summer before her.

Note. "S3" is the setting sentence that directly preceded the test sentence.