Cognitive Science: A Multidisciplinary Journal
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t775653634

Congruity Effects in Time and Space: Behavioral and ERP Measures

Ursina Teuscher [a]; Marguerite McQuire [a]; Jennifer Collins [a]; Seana Coulson [a]
[a] Department of Cognitive Science, University of California, San Diego

Online Publication Date: 01 April 2008

To cite this Article Teuscher, Ursina, McQuire, Marguerite, Collins, Jennifer and Coulson, Seana(2008)'Congruity Effects in Time and Space: Behavioral and ERP Measures',Cognitive Science: A Multidisciplinary Journal,32:3,563 — 578

To link to this Article: DOI: 10.1080/03640210802035084

URL: http://dx.doi.org/10.1080/03640210802035084

Cognitive Science 32 (2008) 563–578

ISSN: 0364-0213 print / 1551-6709 online
DOI: 10.1080/03640210802035084

Congruity Effects in Time and Space: Behavioral and ERP Measures

Ursina Teuscher, Marguerite McQuire, Jennifer Collins, Seana Coulson

Department of Cognitive Science, University of California, San Diego

Received 9 December 2005; received in revised form 14 April 2007; accepted 19 April 2007

Abstract

Two experiments investigated whether motion metaphors for time affected the perception of spatial motion. Participants read sentences either about literal motion through space or metaphorical motion through time written from either the ego-moving or object-moving perspective. Each sentence was followed by a cartoon clip. Smiley-moving clips showed an iconic happy face moving toward a polygon, and shape-moving clips showed a polygon moving toward a happy face. In Experiment 1, using an explicit judgment task, participants judged smiley-moving cartoons as related to ego-moving sentences about space and about time, and shape-moving cartoons as related to object-moving sentences. In Experiment 2, participants viewed the same stimuli, but the cartoons were task-irrelevant. Event-related brain potentials revealed an early attentional effect of congruity on cartoons following sentences about space, and a later semantic effect on cartoons following sentences about time. Results are most consistent with accounts that posit differences in the processing of novel and conventional metaphors.

Keywords: Abstract concepts; Career of metaphor; Conceptual blending; Conceptual integration; Embodiment; Event-related brain potentials (ERPs); Mappings; Metaphor comprehension

1. Introduction

According to conceptual metaphor theory (CMT), metaphorical structuring forms a critical component of our understanding of abstract concepts such as time, causality, and infinity such that conceptual structure in concrete, experientially grounded domains affects the organization of abstract concepts (Lakoff & Johnson, 1999; Lakoff & Núñez, 2000). Perhaps the most controversial aspect of this theory is the psychological reality of metaphorical mappings, or correspondences between domains, that have been proposed to underlie the meaning of

Correspondence should be addressed to Seana Coulson, Department of Cognitive Science, University of California, San Diego, 9500 Gilman Dr., La Jolla, CA 92093-0515. E-mail: coulson@cogsci.ucsd.edu

metaphoric expressions. Gentner (2001) argued that CMT is most compatible with a psychological proposal she called *system mapping*. In system mapping, particular instances of metaphoric language occur because of multiple correspondences between the elements (or objects) and relations (or predicates) in the metaphor's two domains (Gentner, 2001; Gentner, Bowdle, Wolff, & Boronat, 2001). According to system mapping, mappings are activated online during comprehension.

However, a number of appealing alternatives to system mapping have been proposed. For example, Bowdle and Gentner's (2005) *career of metaphor model* (an extension of their earlier *cognitive archeology* proposal; cf. Bowdle & Gentner, 2001) proposes that, although analogical mappings between domains are important for the emergence of novel word senses, once those senses become established, their online comprehension involves the retrieval of abstract relational categories. Alternatively, the *structural similarity* proposal is that a common set of terms denotes elements and relations in the two domains of a metaphor because those domains share inherent similarities (Murphy, 1996, 1997). In contrast to CMT, which posits metaphorical mappings from concrete source domains to more abstract target domains, the structural similarity proposal considers both domains to be equally basic. Moreover, on the structural similarity proposal, metaphor comprehension involves the activation of an abstract schema shared in both domains rather than the activation of source domain concepts.

One of the fundamental metaphors in cognitive linguistics is the mapping between time and space in which spatial terms are used to discuss time. In their original formulation, Lakoff and Johnson (1980) described the time is space metaphor as the *time is a moving object* metaphor in which time can be seen in two different ways. First, it is possible to conceive of time as being a stationary landscape, through which we move (consider such examples as we are *approaching Christmas*, he is *nearing* his 30th birthday). Alternatively, it is possible to conceive of ourselves as being stationary, and of time as moving past us (e.g., time *flies*, the *coming* weeks, the deadline is *approaching*).

Temporal metaphors have been extensively studied in an attempt to determine whether experimental manipulations that affect the way people think about space have consequences for their reasoning about time (Boroditsky, 2000; Boroditsky & Ramscar, 2002; Clark, 1973; Gentner, 2001; Gentner, Imai, & Boroditsky, 2002; Núñez, Motz, & Teuscher, 2006). For example, to prime either the ego- or the object-moving construal of space, Boroditsky (2000) asked participants to imagine either pulling a rolling office chair toward themselves or moving themselves on a rolling office chair. After that, the participants' construal of time was assessed, using the following ambiguous statement: "Next Wednesday's meeting has been moved forward two days. What day is the meeting on now that it has been rescheduled?" (see also McGlone & Harding, 1998). The word *forward* means later in time on the ego-moving construal and earlier on the object-moving construal, so that one's answer to the question suggests which construal the speaker has adopted. Participants in the ego-moving picture condition tended to respond "Friday," consistent with the ego-moving construal of "forward," whereas those in the object-moving condition tended to respond "Monday" (Boroditsky, 2000; see also Boroditsky & Ramscar, 2002; Matlock, Ramscar, & Boroditsky, 2005).

These studies support CMT over competing proposals because they suggest that recent experiences and construals of actual motion influence our interpretation of statements about time. Boroditsky's (2000) findings suggest, moreover, that the influence was asymmetrical:

Spatial primes were able to influence temporal reasoning, but temporal primes did not influence spatial reasoning. However, many studies have involved "offline" measures, and have often been based on participants' interpretation of the Wednesday meeting question (e.g., Boroditsky & Ramscar, 2002; McGlone & Harding, 1998; but, see Torralbo, Santiago, & Lupianez, 2006, for an innovative approach to this issue).

In this study, we addressed the connection between our understanding of motion in space and the progression of time with a novel paradigm. In particular, we tested whether people were able to perceive incongruency between the direction of literal or metaphorical motion in sentence stimuli and the direction of motion in a cartoon clip. In Experiment 1, we used an explicit judgment task; in Experiment 2, we used event-related brain potentials (ERPs) to assess participants' tacit recognition of incongruity.

The system mapping (CMT) proposal posits the activation of spatial schemas for the comprehension of sentences involving literal as well as metaphorical motion, and thus predicts qualitatively similar incongruency effects for both sorts of sentences.

According to the career of metaphor model, the space–time mapping is highly conventionalized so that speakers no longer recruit spatial schemas in their online comprehension of motion metaphors for time. If this proposal is correct, we expect to observe congruency effects for sentences about motion through space, but not for sentences that concern the temporal domain.

According to the structural similarity proposal, the use of motion verbs to describe events in the spatial and temporal domains reflects the fact that the same abstract schemas are recruited in the comprehension of both. Consequently, the structural similarity hypothesis predicts similar (presumably null) effects of congruency for both sorts of sentences, as they evoke similar schemas with only an abstract relation to the motion in the clips.

2. Experiment 1: Behavioral measures

To see if people understand the motion verbs in metaphoric expressions about time as evoking spatial motion, we asked participants to decide whether animated cartoon clips were related to a preceding sentence context. All sentences contained motion verbs, but one half described literal motion through space and one half metaphorical motion through time (see Table 1 for sample stimuli). Cartoon clips involved either a smiley face moving toward a shape, or a shape moving toward a smiley face; clips were designed to be congruent with ego- and object-moving sentences, respectively.

System mapping predicts participants will see the congruency relation both for sentences about space and for sentences about time. The career of metaphor model predicts participants will see congruity relations for sentences about space, but not about time. Structural similarity predicts responses will be randomly distributed both for space and for time.

2.1. Method

Twenty-four undergraduate students of the University of California, San Diego (UCSD) participated in the experiment for course credit. All participants were native English speakers.

Table 1
Sample materials

Variable	Example
Space	
Ego	We are coming closer to the stretch-limo but we can't see who is inside.
Object	The stretch-limo is coming closer but we can't see who is inside. (LONG/BIRTH)
Ego	They are drifting towards small clouds in their hot-air balloon.
Object	Small clouds are drifting towards them in their hot-air balloon. (FLUFFY/HIDE)
Ego	I am approaching the parade, my favorite part is always the baton twirler.
Object	The parade is approaching, my favorite part is always the baton twirler. (MARCHING/UNIVERSITY)
Ego	She was moving toward the buffalo but they didn't seem to care about her.
Object	The buffalo were moving toward her but they didn't seem to care about her. (HERD/CROP)
Ego	He is drawing near to the truck, he could easily be crushed by those huge tires!
Object	The truck is drawing near, he could easily be crushed by those huge tires! (SMASHED/BLOWHOLE)
Time	
Ego	We are drawing near to 8 o'clock when we'll see ourselves on the news.
Object	8 o'clock is drawing near when we'll see ourselves on the news. (ANCHORMAN/CONSTRUCTION)
Ego	I was getting closer to the day of my blind date and I hadn't chosen my outfit!
Object	The day of my blind date was getting closer and I hadn't chosen my outfit! (CLOTHES/HELMET)
Ego	Dottie was quickly moving toward retirement but she was still working as hard as ever.
Object	Retirement was quickly moving toward Dottie but she was still working as hard as ever. (JOB/ROUND)
Ego	We're quickly approaching the day of the exam, I almost have my crib sheet ready.
Object	The day of the exam is approaching, I almost have my crib sheet ready. (CHEAT/HILLSIDE)
Ego	I am drawing near to my week of tango lessons, I don't know if I have the right shoes.
Object	The week of tango lessons is drawing near, I don't know if I have the right shoes. (DANCE/ARMY)
Filler	
	The archaeologists left the mummy in the pyramid in the sepulchral chamber. (EGYPT/CRUISE)
	The masterpiece was hanging above his desk in an ornate frame. (ART/ZOO)
	My uncle works in downtown London close to the subway. (BRITAIN/POWERPOINT)
	The toy is in the doghouse under the dog's tattered blanket. (PLAY/SUNRISE)
	My uniform is at my place in the hamper in the downstairs bathroom. (LAUNDRY/CHECKMATE)

Experimental materials included 80 pairs of sentences describing literal motion through space, either ego-moving or object-moving; another 80 pairs of sentences with the same basic structure described metaphorical motion "through" time, again either ego moving or object moving (see Table 1). Two lists were constructed so that, although no participant read more than a single version (ego–object) of each sentence, across lists both ego- and object-moving versions of all sentences were presented. Besides experimental stimuli, there were 80 filler sentences that described the location of objects in different spatial contexts (see Table 1).

The stimuli also included short animated cartoon clips. Cartoons ranged from 8 to 11 frames, and each frame was presented for 90 msec to 110 msec, such that cartoons ranged from 800 to 1,100 ms in duration. The "smiley-moving" clips showed an iconic happy face moving toward a static geometric figure (e.g., a square, a triangle, a polygon). The "shape-moving" clips showed a geometric figure moving toward a static happy face. One half of the clips in each condition involved leftward motion, and one half involved rightward motion. One half of the filler sentences (40) were followed by clips used in the test condition, and one half (40) by novel clips in which the face conveyed different emotional expressions.

In total, each participant saw a list of 240 sentences—80 spatial, 80 temporal, and 80 filler sentences—each followed by a cartoon clip and a one-word memory probe. Among the experimental stimuli, one half of the sentences in each condition were followed by a congruous, and one half by an incongruous cartoon clip. Pairings between object-moving sentences and shape-moving cartoons were considered incongruent, as were ego-moving sentences and smiley-moving cartoons; pairings between object-moving sentences and smiley-moving cartoons and between ego-moving sentences and shape-moving cartoons were considered incongruous. All clips following filler stimuli were considered incongruous.

Memory probes consisted of a word that was deemed by the experimenters to be either related or unrelated to the preceding sentence context. For example, for the sentence, "The stretch limo is coming closer but we can't see who is inside," the related probe was "long" and the unrelated probe was "birth." One half of the sentences in each condition were paired with a related target word, and one half with an unrelated word. Relatedness was counterbalanced across lists.

Participants were seated alone in a small room in front of a PC running the presentation program E-prime. Each trial began with the presentation of a sentence on a single screen. Participants pressed a button when ready to proceed. Each sentence was followed first by a cartoon clip, and then by a one-word memory probe. Participants were instructed to read the sentence, watch the clip, and then to press the "y" key if they felt it "goes with" the preceding sentence, and the "n" key otherwise. A memory probe followed each clip during which participants were presented with a target word and asked to decide whether it was related (y) or unrelated (n) to the preceding sentence. The experiment began with three practice trials, after which participants were given the opportunity to ask for clarification on the instructions.

2.2. Results and discussion

Average accuracy rate for judging the relatedness of the target words on the memory task was 68.6% correct ($SD = 20.7$). Accuracy scores on the memory probes in each of the experimental conditions, as well as the filler condition, can be found in Table 2. Repeated measures analysis with factors *domain* (space–time) and *congruity* (congruous–incongruous) revealed no reliable effects. Mean reaction times (RTs) for correct responses to the memory probes were trimmed such that RTs more than two standard deviations above or below the overall mean were replaced by the overall mean. This resulted in replacement of less than 1% of the dataset. A similar analysis as for the accuracy scores revealed no effects (all

Table 2
Accuracy scores on the memory probe task

Experimental category	% correct	SD
Experiment 1		
Space congruous	64.5	23.7
Space incongruous	75.3	15.7
Time congruous	60.1	25.5
Time incongruous	72.1	25.1
Fillers	68.6	18.7
Experiment 2		
Space congruous	93	5
Space incongruous	95	4
Time congruous	95	6
Time incongruous	97	3
Fillers	95.5	5

Fs < 1). Performance on the memory probe task suggests participants adequately understood experimental materials.

However, the main point of Experiment 1 was to establish whether participants were sensitive to the congruity relation between the apparent motion in our cartoons and experimental sentences that either described motion through space or that employed motion metaphors to describe temporal events. Accuracy on the congruency judgment task was defined as a yes response to a smiley-moving clip following an ego-moving sentence, or a shape-moving clip following an object-moving sentence. Similarly, other correct responses included no to a smiley-moving clip following an object-moving sentence, or a shape-moving clip following an ego-moving sentence.

Overall, participants were fairly accurate, averaging 72.9% correct. Out of 24 participants, 4 had accuracy rates between 40% and 59%, 11 between 60% and 79%, and 9 between 80% and 100%. The mere fact that 20 out of 24 people performed at a rate far greater than that predicted by chance suggests our participants saw a relation between the perspective of the sentences and the direction of motion in the cartoons.

To assess whether participants were indeed cognizant of this congruity relation, we also computed chi-square statistics for the distribution of yes and no judgments for cartoons following sentences about time versus cartoons following the filler sentences. Results of this test indicated participants were reliably more likely to respond no to cartoons following filler sentences than sentences about temporal events: $\chi^2(1, N = 4000) = 60.9$, $p < .001$. By contrast, a similar analysis of responses following experimental sentences revealed no evidence of a difference in the (overall) distribution of yes and no responses to cartoons following sentences about space versus those about time: $\chi^2(1, N = 4000) = 0.14$, $p < 1$.

Mean RTs for correct responses on the judgment task were trimmed such that RTs more than two standard deviations above or below the overall mean were replaced by the overall mean. This resulted in replacement of 5% of the dataset. Initial analysis with repeated measures analysis of variance (ANOVA) with factors domain (space–time) and congruity (congruous–incongrous) revealed no reliable effects of domain: *participants analysis,* $F1(1,$

23) = 1.29, *ns* and *items analysis* $F2(1, 39) = 1.46$, *ns*; or congruity: $F1(1, 23) < 1$ and $F2(1, 39) < 1$; but an interaction between the two: $F1(1, 23) = 4.78$, $p < .05$ and $F2(1, 39) = 3.83$, $p = .06$. *Post-hoc* tests suggested the interaction resulted because of a trend for longer RTs to cartoons following sentences about space than time on congruent trials: space = 605.2 msec, time = 562.9 msec, $F1(1, 23) = 3.482$, $p = .07$ and $F2(1, 39) = 5.148$, $p < .05$; but not on incongruent trials: space = 545 msec, time = 559.7 msec, $F1(1, 23) < 1$ and $F2(1, 39) < 1$. Mean RTs for filler trials were 600.4 msec (*SD* = 165.2). Longer RTs for congruous than incongruous trials is atypical as participants often respond faster for affirmative than negative response options. Longer responses to space congruent than space incongruent items may be a side effect of participants' bias to respond no in this paradigm (see later discussion). This bias makes it more likely that correct responses for congruent items reflect trials where participants actually saw a relation between the sentence and the cartoon clip, whereas correct responses for incongruent items were more likely to include participants' guesses. More important, however, the reliably longer response times for congruous cartoons following sentences about space than for the other three conditions indicate that the congruity manipulation had a greater impact on participants' behavior following sentences about space than about time.

Values for d' and beta were calculated using participants' accuracy scores on judgments of cartoons following sentences about space and time and were subjected to repeated measures ANOVA with domain (space–time) as a factor. Analysis of values for beta revealed a trend toward higher values for sentences about time ($\beta = 2.7$) than space ($\beta = 1.3$); domain, $F(1, 23) = 3.5$, $p = .07$. This suggested a greater bias to respond no to cartoons following sentences about time. Fig. 1 shows beta values for each participant's congruency judgments for cartoons following sentences about space and sentences about time, respectively. These data indicate that among most of our participants, response bias was close to 1 for sentences about space and sentences about time (i.e., they were essentially unbiased in their congruity judgments). Other participants (numbers 18–21 on Fig. 1) had a slight tendency to favor the no response for cartoons following sentences about time. Difference in response bias is thus driven mainly by a few individuals (numbers 22–24) who were unbiased in their judgments of cartoons following sentences about spatial motion, but judged all cartoons as being incongruent with sentences about time.

Analysis of d′ values suggested participants were similarly sensitive to congruity after sentences about space (d′ = 1.7) and sentences about time (d′ = 1.4); domain, $F(1, 23) = 1.04$, $p = .32$. In fact, d′ values for space and time were reliably correlated ($R = .6713$, $p < .0001$), suggesting a linear relation between participants' ability to discriminate between congruous and incongruous cartoons preceded by sentences about time and sentences about space.

In sum, responses on the judgment task were not random. Participants judged a majority of the cartoons (66%) to be unrelated to the filler sentences, whereas the distribution of responses to cartoons following experimental sentences was more evenly split between yes and no responses (53% no for space and 54% no for time). Although judgment accuracy on experimental items was poor for 4 participants, the other 20 participants scored greater than 60% correct. Analysis of beta values suggested that response strategies varied among our participants, with many adopting a relatively unbiased response pattern to both sorts of

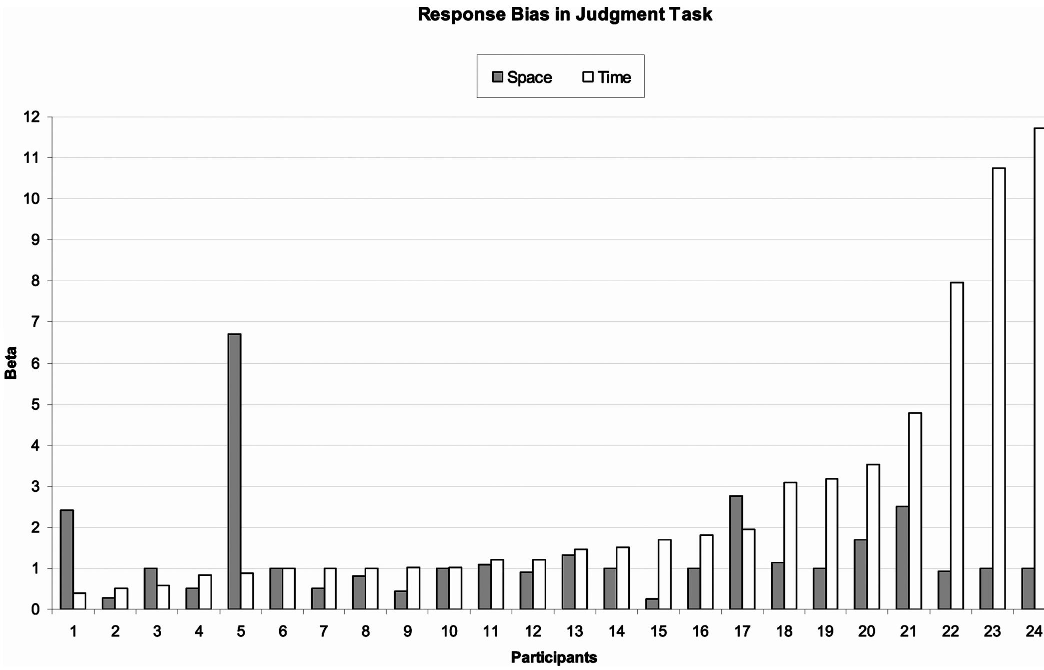

Fig. 1. Response bias (beta) of each participant on the cartoon judgment task.

experimental sentences; 1 tended to judge cartoons to be unrelated to sentences about space, whereas a few others systematically judged cartoons to be unrelated to sentences about time. Analysis of d' scores suggested the difficulty of the congruity judgment task was similar for cartoons following sentences about space and about time, as performance on the former was correlated with performance on the latter. Although some participants saw no relation between cartoons and the sentences about time, the majority were able to register the congruity between the apparent motion in the cartoon clips with sentences about time, just as they did so with sentences about literal motion through space.

3. Experiment 2: ERP measures

One potential criticism of the judgment task in Experiment 1 is that asking participants to make an explicit decision about the compatibility between the sentences and the clips may induce unnatural strategies that do not accurately represent more normal comprehension processes. Experiment 2 addressed this concern by changing the task so that an explicit judgment was no longer required, and by using participants' ERPs as the dependent measure. ERPs timelocked to the onset of the clips were assessed to determine whether the brain response to congruous clips differed from that to incongruous clips and whether congruity effects were similar after literal and metaphorical motion sentences.

3.1. Method

Twelve undergraduate UCSD students (6 women) participated in the experiment. All participants were native English speakers, and had normal or corrected-to-normal vision. None had any reported history of neurological or psychiatric disease.

All materials were identical to those used in Experiment 1, although the procedure differed slightly. Participants were asked to read the sentences, which appeared on the screen for 4,000 msec. As in Experiment 1, they were then presented with a fixation cross on a blank frame for 1,500 msec before they saw the first frame of the cartoon clip. They were asked to fixate on the cross throughout presentation of the cartoon. Frame duration in the cartoons averaged 100 msec, but varied between 90 msec and 110 msec to reduce the presence of timelocked alpha in the EEG. Cartoons were identical to those used in Experiment 1, and ranged from 800 to 1,100 msec in duration. After a pause of 750 msec, the participants were presented with a target word and were instructed to respond by pushing a button to indicate whether it was related or unrelated to the preceding sentence (as in the memory probe task in Experiment 1).

Participants' EEG was recorded with an electrode cap using 29 scalp sites, as in Coulson and Van Petten (2002). Eye movements and blinks were monitored with peri-orbital electrodes. The EEG was recorded and amplified with an SA Instruments isolated bioelectric amplifier at a bandpass of .01 and 40 Hz, and digitized online at 250 Hz.

3.2. Results and discussion

Performance on the memory probe task was quite high. Average accuracy rate for judging the relatedness of the target words was 95% correct, and accuracy scores for each of the stimulus types are listed in the bottom half of Table 2. Good performance on the memory probe task suggests participants were attentive throughout the recording session.

Better performance of participants in Experiment 2 than those in Experiment 1 can be attributed to two factors. Although sentences were similarly displayed in the two experiments, sentence reading in Experiment 1 was self-paced, whereas participants in Experiment 2 were a "captive audience" for 4,000 msec. More important, however, the memory probe task in Experiment 1 was performed after the intervening cartoon judgment task, whereas participants in Experiment 2 merely viewed the cartoons. We suggest that the imposition of the explicit judgment task in Experiment 1 impaired participants' performance on the secondary memory probe task. The high accuracy rates obtained in this study suggest participants can reliably distinguish between our related and unrelated memory probes when they devote adequate attention to task performance and to the sentences themselves.

ERPs were formed by averaging EEG elicited between 100 msec before the onset of the third frame of the cartoon and 900 msec after. The 100 msec interval before stimulus onset served as the baseline. The third frame of the cartoon was chosen because this was the point at which the direction of motion should have been readily apparent. Based on visual inspection of the data, mean amplitude of the ERPs was measured between 250 msec and 400 msec post onset, and between 650 msec and 750 msec post onset. Mean amplitude measurements were analyzed with repeated measures ANOVA with factors domain (space–time), congruity (congruous–icongruous), and electrode site (29 levels). The Greenhouse–Geisser correction for violation of sphericity was applied where relevant. For clarity, we report uncorrected (original) degrees of freedom along with the corrected p values. Because predictions concerned the similarity between effects of the two sentence domains, we also conducted separate follow-up analyses of the congruity manipulation on ERPs to cartoons following sentences about space and on ERPs to cartoons following sentences about time.

Analysis of the early interval (250–400 msec post stimulus) revealed a reliable effect of congruity, $F(1, 11) = 7.58$, $p < .05$; as ERPs to incongruous cartoons were approximately 0.6 microvolts more negative than ERPs to congruous cartoons. Sentence domain did not reliably modulate the amplitude of the ERPs—domain, $F(1, 11) < 1$; Domain × Electrode, $F(28, 308) < 1$, $\varepsilon = 0.10$; and did not interact with the congruity factor—Domain × Congruity, $F(1, 11) < 1$; Domain × Congruity × Electrode, $F(28, 308) < 1$, $\varepsilon = 0.14$. Nonetheless, follow-up analyses revealed a reliable 0.9 microvolt congruity effect for cartoons following sentences about motion through space, $F(1, 11) = 8.44$, $p < .05$; but no comparable effect for cartoons following sentences about time—congruity, $F(1, 11) < 1$; Congruity × Electrode, $F(28, 308) < 1$, $\varepsilon = 0.12$.

Analysis of the late interval (650–750 msec post onset) revealed a reliable effect of congruity, $F(1, 11) = 5.16$, $p < .05$; as ERPs to incongruous cartoons were approximately 0.7 microvolts more negative than congruous cartoons. Sentence domain did not reliably modulate the amplitude of the ERPs—domain, $F(1, 11) < 1$; Domain × Electrode, $F(28, 308) < 1$, $\varepsilon = 0.12$; and did not interact with the congruity factor—Domain × Congruity, $F(1, 11) < 1$; Domain × Congruity × Electrode, $F(28, 308) < 1$, $\varepsilon = 0.15$. Follow-up analysis of cartoons following sentences about motion through space revealed no reliable congruity effects in this interval: congruity, $F(1, 11) = 1.14$; Congruity × Electrode, $F(28, 308) < 1$, $\varepsilon = 0.13$. By contrast, analysis of cartoons following sentences about motion through time revealed a 1 microvolt trend for more negative ERPs to incongruous than congruous cartoons: congruity, $F(1, 11) = 3.84$, $p = .076$.

Fig. 2 shows ERPs recorded at three midline electrode sites to cartoons following sentences about motion through space (left) and time (right). Shading represents the interval where measurements revealed congruity effects. Thus, congruity effects following sentences about motion through space modulated early portions of the ERP, whereas those following metaphorical sentences about time modulated the later portion of the brain response.

The early congruity effect bears some resemblance to the selection negativity, an ERP component related to selective attention that is typically observed in target detection paradigms. For example, in a task where stimuli are either blue or red and participants are asked to respond to blue stimuli that occur on the left-hand side of the screen, blue stimuli on the right-hand side of the screen elicit a larger selection negativity than do the red stimuli appearing in the same location. The selection negativity is thus thought to reflect enhanced processing of the task-relevant feature (Harter & Aine, 1984). Although most target detection paradigms involve selection based on color or shape, the selection negativity has also been elicited by moving stimuli, when targets were distinguished by the speed of motion (Annllo-Vento & Hillyard, 1996).

Although the cartoons in this study were not task relevant, we suggest that participants spontaneously noticed the congruity relation between the direction of motion in the cartoons

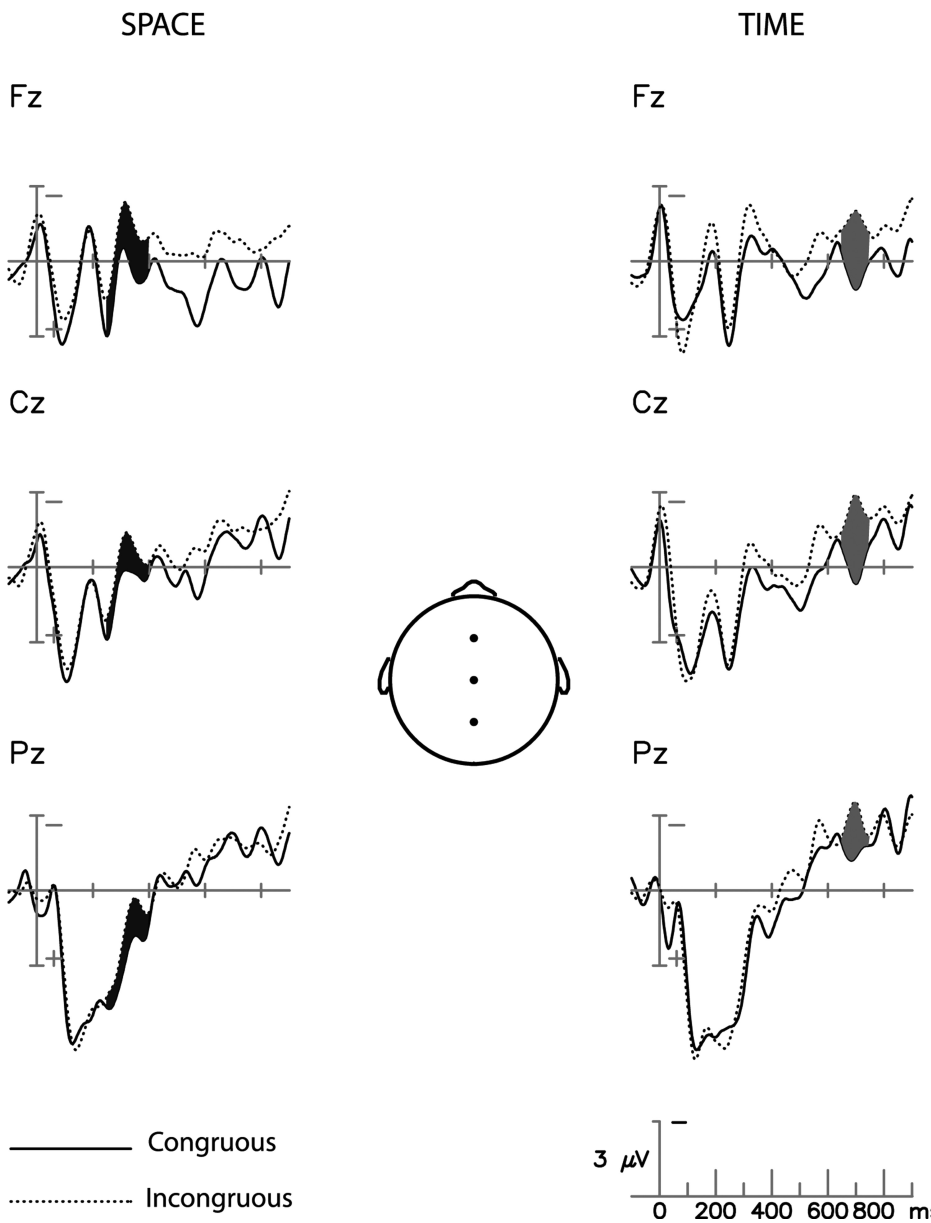

Fig. 2. Event-related potentials to congruous and incongruous sentence–cartoon pairs, timelocked to the third frame in each cartoon. *Note*. Cartoons following sentences about space are on the left, and cartoons following sentences about time are on the right. Negative voltage is plotted up.

and the perspective of the preceding sentences such that it modulated the amplitude of the N2 component (the second negative peak). Similarly, sudden changes in the direction of motion have previously been observed to modulate this component even when attention was directed at another task (Pazo-Alvarez, Amenedo, & Cadaveira, 2004). Examination of Fig. 2 suggests

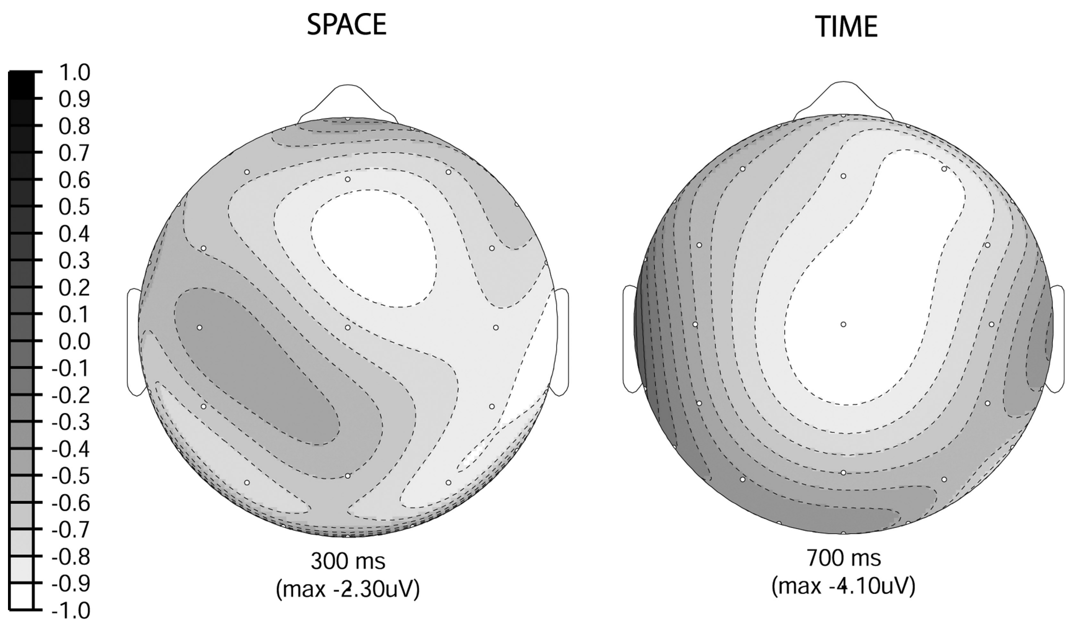

Fig. 3. Topography of the event-related potential congruity effect to cartoons following sentences about space (left) and time (right). *Note*. Voltages have been normalized on a scale from –1 to 1.

that, relative to the congruous condition, incongruous cartoons following sentences about time also elicited more negative ERPs in the early time window. However, this difference was much smaller and less robust than for cartoons following sentences about space. Presumably, this reflects the fact that the early portion of ERPs in the time condition was noisier than those in the space condition due to a more variable response to the metaphorical sentences about time across either items, participants, or both.

The scalp maps in Fig. 3 show the topography of the early congruity effect to cartoons following sentences about space and the late congruity effect to cartoons following sentences about time. These maps were obtained by subtracting the amplitude of the ERPs to congruous cartoons from ERPs to incongruous cartoons at each electrode site and interpolating the values to nearby points on the scalp. Differences in the topography of the two negativities shown in Fig. 3 indicate that the neural generators underlying congruity effects for space and time differ to some extent.

In fact, the scalp topography of the late congruity effect was similar to that of the N400 reported by West and Holcomb (2002) to the last image in a short picture story. West and Holcomb found that contextually incongruous images elicited more negative ERPs than did congruous ones, and this negativity had a frontal focus much like the effect shown in Fig. 3. However, ERPs elicited by the static images employed by West and Holcomb differed in wave shape from those observed in this study, and the relation between the two effects is a matter for further research. More important, this late congruity effect was reliable only for cartoons following sentences about time.

4. General discussion

This study addressed whether people activate mappings between spatial and temporal concepts when they encounter motion metaphors for the progression of time. Although observed effects differ from the predictions of all three accounts outlined in the introduction, we later argue our findings are most consistent with the career of metaphor proposal that conceptual structure in the source domain of a metaphor is important for the establishment of metaphorical meanings, but is often not activated when speakers understand well-established metaphors.

In Experiment 1, participants were explicitly asked whether they could see a relation between motion in cartoon clips and sentences about actual spatial motion and metaphorical motion through time. We found that most participants could relate the motion in the cartoons to both sorts of sentences; and further, that their performance on the metaphorical sentences was well-predicted by their performance on the literal ones. At first blush, these findings are most consistent with system mapping and CMT.

However, CMT does not readily explain why there was more individual variability in people's judgments about time than space. Further, if people automatically activate space–time mappings when they understand motion metaphors for time, it is difficult to explain why RT differences in this task were observed only for cartoons following sentences about space. These findings can, however, be explained by the career of metaphor proposal because speakers' potential awareness of an entrenched mapping would be expected to vary. The individual variability we observed may reflect the fact that some participants treat entrenched temporal motion metaphors more analogically and activate spatial schemas, whereas others treat them categorically and activate abstract relational schemas.

In Experiment 2, we recorded participants' ongoing EEG while they viewed the same materials as in Experiment 1. Although the cartoons were not task relevant, congruity effects were nonetheless observed in the brain's real-time response to the cartoons. Further, congruity effects were qualitatively different for sentences that described literal motion through space and for those that employed motion metaphors for temporal events. Sentences about space led to early effects on a portion of the ERP waveform that indexes stimulus evaluation and motion perception, whereas sentences about time led to later effects that may be related to semantic processing.

The system mapping proposal (based on CMT) could presumably accommodate differences in the timing of the congruity effects for literal and metaphorical motion sentences. However, the existence of qualitatively different ERP congruity effects is difficult to explain because it suggests that different neural generators underlie the congruity effects for literal and metaphorical sentences. Differences in effects following sentences about space and time are thus inconsistent with the system mapping proposal, and are also difficult to reconcile with the structural similarity proposal that both literal and metaphorical uses of motion verbs activate generic schemas that bear a similarly abstract relation to the motion in the cartoons. On the career of metaphor proposal, differences between the congruity effects might be explained by the fact that literal sentences rely on the activation of spatial schemas, whereas conventionalized metaphoric sentences rely on the activation of more abstract relational schemas.

Alternatively, ERP congruity effects observed after sentences about time may reflect the fact that it is possible to "wake up" the underlying source domain for a metaphoric expression, as suggested by some researchers in the framework of conceptual integration, or blending theory (Coulson & Oakley, 2005). Differences between the space and the time congruity effects might be attributed to the emergent structure that arises from the integration of two domains in a metaphor. The possibility of reactivating a mapping during metaphor comprehension would also help explain why the gestures accompanying discourse about abstract topics is interpretable in terms of a concrete source domain (Cienki, 1998). For example, English speakers often point in front of themselves when talking about the future, and behind themselves when talking about the past. In contrast, speakers of the Amerindian language *Aymara,* whose metaphoric expressions for the past invoke the front of their bodies, point in front of themselves when talking about the past (Núñez & Sweetser, 2006).

Although speakers vary in their sensitivity to and awareness of the source domain in entrenched metaphors, the late congruity effect we observed for sentences about time may indicate that source domain schemas can be reactivated even for highly conventionalized metaphors. Perhaps literary metaphors result when speakers particularly attuned to regularities in language reactivate online mappings and elaborate them with novel vocabulary. These findings would help explain why creative metaphors often utilize the same mappings as do entrenched metaphors (Lakoff & Turner, 1990).

In contrast to previous research (Boroditsky, 2000), we also found an influence from the abstract domain (time) on the concrete domain (space). Reading sentences about metaphorical motion in time affected the brain response to the apparent motion in the cartoons. This finding goes beyond the predictions of CMT, which assumes a one-way influence from the concrete to the abstract domain, without any influence from the abstract to the concrete domain. Newer theoretical developments like conceptual blending theory (Fauconnier & Turner, 2002; Grady, Oakley, & Coulson, 1999) or the space structuring model (Coulson & Matlock, 2001) allow for dynamic, multidirectional influence among the domains evoked in metaphoric language and are more consistent with these findings.

We suggest that the ERP measures used in Experiment 2 differ in important ways from the reasoning tasks employed in many previous studies of this issue. On the one hand, the brain response may be more sensitive to subtle processing differences than the behavioral measures often employed in studies of metaphoric mapping (see especially Boroditsky, 2000). On the other hand, the reasoning tasks used by Boroditsky (2000) more explicitly address the predictions of CMT because they directly assess the impact that conceptual structure from a concrete source domain can have on reasoning about an abstract target domain. Participants' ERPs in Experiment 2 reflect their appreciation of the relation between the direction of motion in the cartoon and the recently activated schemas presumably evoked to understand the ego- and object-moving sentences about space and time. Whether the measures used in this study relate to participants' ability to use these schemas in reasoning tasks is a matter for further research.

Acknowledgments

Ursina Teuscher was supported by a fellowship by the Swiss National Science Foundation (fellowship number PBFR1–102861). This research was supported by the Kavli Institute for Brain & Mind at University of California, San Diego.

References

Annllo-Vento, L., & Hillyard, S. A. (1996). Selective attention to color and direction of moving stimuli: Electrophysiological correlates of hierarchical feature selection. *Perception & Psychophysics, 58*, 191–206.

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

Boroditsky, L., & Ramscar, M. (2002). The roles of body and mind in abstract thought. *Psychological Science, 13*, 185–189.

Bowdle, B. F., & Gentner, D. (2005). The career of metaphor. *Psychological Review, 112*, 193–216.

Cienki, A. (1998). Metaphoric gestures and some of their relations to verbal metaphorical expressions. In J.-P. Koenig (Ed.), *Discourse and cognition: Bridging the gap* (pp. 189–204). Stanford, CA: Center for the Study of Language and Information.

Clark, H. H. (1973). Space, time semantics, and the child. In T. E. Moore (Ed.), *Cognitive development and the acquisition of language* (pp. 27–63). New York: Academic.

Coulson, S., & Matlock, T. (2001). Metaphor and the space structuring model. *Metaphor & Symbol, 16*, 295–316.

Coulson, S., & Oakley, T. (2005). Blending and coded meaning: Literal and figurative meaning in cognitive semantics. *Journal of Pragmatics, 37*, 1510–1536.

Coulson, S., & Van Petten, C. (2002). Conceptual integration and metaphor: An event-related potential study. *Memory & Cognition, 30*, 958–968.

Fauconnier, G., & Turner, M. (2002). *The way we think*. New York: Basic Books.

Gentner, D. (2001). Spatial metaphors in temporal reasoning. In M. Gattis (Ed.), *Spatial schemas in abstract thought* (pp. 203–222). Cambridge, MA: MIT Press.

Gentner, D., & Bowdle, B. (2001). Convention, form, and figurative language processing. *Metaphor & Symbol, 16,* 223–247.

Gentner, D., Bowdle, B., Wolff, P., & Boronat, C. (2001). Metaphor is like analogy. In D. Gentner, K. Holyoak, & B. N. Kokinov (Eds.), *The analogical mind: Perspectives from cognitive science* (pp. 199–253). Cambridge, MA: MIT Press.

Gentner, D., Imai, M., & Boroditsky, L. (2002). As time goes by: Evidence for two systems in processing space > time metaphors. *Language and Cognitive Processes, 17*, 537–565.

Grady, J., Oakley T., & Coulson, S. (1999). Blending and metaphor. In R. Gibbs & G. Steen (Eds.), *Metaphor in cognitive linguistics* (pp. 101–124). Amsterdam: Benjamins.

Harter, M. R., & Aine, C. J. (1984). Brain mechanisms of visual selective attention. In R. Parsuraman & D. R. Davis (Eds.), *Varieties of attention* (pp. 292–321). New York: Academic.

Lakoff, G., & Johnson, M. (1980). *Metaphors we live by*. Chicago: University of Chicago Press.

Lakoff, G., & Johnson, M. (1999). *Philosophy in the flesh*. New York: Basic Books.

Lakoff, G., & Núñez, R. (2000). *Where mathematics comes from: How the embodied mind brings mathematics into being*. New York: Basic Books.

Lakoff, G., & Turner, M. (1990). *More than cool reason: A field guide to poetic metaphor*. Chicago: University of Chicago Press.

Matlock, T, Ramscar, M., & Boroditsky, L. (2005). The experiential link between spatial and temporal language. *Cognitive Science, 29*, 655–664.

McGlone, M., & Harding, J. (1998). Back (or forward?) to the future: The role of perspective in temporal language comprehension. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 24*, 1211–1223.

Murphy, G. (1996). On metaphoric representation. *Cognition, 60,* 173–204.

Murphy, G. (1997). Reasons to doubt the present evidence for metaphoric representation. *Cognition, 62,* 99–108.

Núñez, R. E., Motz, B., & Teuscher, U. (2006). Time after time: The psychological reality of the ego- and time-reference-point distinction in metaphorical construals of time. *Metaphor and Symbol, 21,* 133–146.

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

Pazo-Alvarez, P., Amenedo, E., & Cadaveira, F. (2004). Automatic detection of motion direction changes in the human brain. *European Journal of Neuroscience, 19*, 1978–1986.

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

West, W. C., & Holcomb, P. J. (2002). Event-related potentials during discourse-level semantic integration on complex pictures. *Cognitive Brain Research, 13*, 363–375.