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The spatial and temporal meanings of English prepositions can be independently impaired☆

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Abstract

English uses the same prepositions to describe both spatial and temporal relationships (e.g., *at the corner*, *at 1:30*), and other languages worldwide exhibit similar patterns. These space–time parallelisms have been explained by the Metaphoric Mapping Theory, which maintains that humans have a cognitive predisposition to structure temporal concepts in terms of spatial schemas through the application of a TIME IS SPACE metaphor. Evidence comes from (among other sources) historical investigations showing that languages consistently develop in such a way that expressions that originally have only spatial meanings are gradually extended to take on analogous temporal meanings. It is not clear, however, if the metaphor actively influences the way that modern adults process prepositional meanings during language use. To explore this question, a series of experiments was conducted with four brain-damaged subjects with left perisylvian lesions. Two subjects exhibited the following dissociation: they failed a test that assesses knowledge of the spatial meanings of prepositions, but passed a test that assesses knowledge of the corresponding temporal meanings of the same prepositions. This result suggests that understanding the temporal meanings of prepositions does not necessarily require establishing structural alignments with their spatial correlates. Two other subjects exhibited the opposite dissociation: they performed better on the spatial test than on the temporal test. Overall, these findings support the view that although the spatial and temporal meanings of prepositions are historically linked by virtue of the TIME IS SPACE metaphor, they can be (and may normally be) represented and processed independently of each other in the brains of modern adults.

Keywords: Language; Metaphor; Parietal lobe; Semantics; Space; Time

1. Introduction

An intriguing feature of English is that many prepositions are used to describe both spatial and temporal relationships (Table 1; Clark, 1973; Bennett, 1975; Jackendoff, 1983; Lindstromberg, 1998; Rice, Sandra & Vanrespaille, 1999; among others). Remarkably, space–time parallelisms of this general nature are cross-linguistically quite common if not universal. In a survey of 53 languages from diverse families worldwide, Haspelmath (1997; see also Traugott, 1974, 1978) found that all of them, without exception, employ spatial expressions for temporal notions. In addition, he discovered similarities as well as differences in how space–time parallelisms are manifested. For example, expressions for topological spatial relationships like coincidence (*at the corner*), superadjacency (*on the table*), and containment (*in the closet*) are also frequently used to indicate that an event occurred simultaneously with a particular clock time (*at 1:30*), day-part (*in the morning*), day (*on Monday*), month (*in July*), season (*in the summer*), or year (*in 2003*); however, there is a great deal of cross-linguistic variation regarding not only the precise spatial notions that are lexically encoded (Levinson & Meira, 2003), but also which ones are associated with which time periods.

Why are space–time parallelisms so common cross-linguistically? Several explanations have been proposed (see

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Table 1
Space–time parallelisms of English prepositions

Space	Time
She's *at* the corner	She arrived *at* 1:30
Her book is *on* the table	Her birthday is *on* Monday/October 6th
Her coat is *in* the closet	She left *in* the morning/July/the summer/2003
She left her keys somewhere *around* her desk	She had dinner *around* 6:30
She planted flowers *between* the tree and the bush	She likes to run *between* 4:00 and 5:00
She ran *through* the forest	She worked *through* the evening
She hung the chandelier *over* the table	She worked *over* 8 hours
She swept the crumbs *under* the rug	She worked *under* 8 hours
She painted the picture *in* her studio	She painted the picture *in* an hour

Haspelmath 1997, for a review), but the one that appears to be most consistent with the available data is the Metaphoric Mapping Theory (e.g., Boroditsky, 2000, 2001; Boroditsky & Ramscar, 2002; Gentner, 2001; Gentner, Imai & Boroditsky, 2002; Heine, Claudi & Hünnemeyer, 1991; Heine & Kuteva, 2002; Lakoff & Johnson, 1999, 2003; McGlone & Harding, 1998). One of the fundamental tenets of this theory is that metaphor is not merely a literary or rhetorical device, but is instead a powerful computational ability that contributes significantly—and perhaps uniquely (Gentner, 2003)—to human cognition by allowing similar relational structures in different conceptual domains to be identified, and also by allowing candidate inferences from the "base" domain to be projected into the "target" domain, thereby enabling a kind of meaning creation (see Hummel & Holyoak, 2003, for biologically inspired computer simulations; see also Gentner, Bowdle, Wolff & Boronat, 2001). With respect to space–time parallelisms, the Metaphoric Mapping Theory maintains that the three-dimensional domain of space is inherently more concrete and richly organized than the one-dimensional domain of time, so the relational structures of temporal concepts are given greater coherence by being aligned with the relational structures of spatial schemas through the application of a TIME IS SPACE metaphor. For example, moments in time can be construed as being analogous to points in space, and this similarity may account for why the preposition *at* is used to encode both kinds of information (e.g., *at the corner, at 1:30*). The cross-linguistic variation that Haspelmath (1997) documented regarding the specific manifestations of space–time parallelisms shows that some flexibility is available in how correspondences are formulated; however, this flexibility appears to be constrained, and an important claim of the Metaphoric Mapping Theory is that the most regular patterns originate from a universal human predisposition to conceptualize time in terms of space in certain preferential ways.

Evidence for this theory comes from research on semantic change in languages over the course of history. The theory holds that the conceptual domains of space and time are asymmetrically related because the direction of influence only goes one way, with spatial concepts providing familiar relational structures that help make temporal concepts more coherent. This asymmetry predicts that the spatial meanings of prepositions should always be chonologically primary, and that temporal meanings should emerge from them gradually through a process of semantic extension. In his cross-linguistic survey, Haspelmath (1997) confirmed this prediction and found that exceptions are "virtually unattested" (p. 141). For example, German *vor* 'before' (as in *vor August* 'before August') is based on *vor* 'in front of' (as in *vor dem Haus* 'in front of the house') because the temporal sense developed historically from the spatial sense (see also Heine et al., 1991; Heine & Kuteva, 2002; Hopper & Traugott, 2003).

Additional support for the theory comes from language development in children. The spatial meanings of prepositions are typically acquired before the temporal meanings, which is consistent with the notion that these two kinds of semantic structures are asymmetrically related, with the former possibly providing a conceptual foundation for the latter (H. Clark, 1973; E. Clark, 1974). Also, preschool children sometimes produce linguistic errors that reveal a mind creatively shaping temporal concepts by establishing novel correspondences with spatial schemas, as in the following utterances reported by Bowerman (1983):

Can I have any reading behind [=after] the dinner?

The balloons is on the other side, after I ate. But there might have been more on the first side [=before eating].

Today we'll be packing because tomorrow there won't be enough space to pack.

Friday is covering Saturday and Sunday so I can't have Saturday and Sunday if I don't go through Friday.

This leads naturally to the question of whether the TIME IS SPACE metaphor plays an active role in the representation and processing of prepositions for modern adult speakers. This is a controversial issue. Two alternative hypotheses can be distinguished—the strong view and the weak view.

The strong view maintains that the temporal meanings of prepositions are always computed through the on-line application of the TIME IS SPACE metaphor. In other words, part of the relational structure of these meanings is always actively derived from the relational structure of the corresponding spatial meanings through processes of cross-domain alignment and projection. According to this hypothesis, understanding a sentence like *She arrived at 1:30* necessarily involves structuring the concept of a moment in time in terms of the concept of a point on a line. The strong view is obviously a very bold hypothesis, but it is not just a straw man. Some researchers in the field of cognitive linguistics (Croft & Cruse, 2004) apparently endorse this position, as indicated by the following statement from Lakoff and Johnson (1999, p. 166): "Try to think about time without any of the metaphors we have discussed. Try to think about time without motion and space . . .. We have found that we cannot think (much less talk) about time without those metaphors. That leads us to believe that we conceptualize time using those metaphors and that such a metaphorical conceptualization of time is constitutive, at least in significant part, of our concept of time."[1]

By contrast, the weak view maintains that the temporal meanings of prepositions are represented and processed independently of the corresponding spatial meanings, so understanding the former does not necessarily involve on-line application of the TIME IS SPACE metaphor. Just as the word *breakfast* does not require one to think of a morning meal in terms of breaking a fast, so the sentence *She arrived at 1:30* does not require one to think of time as a series of points on a line. Certainly active metaphoric mapping is always available as an optional processing strategy—after all, the cross-linguistic data (and to a lesser extent the developmental data) suggest that the TIME IS SPACE metaphor is an inherent design feature of the human brain. The crucial point is simply that, according to this hypothesis, metaphoric mapping is not obligatory. A more detailed consideration of the weak view is presented in Section 4.

The goal of this paper is to evaluate the two competing hypotheses from a neuropsychological perspective. It is well-established that focal brain lesions can impair certain kinds of concepts while leaving others intact (see Martin & Caramazza, 2003, for recent reviews). For present purposes, the most relevant finding is that concrete and abstract concepts can be disrupted independently of each other. Although the most common dissociation involves impaired abstract concepts and preserved concrete concepts—i.e., the so-called concreteness effect (e.g., Coltheart, 1980; Franklin, Howard & Patterson, 1994; Goodglass, Hyde & Blumstein, 1969; Martin, 1996; Tyler, Moss & Jennings, 1995)—several cases of the opposite dissociation have also been reported (Breedin, Saffran & Coslett, 1994; Cipolotti & Warrington, 1995; Sirigu, Duhamel & Poncet,1991; Warrington, 1975; Warrington & Shallice, 1984). Moreover, concrete and abstract concepts have been associated with different electrophysiological (Weiss & Rappelsberger, 1996; West & Holcomb, 2000) and hemodynamic (Fiebach & Friederici, 2004; Mellet, Tzourio, Denis & Mazoyer, 1998; Wise et al., 2000) patterns in the brains of normal subjects. Given that spatial concepts are arguably more concrete than temporal ones, it would be of theoretical interest to determine whether these two types of prepositional meaning can be dissociated from each other by brain injury. The strong view predicts that if a subject's knowledge of the spatial meanings of prepositions is impaired, his or her ability to use the same prepositions in a temporal context should also be disrupted, because it is assumed that the temporal meanings always require access to their spatial correlates in order to be metaphorically grounded. However, the weak view predicts that the spatial meanings could be impaired without necessarily affecting the corresponding temporal meanings, because the latter are assumed to be processed independently of the former. These competing predictions were explored in an experiment described below.

[1] A similar proposal was recently made about the interpretation of metaphoric uses of action verbs like *grasp*—e.g., *grasp an idea* or *grasp an opportunity* (Feldman & Narayanan, 2004).

2. Method

2.1. Subjects

2.1.1. Brain-damaged subjects

Four subjects with circumscribed left-hemisphere brain damage caused by cerebrovascular disease were selected from the Patient Registry of the University of Iowa's Division of Cognitive Neuroscience. The information provided below about the subjects' lesion sites comes from magnetic resonance imaging scans that were used to reconstruct each subject's lesion in three dimensions using Brainvox (Damasio & Frank, 1992). The information about the subjects' language status comes from tests that are part of the battery of standard protocols of the Benton Neuropsychology Laboratory (Tranel, 1996).

2.1.1.1. Subject 1. 1760KS is a 47-year-old right-handed man with 12 years of education. He suffered a left-hemisphere CVA in 1991 that damaged most of the posterior inferior premotor/prefrontal cortex and underlying white matter, a small portion of the inferior pre- and postcentral gyri, the supramarginal and angular gyri, the insula, and the posterior sector of the superior temporal cortex, extending into the sylvian fissure. The lesion caused a very severe Broca-type aphasia which has remained stable.

2.1.1.2. Subject 2. 1978JB is a 54-year-old right-handed woman with 12 years of education. A left-hemisphere CVA in 1995 caused a lesion involving the posterior inferior premotor/prefrontal cortex extending deep into the basal ganglia, the inferior half of the pre- and postcentral gyri, the anterior sector of the supramarginal gyrus, and the insula. She was initially a global aphasic; however, this resolved into a persisting severe Broca-type aphasia.

2.1.1.3. Subject 3. 1962RR is a 70-year-old right-handed man with 18 years of education. He experienced a left-hemisphere CVA in 1991 which damaged a small portion of the posterior inferior premotor/prefrontal cortex, the entire supramarginal and angular gyri, and the posterior two-thirds of the superior temporal gyrus, extending into the sylvian fissure. Acutely he displayed global aphasia, but this gradually resolved into a predominantly anomic aphasia with some residual agrammatism.

2.1.1.4. Subject 4. 2127HW is a 59-year-old right-handed woman with 11 years of education. Her lesion, which occurred in 1997, is predominantly in two regions of the white matter of the left hemisphere. One region is in the territory superior and lateral to the frontal horn and anterior body of the lateral ventricle, subjacent to the middle and inferior frontal cortices; and the other, smaller region is near the posterior body of the lateral ventricle, subjacent to the terminus of the sylvian fissure. In the acute epoch, her speech and language were consistent with transcortical motor aphasia; in the chronic epoch, she manifested a stable mild non-fluent aphasia notable for hesitancy and occasional word-finding difficulty.

The first three subjects—1760KS, 1978JB, and 1962RR—have participated in several previous neurolinguistic investigations. The findings that are most relevant to the current study are as follows. First, all of the subjects manifested consistently poor performance on a large battery of tests that focus on multiple ways of processing the spatial (more specifically, the locative) meanings of prepositions (Kemmerer & Tranel, 2000, 2003; Tranel & Kemmerer, in press). Only one of the tests was used in the current study, however, because it was deemed most suitable for comparison with a new test that focuses on the temporal meanings of prepositions (see below). Second, the stimuli for all of the tests in the spatial prepositions battery include photographs and line drawings of concrete entities in various spatial relationships, but as noted in the references cited above, the subjects' difficulties with the tests were most likely due to impaired knowledge of the relevant meanings of the prepositions, since none of the subjects had significant trouble with a variety of other tests that evaluate visuospatial processing and visual object recognition.

2.1.2. Normal control subjects

The four brain-damaged subjects were compared with 10 neurologically healthy right-handed control subjects, five male and five female. Average age was 50.1 years (S.D. = 8.6), and average education was 13.6 years (S.D. = 2.2).

2.2. Tests

2.2.1. Assessing knowledge of the spatial meanings of prepositions

Subjects were given the Spatial Matching Test (referred to as the Matching #1 Test in Kemmerer & Tranel, 2000, 2003). The stimuli include 80 black-and-white photographs of real objects that bear certain spatial relationships to each other. In each picture, the "figure" (i.e., the object whose location is the focus of attention) is indicated by a red arrow, and the "landmark" (i.e., the object that serves as a point of reference for locating the figure) is indicated by a green arrow. Based on normative data, each picture is associated with either a single preposition or with two very similar prepositions (e.g., *in back of* and *behind*). For each picture, the subject's task is to determine which of three prepositions best describes the depicted spatial relationship. For instance, one picture shows a cap lying on the supporting surface on a chair, and the subject must indicate which preposition best completes the sentence "The cap is *in/on/beside* the chair" (answer = *on*). The items were carefully designed to probe the subject's knowledge of various types of categorical spatial distinctions captured by the following English prepositions: *on*, *in*, *around*, *between*, *through*, *over*, *under*, *above*, *below*, *in front of*, *in back of* (*behind*), and *beside* (*next to*) (see Kemmerer & Tranel, 2000, for details).

2.2.2. Assessing knowledge of the temporal meanings of prepositions

Subjects were also given the Temporal Matching Test, which has 60 items. As in the Spatial Matching Test, the task is to complete a sentence by selecting one of three prepositions, only in this case the context calls for a temporal, not a spatial, meaning—e.g., "It happened *through/on/in* 1859" (answer = *in*). The principal difference between the two methods is that pictures are used in the Spatial Matching Test but not in the Temporal Matching Test (pictures were not included in the latter test because the temporal meanings of most prepositions are too abstract to be clearly depicted). The 60 items consist of 15 instances of four sentence frames that focus on different aspects of event structure: the occurrence itself ("It happened . . ."), the beginning ("It began . . ."), the end ("It finished . . ."), and the duration ("It lasted . . ."). The syntactic simplicity and consistency of the sentence frames minimizes the amount of language processing that is necessary. The subject is told that each sentence refers to some vague event (expressed merely as "it"), and that he/she should concentrate on determining which preposition is most appropriate. Eight prepositions are used: *at*, *on*, *in*, *around*, *between*, *through*, *over*, and *under*. All but one of them (*at*) are also used in the Spatial Matching Test. The 60 items instantiate all of the different types of temporal situations illustrated in Table 1.

In order to perform well on the test, the subject must determine which prepositional meaning is most compatible with the other elements in the sentence. This requires identifying which aspect of event structure the verb denotes, accessing the temporal meanings of the three prepositions, and understanding the kind of landmark time period expressed by the noun-phrase. The landmark time periods are as follows: precise clock times (e.g., *9:15*); day-parts (e.g., *morning*); days of the week (e.g., *Tuesday*); months of the year (e.g., *July*); seasons (e.g., *summer*); and years (e.g., *1859*). For two kinds of landmark time period—namely, clock times and years—there are a potentially unlimited number of possible instantiations, so the correct preposition must be determined by means of semantic computations based on certain rules of English that stipulate which preposition is associated with which temporal category. For example, some of the test items have the same verb and the same array of prepositions to choose from, but differ with regard to whether the landmark time period is a particular clock time or a particular year. This is exemplified by the following two items: “It happened *on*/*in*/*at* 9:15” and “It happened *at*/*in*/*on* 1831.” Because the first item specifies that an event coincided with a clock time, the correct preposition is *at*, and because the second item specifies that an event occurred during a year, the correct preposition is *in*. For the other four kinds of landmark time period—namely, day-parts, days, months, and seasons—there are only a few conventionalized instantiations expressed by certain sets of nouns, and for this reason it is possible that people store in long-term memory specific preposition-noun collocations (e.g., *in the afternoon*, *on Friday*, *in May*, *in the spring*). However, an essential point is that even if such collocations are memorized, they must be tagged with the semantic information that they are only suitable when the temporal relationship involves “overlap”—i.e., occurrence of the focal event at some point during the landmark time period. Successful performance on the test depends crucially on this kind of semantic knowledge, because some of the items have the same array of prepositions to choose from and also the same landmark time period, but differ with regard to which verb is used and, consequently, with regard to which kind of temporal relationship is involved. Consider, for example, the following two items: “It began *through*/*on*/*in* the evening” and “It lasted *in*/*through*/*on* the evening.” The first item specifies a temporal overlap scenario, so the correct preposition, given that the landmark time period is a day-part, is *in*. By contrast, the second item specifies a “coextension” scenario (i.e., the focal event co-occurs with the entire extent of landmark time period), so the correct preposition, regardless of the exact nature of the landmark time period, is *through*.

Two short control tests were used to evaluate knowledge of the kinds of nouns and verbs that appear in the Temporal Matching Test. First, the Temporal Nouns Test involves words for landmark time periods. It employs a three-alternative forced-choice paradigm and contains 18 items. For each item, a single noun denoting a particular time period is presented together with three different choices of definitions. For example, “Summer is (a) a year, (b) a season, or (c) a day of the week.” Nouns for six different types of time period are included (clock times, day-parts, days, months, seasons, and years), and there are three instances of each type. Second, the Temporal Verbs Test focuses on the four verbs that occur repeatedly in the Temporal Matching Test: *begin*, *finish*, *happen*, and *last*. The test employs a three-alternative forced-choiced paradigm and contains eight items that are divided into two sets with four items each. For each set, there is a single “reference scenario” that is described with a simple sentence, followed by a series of four additional sentences, each of which is based on the reference scenario and includes one of the four verbs. The task is to match each sentence with the correct interpretation. For example, the first set of items is as follows. Reference scenario: “Imagine that a man drove from Iowa City to Chicago.” Item 1: “The sentence *That’s what happened* is about (a) just the first part of the trip, (b) the whole trip, or (c) just the final part of the trip.” Item 2: “The sentence *He was tired when he began* is about (a) how long the trip took, (b) just the first part of the trip, or (c) just the final part of the trip.” Item 3: “The sentence *He was tired when he finished* is about (a) just the final part of the trip, (b) the whole trip, or (c) how long the trip took.” Item 4: “The sentence *The trip lasted three hours* is about (a) how long the trip took, (b) just the first part of the trip, or (c) just the final part of the trip.”

3. Results

The control subjects obtained the following average scores on the tests: Spatial Matching Test = 97.1% (2.3); Temporal Matching Test = 99% (1.3); Temporal Nouns Test = 100%; Temporal Verbs Test = 95.2% (6.2). The four brain-damaged subjects’ performance profiles are reported below (Fig. 1).

1760KS selected the correct preposition for only 39 (46%) of the 80 items in the Spatial Matching Test, yet he scored 56/60 (90%) on the Temporal Matching Test—a highly significant difference (chi-square (1) = 31.2, $p < 0.001$). 1978JB exhibited a similar, albeit milder, dissociation between the two matching tests (Spatial = 66/80, 83%; Temporal = 58/60, 97%; chi-square (1) = 6.8, $p < 0.01$). Both subjects manifested the dissociation for every preposition that was commonly used across the tests, the only (minor) exception being *under* for 1978JB. In addition, both subjects performed well on the Temporal Nouns Test (1760KS = 100%; 1978JB = 100%) and on the Temporal Verbs Test (1760KS = 88%; 1978JB = 100%).

The other two brain-damaged subjects were the opposite of the first two insofar as they performed significantly worse on the Temporal Matching Test than on the Spatial Matching Test. 1962RR failed both tests, yet his score for the Temporal test was far lower than his score for the Spatial test (21/60, 35%, and 56/80, 70%, respectively; chi-square (1) = 16.9, $p < 0.001$). Moreover, he manifested the dissociation for five of the seven prepositions that were used in both tests. He was at ceiling on the Temporal Nouns Test, so his failure on the Temporal Matching Test cannot be attributed to impaired knowledge of the meanings of words for landmark time peri-

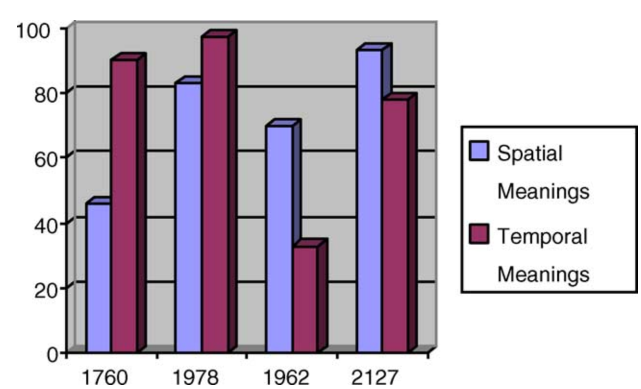

Fig. 1. Performance scores of the four brain-damaged subjects on the Spatial Matching Test, which evaluates knowledge of the spatial meanings of prepositions, and the Temporal Matching Test, which evaluates knowledge of the temporal meanings of the same prepositions.

ods. However, his score for the Temporal Verbs Test was 6/8 (75%), and both of his errors were for the verb *finish*, which suggests that he may have some trouble understanding this particular verb. If so, this raises the possibility that his extremely low score (13%) on the 15 items in the Temporal Matching Test that employ the "It finished . . ." frame might reflect not only impaired knowledge of the relevant temporal meanings of the four prepositions that occur in that frame (*at*, *on*, *in*, and *around*), but also a comprehension deficit for the verb *finish*. Finally, turning to 2127HW, she was unimpaired on the Spatial Matching Test but had a moderate degree of difficulty with the Temporal Matching Test (74/80, 93%, and 47/60, 78%, respectively; chi-square (1) = 5.9, $p < 0.025$)—a pattern which complements that of 1978JB. She performed well on both the Temporal Nouns Test (100%) and the Temporal Verbs Test (88%), suggesting that her poor performance on the matching test was due to partially defective knowledge of the temporal meanings of prepositions.

4. Discussion

4.1. Double dissociation between the spatial and temporal meanings of prepositions

The dissociation manifested robustly by 1760KS, and to a lesser extent by 1978JB, constitutes evidence that impaired knowledge of the spatial meanings of prepositions does not necessarily lead to disrupted appreciation of the analogous temporal meanings of the same prepositions. For instance, in the Spatial Matching Test 1760KS failed an item in which the picture shows a baseball in a baseball glove and the sentence is "The ball is *on*/*in*/*against* the glove" (he selected *against* instead of *in*); however, in the Temporal Matching Test he correctly chose *in* for an item in which the sentence is "It happened *through*/*on*/*in* 1859." This example, together with others like it, suggests that a disturbance of the knowledge that *in* is used to specify that an entity is located within an idealized container does not necessarily preclude understanding that the same preposition is also used to specify that an event occurred during a particular year. This finding, as well as similar findings involving the other prepositions considered in this study, has significant implications for the controversial question of whether the TIME IS SPACE metaphor actively influences the way that prepositional meanings are represented and processed. In particular, the dissociation challenges the strong view, since this hypothesis claims that understanding the temporal meanings of prepositions always requires on-line structural alignment with the corresponding spatial schemas; conversely, the dissociation supports the weak view, since this alternative hypothesis claims that such an alignment process is not obligatory.

If only the one-way dissociation manifested by 1760KS and 1978JB had been found, this study would be vulnerable to the following criticism, one that plagues one-way dissociations of all kinds. Perhaps the Spatial Matching Test and the Temporal Matching Test both require certain processing mechanisms, but the former test recruits these mechanisms to a greater degree; in other words, it is more difficult. If so, the dissociation could be a reflection of damage to these shared mechanisms, as opposed to a reflection of damage to an independent neural network for the spatial meanings of prepositions. However, this potential "resource artifact" criticism (Shallice, 1988) is obviated, or at least rendered less plausible, by the additional finding that both 1962RR and 2127HW, but especially the former, performed significantly worse on the Temporal Matching Test than on the Spatial Matching Test. The presence of a double dissociation between the two types of prepositional meaning therefore strengthens the proposal that they have separate neural substrates and are represented and processed independently of each other.

4.2. Functional–anatomical issues

The neuroanatomical correlates of the spatial meanings of prepositions are slowly being elucidated, with neuroimaging (Damasio et al., 2001) and neuropsychological (Kemmerer & Tranel, 2000, 2003; Tranel & Kemmerer, in press) studies suggesting that the left supramarginal gyrus is a critical structure (see also Kemmerer, submitted for publication). This cortical region is damaged in all three of the subjects in the current study who exhibited impaired knowledge of the spatial meanings of prepositions (1760KS, 1978JB, and 1962RR) and is spared in the single subject who exhibited intact knowledge of these meanings (2127HW).

As for the neuroanatomical correlates of the temporal meanings of prepositions, this study is the first one to address the topic, and the data are equivocal. While these meanings are preserved for both 1760KS and 1978JB, they are disrupted for both 1962RR and 2127HW (although to a much greater degree for 1962RR), and yet the lesion sites for 1760KS, 1978JB, and 1962RR overlap to a large extent (especially those of 1760KS and 1962RR) and also include or encroach on the white matter regions that are damaged in 2127HW. Hence it is difficult to identify neuroanatomical dissociations that match the neuropsychological dissociations. Still, the left perisylvian cortex appears to be implicated, which is interesting in light of neuroimaging (e.g., Bellin et al., 2002; Coull & Nobre, 1998; Rao, Mayer & Harrington, 2001), electrophysiological (e.g., Mohl & Pfurtscheller, 1991), and neuropsychological (e.g., Critchley, 1953; Harrington & Haaland, 1999; Mangels & Ivry, 2001) studies indicating that the right inferior parietal cortex is important for time perception (see Walsh, 2003, for a review). Note, however, that these studies focus on the perceptual coding of fine-grained temporal magnitudes, as opposed to the semantic coding of coarse-grained temporal notions; in addition, there is independent evidence that more generally the right hemisphere is dominant for coordinate (i.e., metrically precise) representations whereas the left hemisphere is dominant for categorical representations (e.g., Ivry & Robertson, 1998; Jager & Postma, 2003; Laeng, Chabris & Kosslyn, 2003).

4.3. Methodological issues

A methodological limitation of the current study is that the design characteristics of the two matching tests are not perfectly equated. For the items in the Spatial Matching Test, all three prepositions are compatible with the linguistic context of the sentence, so identifying the correct preposition depends entirely on determining which one accurately characterizes the spatial relationship shown in the visual stimulus. For instance, in the item "The ball is *on*/*in*/*against* the glove," all of the prepositions yield well-formed sentences with reasonable interpretations, and *in* is the correct choice because its meaning corresponds best to the depicted scene. On the other hand, for the items in the Temporal Matching Test, only the correct preposition gives rise to a legitimate sentence. Thus, in the item "It happened *through*/*on*/*in* 1859," the correct answer is *in* because it is the only preposition that is fully compatible with both the verb *happened* and the noun *1859*. This methodological discrepancy between the two matching tests is admittedly a limitation of the present study, and overcoming it should be a goal of future research. However, it is worth emphasizing that successful performance on the Temporal Matching Test cannot be reduced to mere statistical knowledge of the brute co-occurrence possibilities of the forms of words, but instead depends crucially on quite specific semantic knowledge of how temporal concepts are encoded in English (cf. Section 2.2.2). Returning to the example above (which is, for present purposes, representative of the other items in the test), although the two incorrect prepositions—*through* and *on*—are incompatible with the entire sentence frame established by the flanking expressions *It happened* and *1859*, the only two-word combinatorial pattern that is truly ungrammatical is the phrase *on 1859*, and in order to recognize that this phrase is ungrammatical, one must appreciate the following semantic points: first, *1859* denotes a time period of the category "year"; and second, for temporal overlap scenarios involving this kind of time period, English stipulates that the appropriate preposition is *in*. The preposition *through* can easily co-occur with nouns denoting years, specifically when the temporal context involves coextension—e.g., *It lasted through 1859*. Finally, both *through* and *on* can easily co-occur with the verb *happened*—e.g., the sentence *It happened through the efforts of many people* specifies causation, and the sentence *It happened on Tuesday* specifies temporal overlap with a day. Details like these were carefully manipulated during the construction of the Temporal Matching Test, and while it is true that the test does have shortcomings, I submit that it nevertheless serves as a useful first attempt to evaluate people's knowledge of how English prepositions encode the complex semantic domain of time—a domain that is treated somewhat differently by all the languages that have been systematically investigated (Haspelmath, 1997).[2]

4.4. Refining the weak view

The findings reported in this paper suggest that the TIME IS SPACE metaphor does not play a necessary role in the on-line processing of prepositional meanings. This does not imply, however, that the metaphor is "dead" in the minds of modern adults. Several studies have shown that when spatial cues are provided to people, they spontaneously and sometimes unwittingly exploit them when confronted with tasks that involve explicit, linguistically mediated reasoning about time, presumably because the TIME IS SPACE metaphor is a useful aid to problem-solving, one that is made prepotent by the innate design of the human brain. Most of this research focuses on two specific metaphors that are commonly used to talk about sequences of events: the ego-moving metaphor, wherein the observer progresses along the timeline toward the future (e.g., *We are fast approaching the holidays*); and the time-moving metaphor, wherein time progresses toward the observer from the future (e.g., *The holidays are coming up fast*). McGlone and Harding (1998) presented subjects with the ambiguous statement *Wednesday's meeting was moved one day forward* and found that it was preferentially interpreted as Thursday if the preceding metaphoric context was ego-moving, but as Tuesday if the preceding metaphoric context was time-moving (see also Boroditsky, 2000, and Gentner et al., 2002, on metaphor consistency effects). Pursuing this line of inquiry further, Boroditsky and Ramscar (2002) discovered that the same ambiguous statement was more likely to be interpreted as Thursday—possibly reflecting application of the ego-moving metaphor—if subjects were simply engaged in the physical act of moving closer to a goal such as the end of a lunch line or the end of a train ride. In addition, Boroditsky (2000) found that when subjects answered questions about time, their responses were significantly faster (129-ms benefit) if they were first primed with spatial schemas. Boroditsky (2001) also demonstrated that this priming effect is influenced by cross-linguistic differences in space–time metaphors. To talk about the order of events, English speakers often use horizontal terms oriented along the egocentrically grounded anterior/posterior axis (e.g., the bad times *behind* us and the good times *ahead* of us), whereas Mandarin speakers often use vertical terms—specifically, earlier events are said to be

[2] A new approach might be to design a three-alternative forced-choice sentence completion test that evaluates knowledge of both the spatial and temporal meanings of prepositions with minimally varying items like the following: "It happened *through*/*on*/*in* the garden" versus "It happened *through*/*on*/*in* 1859." The non-target prepositions in both items yield unacceptable sentences, so that factor is controlled. It is noteworthy, however, that preposition choice for the spatial item depends on complex aspects of how gardens are conceptualized for purposes of linguistic expression in English (e.g., whether they are better construed as idealized containers or idealized surfaces—cf. Hawkins, 1998), whereas preposition choice for the temporal item depends on the relatively simpler and more abstract knowledge that 1859 is a year. This difference in semantic complexity and concreteness is unavoidable because it reflects the fact that the temporal meanings of prepositions are always more grammaticalized than the spatial meanings (Haspelmath, 1997; Heine et al., 1991; Heine & Kuteva, 2002; Hopper & Traugott, 2003; Natalya Kaganovitch, personal communication).

shang or "up," and later events are said to be *xia* or "down." Remarkably, when answering true/false questions about time (e.g., "March comes earlier than April"), English speakers were faster if they had just seen a horizontal array of objects, and Mandarin speakers were faster if they had just seen a vertical array.

Overall, these studies suggest that spatial information can be very useful for thinking about time, and other studies point to an even more fundamental link between spatial and temporal perception (see Walsh, 2003, for a review). However, there is no evidence that spatial schemas are absolutely necessary for temporal reasoning, and in fact Boroditsky (2000) reports that temporal primes do not facilitate performance on spatial reasoning tasks, which suggests that thinking about time does not automatically trigger or depend on the activation of corresponding spatial representations. This result converges nicely with the neuropsychological data presented above, since both discoveries support the weak view over the strong view. Further support for the weak view comes from a series of psycholinguistic experiments with normal adults which demonstrated that in on-line as well as off-line tasks, the spatial and temporal meanings of *at*, *on*, and *in* were treated quite differently (Sandra & Rice, 1995; Rice et al., 1999). These findings are consistent with many people's impression that space–time parallelisms like those shown in Table 1 are so conventional that they are not very salient or transparent to awareness (Jackendoff & Aaron, 1991).

The fact that space–time parallelisms reflect highly conventionalized metaphors allows some theoretical refinements to made to the weak view. As noted in Section 1, it may be the case that the TIME IS SPACE metaphor contributes to the initial learning of the temporal meanings of prepositions during language acquisition. However, it is likely that those meanings eventually become stored entirely in the conceptual domain of time, so the metaphor can be set aside like a scaffolding that is no longer needed. From a computational perspective, this process—which Gentner (2001) calls "the career of metaphor"—would be more efficient than always having to establish structural alignments with spatial schemas via metaphoric mapping whenever a preposition is used to encode a temporal meaning. As Boroditsky (2000, p. 4) puts it, "spatial metaphors may play a role in shaping the domain of time. However, with frequent use, an independent representation is established in the domain of time, and so spatial schemas may no longer need to be accessed in thinking about time."

4.5. The broader application of spatial schemas in abstract language and thought

A number of scholars have been justifiably impressed by the discovery that spatial schemas provide a framework for structuring not just the conceptual domain of time, but also a variety of other abstract conceptual domains—indeed, so many that Gentner et al. (2001, p. 242) suggest that the domain of space deserves "universal donor" status. Levinson (2003, p. 16) provides an illuminating list—although it is only intended to reveal the tip of an iceberg (e.g., Cienki, 1998; Dirven, 1993; Gattis, 2001; Heine et al., 1991; Heine & Kuteva, 2002; Kuteva & Sinha, 1994; Lakoff & Johnson, 1999, 2003; Lindstromberg, 1998; Pinker, 1989; Radden, 1985)—of some of the abstract arenas that we routinely talk about in spatial terms: "kinship (as in 'close' and 'distant kin', or the vertical metaphor of 'descent' in kinship) and social structure more generally (as in 'high' and 'low status'), music ('high' and 'low tones'), mathematics ('high' and 'low numbers', 'narrow intervals', 'lower bounds', 'open' and 'closed sets', etc.), emotions ('high spirits', 'deep depressions'), and much more ('broad learning', 'a wide circle of friends', 'the place for respect', and so on)." These and other considerations raise the possibility that the capacity to convert non-spatial problems into spatial ones is a key feature of human cognition. The neurobiological and evolutionary foundations of this remarkable capacity clearly deserve further investigation.

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