The Meaning of Metaphorical Gestures

Daniel Casasanto & Sandra Lozano

Department of Psychology, Stanford University

Draft: August, 2006

To appear in: *Metaphor and Gesture*.
A. Cienki & C. Müller (Eds.) Amsterdam: John Benjamins.
(Expected 2007)

Corresponding author:

Daniel Casasanto

Stanford University Department of Psychology

Jordan Hall, Bldg. 420

Stanford, CA 94305

casasan@stanford.edu

Abstract

In gesturing metaphorically, people use physical space to represent abstract ideas that have no spatial instantiation in the world (e.g., gesturing upward to indicate *high intelligence*). This volume illustrates the range of metaphorical gestures that people produce, yet researchers have only just begun to explore the psychological significance of these gestures. What functions might they serve in the mind of the gesturer? Do metaphorical gestures serve the same cognitive or communicative functions as concrete gestures? What do metaphorical gestures mean for theories of how people mentally represent abstract concepts?

In this chapter, we describe a series of experiments in which concrete and abstract gestures (Müller, 1998) were either elicited or inhibited, to elucidate relationships between mental representations of physical space and mental representations of abstract conceptual domains that are typically described using spatial metaphors (e.g., *value*, *rank*, *time*). Results showed that speakers' spontaneous gestures were overwhelmingly consistent with the spatial schemas implied by their utterances, regardless of whether space was used literally (e.g., *the rocket went up*) or metaphorically (e.g., *my grades went up*). This was true even when abstract concepts were described without using any spatial language (e.g., *my grades got better*). Participants who were prevented from gesturing produced more verbal disfluencies when describing literal and metaphorical spatial concepts than those who were allowed to gesture freely. Further experiments manipulating the visibility of the gesturer and recipient showed that gestures corresponding to literal spatial concepts appear to be designed for the listener, but gestures corresponding to metaphorically spatialized concepts may principally serve internal cognitive functions for the speaker. Findings suggest that people 'recycle' some of the mental representations used for reasoning about physical motion and space in order to instantiate abstract concepts.

Keywords: Metaphor; Gesture; Embodied Cognition

Introduction

Do metaphors in language reveal the structure of abstract concepts? According to Conceptual Metaphor Theory (Lakoff & Johnson, 1980, 1999), linguistic metaphors (e.g., a *long* time, a *high* grade, a *deep* thought) show that many of our abstract ideas are structured in terms of a few simpler concepts grounded directly in perceptuo-motor experience (e.g., experience with physical motion, force, and space). This idea is supported by an impressive body of linguistic theory and data (Clark, 1973; Gibbs, 1994; Gruber, 1965; Jackendoff, 1983; Langacker, 1987; Pinker, 1997; Sweetser, 1990; Talmy, 1988). Still, some researchers have remained skeptical that the significance of metaphor extends beyond language (Murphy, 1996, 1997). Arguably, Conceptual Metaphor Theory cannot be tested with linguistic data alone, because in order to know how people structure their abstract concepts it is necessary to determine whether they rely on perceptuo-motor representations even when they're not using metaphorical language.

Gestures corresponding to abstract ideas provide a potential source of convergent evidence for Conceptual Metaphor Theory. Metaphorical gestures constitute one of McNeill's (1992) basic gesture types (see also Müller, 1998). Whereas *Iconics* are gestures that resemble concrete objects or actions (e.g., pantomiming a spherical shape to represent a ball), *Metaphorics* resemble something concrete in order to represent something abstract (e.g., pantomiming a spherical shape to represent the idea of wholeness). Every gesture presumably corresponds to a spatio-motoric representation in the gesturer's mind: if people form gestural representations when they express abstract ideas, they must also form corresponding mental representations. Yet, the fact that people gesture metaphorically does not, in itself, support Conceptual Metaphor as a theory of mental representation (as opposed to a theory of language and communication). We need to know more about both the cognitive and communicative functions of metaphorical gestures to determine whether they reveal metaphorically structured concepts. Based on the evidence available so far, there are several possible answers to the questions, *why do people produce metaphorical gestures,* and *what do they mean for theories of abstract mental representations?* Here we consider three possibilities:

1. Metaphorical gestures could be epiphenomenal.

It would be incoherent to suggest that metaphorical gestures are arbitrarily related to their lexical affiliates, as numerous studies have documented systematic relations (Alibali, et al., 1999; Calbris, 2003; Cienki, 1998, 2005; Enfield, 2005; Kita, Danzinger, & Stolz, 2001; McNeill, 1992; Nuñez, 2004; Nuñez & Sweetser, 2005; Sweetser, 1998). However, by definition, metaphorical gestures are linked to abstract concepts via their resemblance to some concrete object or action. For example, Calbris (2003) described French speakers' execution of cutting gestures affiliated with abstract uses of the verbs like *trancher* (literally *to cut*, figuratively *to decide* between alternatives). On one interpretation of these data, cutting gestures during speech about decision making provide evidence that speakers mentally represent the abstract process of *deciding* metaphorically, in terms of the concrete act of *cutting*. On a skeptical alternative interpretation, however, speakers may sometimes make cutting motions when talking about decisions simply because they're using the verb *trancher*. Iconic gestures that correspond to literal uses of 'cutting' verbs are presumably meaningful, but when the same gestures correspond to figurative uses of these words they may be epiphenomenal: the result of incidental co-activation of an articulatory-phonological word form and the manual gestures that habitually accompany it. If so, then metaphorical gestures provide little support for Conceptual Metaphor as a theory of abstract mental representation.

2. Metaphorical gestures could be for communicating.

If metaphorical gestures are not merely epiphenomenal, a simple assumption is that they are intended to be communicative (Kendon, 2001). The majority of studies documenting metaphorical gestures have analyzed speakers in particularly challenging communicative settings, such as professors giving academic lectures (Nuñez, 2004; Sweetser, 1998), or participants deliberately explaining abstract relations in *mathematics* (Alibali, et al., 1999), *time* (Nuñez & Sweetser, 2005), or *kinship* (Enfield, 2005) to an experimenter or confederate (who, in the latter studies, did not share the speakers' native language). Data from these studies are consistent with the hypothesis that speakers conceptualize abstract domains like *math*, *time*, and *kinship* metaphorically, in terms of space. However, they are equally consistent with the hypothesis that people conceptualize these domains directly, in their own terms, and only spatialize them in gesture for the sake of communicating.

3. Metaphorical gestures could be for thinking.

In addition to any communicative function they may serve, concrete gestures corresponding to objects and actions in physical space appear to serve internal cognitive functions for the gesturer, facilitating lexical retrieval (Krauss, 1998; Krauss & Hadar, 1999) or conceptual planning for speech (Alibali, Kita, & Young, 2000). The same could be true for co-speech gestures corresponding to abstract entities that are commonly spatialized in verbal metaphors -- not only when gesturers are using verbal metaphors (e.g., *a high price*) but also when they're conveying abstract ideas without using any metaphorical language (e.g., *an expensive price*). If so, then gestures could provide evidence that people conceptualize abstract entities metaphorically even when they're not talking about them that way (Cienki, 1998; Sweetser, 1998).

In a series of six experiments, we evaluated these contrasting views of the significance of metaphorical gestures, and of the relationship between concrete and abstract domains of knowledge. We elicited spontaneous gestures during storytelling in some experiments and inhibited them in others, in order to address the questions: (1) To what extent are speakers' gestural representations (and, by inference, their mental representations) consistent with the literal and metaphorical spatial content of their stories? (2) To what extent do speakers still express abstract ideas through gesture even when they're not using any spatial language? (3) What cognitive or communicative functions do these gestures serve for the speaker? We reasoned that if spatio-motoric mental representations underlie people's abstract concepts, as Conceptual Metaphor Theory posits, then speakers should form such representations when they express abstract ideas whether or not they're using any spatial language; gestures provide an extralinguistic index of spatio-motor representations in the mind. If gesture data are to support Conceptual Metaphor as a theory of mental representation (and not just of language), then the functions of these spatio-motor representations should not be limited to communication; rather, metaphorical gestures should serve other internal cognitive functions for the gesturer.

Experiment 1: Spatializing the Non-Spatial

Do speakers produce spontaneous gestures that are consistent with both the literal and metaphorical spatial content of the stories they tell? Even when they're not using any spatial language? To find out, we asked pairs of naïve participants to take turns reading and retelling brief stories to one another. Participants knew that they were being videotaped, but they were not instructed to gesture, nor did they know the experiment had anything to do with gestures. Each participant retold three types of stories:

(1) Literal Spatial Language stories (e.g., My rocket *went higher*…)

(2) Metaphorical Spatial Language stories (e.g., My grades *went higher*…)

(3) Non-Spatial Language stories (e.g., My grades *got better*…)

Literal Spatial Language (LSL) stories described physical objects and events oriented along either a horizontal or vertical axis, and directed either upward, downward, right, or left. Metaphorical Spatial

Language (MSL) stories described non-spatial phenomena that are nevertheless commonly expressed using spatial metaphors implying both orientation and direction (e.g., *looking forward to* the future; the price *went lower*). Non-Spatial Language (NSL) stories were identical to the MSL stories, except that all metaphorical spatial language was replaced with non-spatial language conveying nearly the same meaning (e.g., *anticipating* the future; the price *got cheaper*).

The Literal Spatial Language condition was included to confirm that participants would produce spontaneous gestures consistent with the direction and orientation of the literal spatial scenario described in the story. For the Metaphorical Spatial Language condition, we reasoned that if people not only talk about abstract concepts using spatial words but also think about them using spatial representations, then participants should produce gestures consistent with the metaphorical spatial schemas implied by the stories. The Non-Spatial Language condition provided a stronger test of this hypothesis. Importantly, if metaphorical gestures correspond to spatialized concepts (and not just to spatial words), then no difference in the rate or schema consistency of gestures should be found between the Metaphorical Spatial Language and Non-Spatial Language conditions.

Methods

Materials and Procedure 28 Stanford University undergraduates (14 male) were recruited in pairs, and participated in exchange for course credit. Participants took turns telling brief stories (50-100 words). Each story contained one of 3 types of language (Literal Spatial Language, Metaphorical Spatial Language, or Non-Spatial Language, see above), and the target items in each story implied motion or extension in one of 4 directions (upward, downward, right, or left). After telling a warm-up story, each participant told 6 target stories: 2 LSL, 2 MSL, and 2 NSL. Each story contained between 3 and 7 targets. The order of stories was randomized, and content of stories was counterbalanced so that each pair of participants received only one version of each metaphorical story: either MSL or NSL (i.e., one pair of Ss would receive the MSL story about ‘grades *going higher*’, another pair of Ss would receive the minimally paired NSL story about ‘grades *getting better*’).

Participants were seated facing one another across a small table. Stories appeared on an iMac computer monitor positioned in front of each participant. They were given 60 seconds to study each story. When the story disappeared, they were instructed to try to retell it to their partner as accurately as possible, and told their partner would be quizzed on the content of the stories that they heard at the end of the experiment. The post-experiment quiz was only intended to motivate participants to be attentive while telling stories and listening to them; it was not intended to diagnose performance. Stories were written in the second person (e.g., *You're* testing some new model rockets…), but participants were asked to retell the stories in the first person (e.g., *I'm* testing some new model rockets…) as if relating their own experiences, to encourage them to adopt their own perspective when gesturing. Participants were told that the experiment was "about storytelling," and although they aware that they were being videotaped, they were not instructed to gesture. Each testing session lasted 20-30 minutes.

Data coding and analysis A 'blind-then-deaf' coding procedure was implemented involving 3 independent coders. Coder 1 transcribed the audio portion of the participants' stories with the video turned off. Timestamps were recorded for clauses containing target ideas (e.g., 'the rocket *went up*'), and silent video clips were made showing the storytellers actions during each target clause. Coders 2 and 3 then viewed only the silent video clips, so that the content of the speech could not influence their interpretation of the videos. For each silent clip of a target clause, coders determined whether the participant gestured, and recorded the orientation and direction of each gesture stroke, if it could be clearly determined. Inter-coder agreement exceeded 98%. Finally, the direction and orientation of each gesture were compared with our *a priori* predictions based on the spatial trajectory implied by each target clause.

Predictions for vertical targets were simple: upward gestures were predicted to accompany speech implying literal or metaphorical motion or extension in an upward direction (likewise for downward speech and gestures). Predictions for the horizontal targets were equally simple for the LSL stories, which concerned physical motion or extension rightward or leftward. Predictions for the horizontal MSL and NSL stories, which all concerned sequences of events extending into the past or future, were based on previous research on graphic and manual representations of time. English spatiotemporal metaphors imply that time flows horizontally along the speaker's sagittal axis (e.g., moving the meeting *forward*, pushing the deadline *back*). However, Tversky, Kugelmass, and Winter (1991) found that in graphic productions, English speaking participants spontaneously mapped a series of events (i.e., breakfast, lunch, dinner) onto a horizontal line that was directed rightward, placing earlier events to the left and later events to the right. This left-to-right mapping is also found in American Sign Language, which uses the sagittal axis (front/back) for indicating deictic time (e.g., *next Friday*), but the transverse axis (left/right) for indicating temporal sequences (e.g., *lunch comes before dinner*) (Emmorey, 2001). Since our stories contained sequences of events whose order was determined relative to one another (rather than with respect to the speaker's deictic context), we predicted that participants would map time onto the transverse axis, gesturing leftward for earlier events and rightward for later events.

Results and Discussion

Participants' retelling of the stories was highly accurate. 92% of target ideas were recalled overall, and the recall rate did not differ across conditions ($F(2,81) = 1.75$, *ns*). When participants recalled targets, they also produced co-speech gestures 45% of the time, overall: 53% of LSL targets, 39% of MSL targets, and 42% of NSL targets that were produced in speech were also accompanied with gestures. A one-way ANOVA showed that the rate of gestures differed significantly across conditions ($F(2,81) = 3.78$, $p<.03$). Post-hoc paired-sample t-tests showed that this difference was driven by the LSL condition: the rate of LSL gestures was greater than the rate of MSL gestures ($t = 3.63$, $p<.001$) and NSL gestures ($t = 2.83$, $p<.004$). This difference is consistent with previous findings (Krauss, 1998) that gesture rates correlate positively with the concreteness of the material speakers are discussing (LSL stories focused on concrete objects, whereas MSL and NSL stories focused on abstract ideas like *time, expense, goodness, grades, rank*, etc.) Importantly, the rate of gestures did not differ between MSL and NSL conditions ($t = 0.76$, *ns*). When describing abstract ideas, participants were equally likely to gesture whether or not they were using spatial metaphors in their speech.

These gesture rates are only meaningful to the extent that the gesture content can be interpreted with respect to our predictions. Overall, 87% of participants' gestures were consistent with predicted orientations and directions, based on the spatial trajectories implied by the stories (Figure 1). This was true not only in the Literal Spatial Language condition (e.g., upward gesture accompanying "the rocket *went higher*"), but also in the Metaphorical Spatial Language condition (e.g., upward gesture accompanying "my grades *went higher*"), and critically in the Non-Spatial Language condition, as well (e.g., upward gesture accompanying "my grades *got better*"). Schema consistency did not differ across conditions ($F(2,81) = 0.50$, *ns*). Even when participants used no spatial language, their gestures revealed that they formed spatio-motor representations corresponding to the abstract ideas they expressed.

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Experiment 2: Gesturing for Thinking?

What was the significance of participants' literal and metaphorical gestures? Setting aside their possible communicative function, Experiment 2 tested whether the gestures observed in Experiment 1 served an internal cognitive function for the speaker. Krauss (1998) noted that co-speech gestures tend to be far more frequent during phrases with spatial content than during phrases without it, and hypothesized that gesturing facilitates lexical access for spatial words. To test this hypothesis, Krauss and colleagues compared the rate of verbal disfluencies speakers produced when they were allowed to gesture and when they were prevented from gesturing. Results showed that gesture prevention selectively impaired production of spatial phrases. Krauss (1998) concluded that "the effect of preventing gesturing depends on whether the content of the speech is spatial or not: with spatial content, preventing gesturing increases the rate of disfluency; with non-spatial content, preventing gesturing has no effect" (pg. 57).

For the present experiment, we reasoned that if gestures aid speakers in accessing spatial words or concepts, then preventing gestures should selectively impair participants' production of both the literal and metaphorical spatial content of the stories used in Experiment 1.

Methods

Materials and Procedure (*N* = 28, 14 male) Materials and procedures were identical to those used in Experiment 1, with the following exception: participants were prevented from gesturing during storytelling. They were instructed to hold down keys on the far left and right sides of a computer keyboard that they held on their laps, one key with each hand, during the entire time they were speaking. They were told that the keys activated the left and right channels of the stereo microphones mounted on top of the computer monitor in front of them. (In fact, these microphones were nonfunctional, and participants' voices were recorded by microphones attached to the video cameras, as in the previous experiment.)

Data coding and analysis Participants' video recordings were surveyed to make sure they followed instructions and did not gesture. Their audio recordings were transcribed and parsed into clauses that contained target ideas (Target Clauses) and those that did not (Non-Target Clauses). Two independent coders determined whether each clause contained a verbal disfluency, and recorded the types of any disfluencies found (i.e., repeats, repairs, fillers (*uh*, *um*, etc.), and insertions). Finally, we tallied the number of Target Clauses and Non-Target Clauses that contained disfluencies. The same disfluency coding procedure was implemented for data from Experiment 1, for comparison with data from Experiment 2. Inter-coder agreement exceeded 99%.

Results and Discussion

The rate of verbal disfluencies was far greater for Target Clauses than for Non-Target Clauses, both when gestures were allowed ($M_{targets}$= 0.18, *SD* = 0.02; $M_{non\text{-}targets}$= 0.02, *SD* = 0.009) and when they were prevented ($M_{targets}$= 0.55, *SD* = 0.02; $M_{non\text{-}targets}$= 0.02, *SD* = 0.009). A 2-way mixed ANOVA with Spatial Content (Target, Non-Target) as a within-subjects factor and Gesturing (Allowed, Prevented) as a between-subjects factor showed main effects of Spatial Content ($F(1,54) = 14{,}115.40$, $p<.0001$) and of Gesturing ($F(1,54) = 4574.10$, $p<.0001$), as well as an interaction of Spatial Content and Gesturing ($F(1,54) = 4079.20$, $p<.0001$). Overall, gesture prevention dramatically increased the rate of verbal disfluencies for Target Clauses, which had literal or metaphorical spatial content, but it had no measurable effect on production of Non-Target Clauses, which had little or no spatial content.

A second analysis compared the effect of gesture prevention on Target Clauses across conditions (Figure 2). A 3x2 mixed ANOVA with Language (LSL, MSL, NSL) as a within-subjects factor and Gesturing (Allowed, Prevented) as a between-subjects factor showed a main effect of Gesturing ($F(1,54) = 6421.00$, $p<.0001$) and a marginally significant interaction of Language and Gesturing ($F(1,54) = 3.70$, $p<.06$), but no main effect of Language ($F(1,54) = 1.00$, *ns*). Post-hoc paired t-tests revealed that the marginal interaction was driven by small but significant pairwise differences across all Language conditions in the rate of disfluencies when gestures were allowed; by contrast, there were no differences across Language conditions that approached significance when gestures were prevented. Gesture prevention produced similar increases in disfluency during Target Clauses across all language conditions ($M_{increase\_LSL}$= 34%, $M_{increase\_MSL}$= 39%, $M_{increase\_NSL}$= 37%).

To summarize, gesture prevention did not increase the rate of verbal disfluencies for non-target clauses, but it nearly tripled the rate of disfluencies for target clauses, in all language conditions. These findings suggest that the co-speech gestures produced during Experiment 1 were not merely epiphenomenal, but rather aided participants in accessing words or concepts during storytelling. The findings in the LSL condition echo those reported in Krauss (1998): gesture prevention impairs speech with literal spatial content, but does not affect speech with non-spatial content. The findings in the MSL and NSL conditions are novel, and show that gesture prevention also impairs speech with metaphorical spatial content.

A skeptical interpretation of the MSL results might be that the gestures corresponding to target words were linked to those particular lexical items (e.g., *higher*, *lower*, *before, after*, etc.), which have literal as well as metaphorical spatial meanings. Gestures affiliated with metaphorical uses of these words could merely reveal automatic connections between their articulatory-phonological word forms and the hand movements that habitually accompany them during literal spatial uses. However, the NSL results militate against this interpretation, because the target items (e.g., *better*, *worse*, *earlier*, *later*, etc.) have no literal spatial uses. Although the results of Experiments 1 and 2 leave open the question of how exactly gesture interacts with speech production (and how gesture prevention disrupts it), they suggest that gestures influence how people access literal and metaphorical spatial schemas – not just spatial words (Alibali, Kita, & Young, 2000; cf. Krauss, 1998).

@@ Insert Figure 2 about here

Experiment 3: Marble Madness – How does gesture interact with speech?

It is tempting to conclude from the results of Experiments 1 and 2 that gestures *help* people to access spatial schemas during speech production. Yet, based on these data (and other gesture prevention data in the literature) it is not possible to determine whether schema congruent gesturing *facilitates* accessing spatial words and concepts, or whether gesture prevention *disrupts* this process (Beattie & Coughlan, 1999; Emmorey & Casey, 2001; Graham & Argyle, 1975; Graham & Heywood, 1975; Krauss, 1998; Rauscher, Krauss, & Chen, 1996). In order to address this question, it is important to specify how gesture might interact with speech production.

One possibility is that gesturing only appears to facilitate speech production because gestures ordinarily carry some of the speakers' communicative burden. Speech and gesture form a composite signal (Clark, 1996), in which information conveyed via the verbal and manual modalities become blended in the minds of recipients (McNeill, Cassell, & McCullough, 1994), and perhaps in the minds of communicators, as well. If messages are usually carried by both modalities, then speakers accustomed to distributing their messages' content between speech and gesture should be expected to show difficulties during gesture prevention, which requires them to channel all of the content into a single modality. If so, then gesturing doesn't necessarily *help* people to produce speech; rather, gesturing is just part of our communicative 'business as usual', as is evidenced by the finding that speakers continue to gesture even when communicating by telephone (de Ruiter, 1995). Gesture prevention may disrupt speech production by requiring speakers to decompose the composite signal, and to redistribute their communicative load in an unusual way.

Alternatively, gesturing may indeed facilitate speech with spatial content by activating or reinforcing spatio-motoric representations that underlie concrete and abstract word meanings. Several recent studies have highlighted the impact of perceptuo-motor activity on language comprehension. Glenberg and Kaschak (2002) found that participants were faster to judge sentences implying transfer of abstract or concrete entities when the implied direction of transfer was congruent with the direction of their manual responses (see also Kaschak, et al., 2005; Richardson, et al., 2003; Zwaan & Taylor, 2006). Motor activity may be important for language production, as well. If gesturing does enhance verbal fluency, the 'active ingredient' in gesture may be the underlying spatio-motor programs. Speech with spatial content should be facilitated to the extent that spatio-motor programs executed with the hands are congruent with the spatio-motor schemas underlying word meanings.

These proposals for how gestures might facilitate speech production and how gesture prevention might disrupt it are not mutually exclusive, but they do generate contrasting predictions. To test these proposals, we administered a version of the storytelling task which prevented participants from making communicative gestures, but also forced them to execute directed motor movements. Participants told the stories used in Experiments 1 and 2 while continuously transferring marbles between boxes that were stacked on top of one another, and positioned on the right and left of the computer screen. Marble movements were timed by a metronome, and were either congruent or incongruent with the spatial schemas implied by the target clauses. We compared the rate of verbal disfluencies produced during target clauses with schema congruent and incongruent marble movements.

We reasoned that if the role of gesture in speech production is to share the communicative load, then participants should produce more disfluencies during both congruent and incongruent marble movements than they did during free gesturing in Experiment 1, since both congruent and incongruent marble movements prevent participants from making communicative gestures. According to this first proposal, because all marble movements prevent communicative gesturing (regardless of their schema congruity), they shift some of the communicative burden normally carried by gesture onto speech, and should therefore increase disfluency just as gesture prevention by button holding did in Experiment 2.

By contrast, if the role of gesture is to enhance activation of spatial schemas underlying word meanings, then schema congruent and incongruent marble movements should have opposite effects on verbal fluency. Schema incongruent marble movements should impair verbal fluency, perhaps even more than gesture prevention by button holding did, because incongruent movements correspond to spatio-motor representations in the mind that conflict with the spatio-motor schemas underlying target word meanings. Schema congruent marble movements should promote verbal fluency. In fact, this proposal leads to a rather counterintuitive prediction regarding fluency during free gesturing vs. schema congruent marble moving. During the free gesture task (Experiment 1), participants gestured spontaneously for 45% of target clauses. Most of these gestures were schema congruent, so they produced schema congruent hand movements during approximately 40% of target clauses, overall. The marble task, however, forces participants to make schema congruent hand movements during all (or nearly all) of the target clauses. Therefore, participants should produce *fewer* verbal disfluencies during schema congruent marble movements than during free gesturing, despite the fact that continuous marble moving constitutes a potentially distracting secondary task.

Materials and Procedure (*N* = 16, 9 male) Materials and procedures were identical to those used in Experiment 1, with the following exceptions: participants told the stories used in Experiments 1 and 2 while transferring marbles with both hands between boxes that were stacked on top of each other, and positioned on the right and left of the computer screen. Participants were instructed to deposit one marble with each hand into the appropriate box at the instant that they heard a metronome tick (once every 2000 ms). Each pair of participants was assigned to make either upward, downward, leftward, or rightward movements, so their marble movements were always in the same direction. Since each participant told stories with target items implying motion or extension in all four directions, marble movements were congruent with some of their target clauses and incongruent with others. For example, a target clause like *the temperature went up* was accompanied by congruent movements for participants who were assigned to move marbles upward (from the lower to the upper boxes), but it was accompanied by incongruent movements for participants who were assigned to move marbles downward (from the upper to the lower boxes). Stories and marble directions were counterbalanced across participants.

Data coding and analysis Marble movements were classified as either *congruent* with the spatial schema implied by a target clause (correct axis and correct direction: e.g., upward movement during a target clause implying upward motion), *incongruent* (correct axis but incorrect direction: e.g., upward movement during a target clause implying downward motion), or *irrelevant* (incorrect axis: e.g., upward movement a during target clauses implying leftward motion). Irrelevant movement trials served as fillers. Disfluencies were coded as described in Experiment 2, and the rate of disfluencies was compared for target phrases during schema congruent and incongruent marble movements. Inter-coder agreement exceeded 99%. In addition, we computed the rate and success with which participants' executed schema congruent and incongruent marble movements.

Results and Discussion

Overall, speakers were dramatically more disfluent when producing both literal and metaphorical target clauses during schema incongruent marble movements ($M_{disfluency\_incongruent}$ = 62%) than during schema congruent marble movements ($M_{disfluency\_congruent}$ = 1%, difference of means = 61%, $t(15)=33.50$, $p<.00001$). Disfluency rates were nearly identical across all language conditions, both for target clauses ($M_{disfluency\_LSL}$= 62%, $M_{disfluency\_MSL}$= 63%, $M_{disfluency\_NSL}$= 62%) and for non-target clauses ($M_{disfluency\_LSL}$= 6%, $M_{disfluency\_MSL}$= 6%, $M_{disfluency\_NSL}$= 6%). Planned comparisons of results from Experiments 1, 2, and 3 revealed that disfluency rates for target clauses varied significantly as a function of gestures or directed motor movements during storytelling ($F(3,84)=1277.64$, $p<.00001$; see Figure 3). Storytellers produced verbal disfluencies at a significantly higher rate in Experiment 3 during schema incongruent marble movements than in Experiment 2 during gesture prevention via button holding (difference of means = .17, $t(42)=36.76$, $p<.00001$). Of particular interest, storytellers produced a significantly *lower* rate of verbal disfluencies in Experiment 3 during schema congruent marble movements than in Experiment 1, during free gesturing (difference of means = .08, $t(42)=5.25$, $p<.00001$).

To summarize, schema incongruent gestures during target phrases resulted in even greater verbal disfluency than gesture prevention via button holding did, presumably because incongruent movements caused participants to form spatio-motor representations that expressly conflicted with the spatio-motor schemas underlying target word meanings. Schema congruent marble movements promoted even greater verbal fluency than free gesturing, presumably because congruent movements caused participants to form spatio-motor representations that accorded with the schemas underlying word meanings for nearly every target clause. Overall, participants were the most verbally fluent during schema congruent marble movements, despite the attentional demands of continually moving marbles on cue, which were absent from the free gesture condition. Schema congruent and incongruent marble movements had opposite effects on verbal fluency, even though both kinds of movements prevented participants from using their hands for communicative purposes. This finding offers no support for the proposal that gesture prevention impairs verbal fluency by shifting the communicative burden unnaturally from gesture to speech. Rather, this pattern of results suggests that schema congruent gestures indeed *help* speakers to produce speech with literal or metaphorical spatial content, and that spatio-motor schemas, themselves, are the active ingredient in the cognitive functioning of literal and metaphorical gestures.

In a surprising additional finding of Experiment 3, not only did marble movements affect participants' ability to tell stories, but storytelling also affected their ability to complete marble movements. Participants initiated an average of 60 schema congruent marble movements, and successfully completed all of them. By contrast, they only initiated an average of 49 schema incongruent marble movements (difference of means = 10.97, $t(15)=19.86$, $p<.00001$), and failed to complete 4% them. The rate of marble dropping did not differ across language conditions ($M_{marbledropping\_LSL}$= 4%, $M_{marbledropping\_MSL}$= 4%, $M_{marbledropping\_NSL}$= 4%). During target clauses for which hand movements were incongruent with the literal or metaphorical spatial content of speech, our participants were quite literally *losing their marbles*. A sign test showed that the total number of marbles dropped during schema incongruent movements ($n = 45$) differed significantly from the number dropped during schema congruent movements ($n = 0$; $p=5.86\text{x}10^{-14}$).

Results of Experiment 3 converge with those of studies demonstrating 'embodied' sentence comprehension (Glenberg & Kaschak, 2002; Kaschak, et al., 2005; Richardson, et al., 2003; Zwaan & Taylor, 2006), but additionally, these data also show that (a.) action-language congruity effects extend beyond language comprehension to language production, and that (b.) influences of language and action are bidirectional. Using language with literal or metaphorical spatial content influences the execution of simple motor actions – and vice versa.

@@ Insert Figure 3 about here

Experiment 4: Barriers to Communication

Experiments 1-3 focused on whether co-speech gestures (and other directed motor movements) aid speakers in formulating the literal and metaphorical spatial contents of stories. Experiments 4 and 5 explored whether gestures are designed by the speaker to be communicative. For Experiment 4, participants took turns telling each other stories while sitting face-to-face across a small table, as in Experiments 1 and 2, only now they were separated by a barrier that occluded all but the extreme upper limit of their natural gesture space (McNeill, 1992). Seated on stools, participants could see just the tops of each others' faces. We reasoned that if gestures during storytelling were designed to be communicative, then speakers would tend to raise their hands above the barrier so that they would be visible to the listener – even though this would require speakers to execute their gestures in an unnaturally high space. On the other hand, if gestures serve primarily an internal cognitive function for the speaker, participants should continue to gesture in the occluded space even though their gestures would clearly be invisible to the listener.

Methods

Materials and Procedure (*N* = 28, 11 male) Materials and procedures were identical to those used in Experiment 1, with the following two exceptions. (1) Some stories were revised to maximize similarity between literal and metaphorical spatial language conditions. (2) Participants were partially separated by a barrier formed by a pair of dry-erase whiteboards, back-to-back, which measured 3 ft. wide by 2 ft. high from the table's surface. When participants were seated on their stools they could see the tops of each others' faces, including the eyes. If speakers gestured in their natural space, nearly all of their gestures would be invisible to the listener, but it was possible for speakers to make their gestures visible by lifting their hands above eye-level. Participants were told that the whiteboards were there to help them with the quiz at the end of the experiment. They were instructed to jot down 3 'keywords' with a dry-erase marker after each story they heard, to remind them of the story's content. (The quiz was intended to encourage participants to be attentive during storytelling, and also to justify the presence of the whiteboards. As in previous experiments, the quiz was not intended to measure performance.)

Data coding and analysis Data were collected and coded exactly as in Experiment 1, with the following addition: each gesture was tagged as having been executed above the barrier (i.e., visible to the listener) or below the top of the barrier (i.e., invisible to the listener). Inter-coder agreement exceeded 99%.

Results and Discussion

Participants continued to gesture frequently, despite the barrier (see Alibali, Heath, & Myers, 2001). When speakers produced target phrases, they also produced co-speech gestures 81% of the time, overall: 84% of LSL targets, 77% of MSL targets, and 82% of NSL targets were accompanied with gestures. Gesture rate did not vary significantly across language conditions ($F(2,81) = 1.27$, *ns*).

Remarkably, of the 440 gestures observed, 99% were consistent with the predicted orientations and directions. The schema consistency rate was 98% for LSL stories (135 gestures), 100% for MSL stories (147 gestures), and 100% for NSL stories (158 gestures). The overwhelming schema consistency of gestures replicates the principal finding of Experiment 1.

The question of primary interest for Experiment 4 was whether speakers would raise their gestures above the barrier, making them visible to the listener. Results showed that the majority of gestures accompanying Literal Spatial Language target ideas were raised above the barrier. By contrast, nearly all of the gestures accompanying Metaphorical Spatial Language and Non-Spatial Language targets were produced below the top of the barrier, and were invisible to the listener (Figure 4). The proportion of gestures visible above the barrier differed significantly across conditions ($F(2,81) = 253.90$, $p<.0001$). Post-hoc paired t-tests showed that the proportion of visible gestures was significantly greater in the LSL condition than in the MSL and NSL conditions, which did not differ significantly from one another. Data from Experiments 1-3 suggest that gestures in all conditions appear to serve an internal cognitive function for the speaker; data from Experiment 4 suggest that only gestures accompanying literal spatial target ideas appear to serve a communicative function, as well.

@@ Insert Figure 4 about here

Experiment 5: Gesturing for the Blindfolded?

We interpreted the finding that participants in Experiment 4 often raised their literal spatial gestures above the barrier as evidence that they were 'designed' for the recipient (Bavelas, et al., 2002), but that MSL and NSL gestures were not. An alternative possibility is that participants' spatio-motor representations of literal spatial scenarios were simply bigger than their spatio-motor representations of abstract, metaphorically spatialized entities. Experiment 5 investigated whether gestures expressing literal and metaphorical spatial ideas differed in their communicative function, or only in their size. Speakers told LSL, MSL, and NSL stories over a barrier, as in Experiment 4, but now the listener was blindfolded. We reasoned that if literal and metaphorical spatial gestures have similar communicative functions and simply differ in size, then speakers should continue to gesture above the barrier for LSL targets. However, if speakers in Experiment 4 designed their literal spatial gestures for the recipient (consciously or unconsciously), speakers in Experiment 5 should no longer gesture above the barrier, since they could see that the listener was blindfolded.

Methods

Materials and Procedure ($N = 28$, 16 male) Materials and procedures were identical to those used in Experiment 4, with the following exception: participants put on a blindfold before listening to each story (but took off the blindfolded before storytelling).

Data coding and analysis Data were collected and coded exactly as in Experiment 4. Inter-coder agreement exceeded 99%.

Results and Discussion

Despite the barrier and the listener's blindfold, speakers gestured with targets 82% of the time, overall: gesture rates did not vary across language conditions ($F(2,81) = 2.15$, *ns*). The fact that the recipient was blindfolded did not diminish the number of gestures speakers produced, which was greater than in the previous experiment in which the listener could see. Of the 485 gestures observed, 99% were schema consistent. The schema consistency rate was 98% for LSL stories (156 gestures), 100% for MSL stories (158 gestures), and 100% for NSL stories (168 gestures). Crucially, less than 1% of gestures were executed above the barrier overall, and the proportion of gestures above the barrier did not differ across conditions (Figure 5; $F(2,81) = 2.06$, *ns*). When speakers knew that listeners were blindfolded they no longer lifted their gestures into the space above the barrier, suggesting that LSL gestures in Experiment 4 were designed for the recipient, and that literal and metaphorical spatial gestures differ in their communicative functions.

Participants continued to gesture with striking frequency and schema consistency across all conditions -- even when they knew these gestures were invisible to their listener. This further supports the claim that both literal and metaphorical gestures serve non-communicative cognitive functions for the speaker. Surprisingly, we find no evidence that metaphorical gestures were intended to serve any communicative function. This does not rule out the possibility that speakers sometimes intend their metaphorical gestures to be communicative, or that metaphorical gestures are informative to observers (see Cienki, 2005). Still, our findings urge caution in interpreting the meaning of metaphorical gestures, and underscore the importance of experimental interventions to complement observational gesture research.

@@ Insert Figure 5 about here

Experiment 6: More Marble Madness – Beyond thinking for speaking?

Taken together, Experiments 1-5 suggest that metaphorical gestures (and other directed motor movements) help people to formulate the abstract concepts that they're expressing in speech. These gestures and movements facilitate speech production even when they have no communicative value for the speaker or listener. Yet, in all of these experiments, participants were tested in a communicative setting. It is possible that schema congruent gestures and motor movements are only helpful for formulating the kinds of mental representations that people use during verbal communication -- the process Slobin (1987) has called *thinking for speaking* (see also Cienki, 2005; McNeill & Duncan, 2000). If motor movements play a role in accessing or constituting abstract concepts more generally, then schema congruity effects should be detectable even in non-communicative contexts.

To test this proposal, for Experiment 6 we conducted a 'motor-meaning interference' task. Participants saw single abstract words referring to metaphorically spatialized concepts while moving marbles into boxes positioned to require schema congruent or incongruent motions. We reasoned that if spatio-motor schemas are automatically activated when people see abstract words – even if they're not planning to speak the words or communicate their content – then schema congruity should affect the speed of the marble movements themselves (an on-line effect), and also affect subsequent memory for the stimulus words (an off-line effect).

Methods

Materials and Procedure (*N* = 18, 9 male) Individual participants were seated in front of a computer screen. Stacked next to the screen on both the right and left there were three large boxes. The top box was red, and the bottom box was blue (or vice versa, counterbalanced across subjects). The middle box was white, and was filled with hundreds of marbles. 48 words appeared briefly (2000 ms) in the center of the computer screen, one at a time, in either blue or red font. The words were nouns and adjectives referring to abstract entities that have no spatial instantiation in the world, but which are often associated with vertical spatial metaphors (e.g., *wealthy*, *poor*, *virtuous*, *evil*, *hero*, *villain*, etc.), and which subjects in a previous norming study spatialized accordingly (e.g., placing *wealthy* above *poor*, *virtuous* above *evil*, etc.). Participants were instructed that as soon as each word appeared, they should move one marble with each hand into the box corresponding to the color of the word's font, as quickly as possible. Unknown to the participants, half of their marble movements were either schema-congruent (e.g., if the word *wealthy* appeared in blue and the blue box was on top) while the other half were schema-incongruent (e.g., if the word *wealthy* appeared in red and the red box was on bottom). The assignment of font colors to words was counterbalanced across subjects. The color of the words was their only attribute that was relevant for performing the marble task. A video camera placed behind the participant recorded their marble movements. Participants were not instructed to read or remember the words. After completing the marble moving task, they performed a surprise old/new recognition memory task during which all words presented previously as cues for marble movements were presented again in black font, randomly intermixed with an equal number of distractor words matched with targets for length, frequency, valence, and concreteness.

Data coding and analysis The speed and accuracy of marble movements and the accuracy of recognition memory were compared for schema congruent and incongruent trials.

Results and Discussion Participants were dramatically faster to make schema congruent marble movements than schema incongruent marble movements ($M_{congruent}$= 951 ms; $M_{incongruent}$= 1259 ms; difference of means = 308 ms, $t(17)=13.50$, $p<.00001$; see Figure 6a). We found an equally dramatic effect of schema congruity on recognition memory. On average, participants correctly recognized 94% of words incidentally encoded during schema congruent marble movements, but were at chance recognizing words encoded during schema incongruent movements (54% correct recognition; difference of means = 0.40, $t(17)=10.99$, $p<.00001$; see Figure 6b). Even though participants were only required to process stimulus words superficially according to their font color, words that required schema incongruent movements caused participants to 'lose their marbles' significantly more often than words that required schema congruent movements (number of marbles dropped = 12 vs. 1, $p<.003$).

Experiment 6 provides novel evidence for the automatic activation of spatio-motoric image schemas underlying the meanings of abstract words. The bidirectional influences of motor action and language that we observed in Experiment 3 are not restricted to communicative contexts; the relation between language and motor action extends beyond *thinking for speaking*.

@@ Insert Figures 6a and 6b about here

General Discussion

Results of experiments 1-6 suggest that spontaneous gestures and directed motor movements reveal spatio-motor representations underlying a variety of abstract concepts, supporting the central claim of Conceptual Metaphor Theory: abstract domains of knowledge depend, in part, on mental representations built up through perceptuo-motor interactions with the physical world. Our data argue against the possibility that metaphorical gestures are epiphenomena of using words that have both metaphorical and literal spatial meanings. They also militate against the suggestion that metaphorical gestures serve principally communicative functions; not only do people talk about abstract domains using the language of *space* and *motion*, they also think about domains like *time*, *rank*, and *value* using spatio-motor image schemas.

One robust finding of these experiments bears consideration because it supports Conceptual Metaphor Theory in some ways but challenges it in others. Although half of the stories that participants told focused on conceptual domains associated with vertical spatial metaphors (e.g., *temperature*, *grades*, *price*, etc.), the other half focused on sequences of events extending into the *past* or *future*. In English and many other languages, we ordinarily talk about time as if it flows linearly along a horizontal axis (Alverson, 1994; Clark, 1973; cf. Boroditsky, 2001). In particular, English space-time metaphors place the future in front of the speaker (e.g., *the best years are ahead of us*) and the past behind the speaker, (e.g., *our salad days are behind us*), implying that time flows along the sagittal (front/back) axis. However, consistent with previous reports (Calbris, 1990; Cienki, 1998; Núñez & Sweetser, 2005), our participants systematically gestured along the transverse (left/right) axis, placing the past to the left and the future to the right. Experiments 1, 4, and 5 showed that this pattern was equally reliable in the Metaphorical Spatial and Non-Spatial Language conditions. Experiment 3 showed that marble movements that were incongruent with this left-right mapping (e.g., rightward movements during a phrase like *a century earlier*) increased the rate of verbal disfluencies relative to congruent movements.

Although sequences of events are also mapped onto a left-right axis in signed languages (Emmorey, 2001) and in spontaneous graphic productions (Tverky, Kugelmass, & Winter, 1991), this pattern in English speakers' spontaneous gestures is somewhat surprising given that left-right spatio-temporal metaphors are entirely absent from English speech. As Cienki (1998) notes, "*I did X to the left of Y* is not used to mean *I did X before Y*" (pg. 198). It has been proposed that the direction of gestures for time follows other culture-specific conventions in which space and time are conflated, such as the arrangement of days on a calendar or the direction in which the eyes and hands move during reading and writing (Calbris, 1990; Cienki, 1998). This proposal has not been tested for gesture, but the mapping of events onto left/right or right/left space in spontaneous graphic productions has been demonstrated by Tversky, Kugelmass, and Winter (1991). Whereas English speakers tended to arrange events on a piece of paper horizontally from left to right, speakers of Arabic (which is written from right to left) tended to arrange them from right to left. It is somewhat revealing that spontaneous spatial representations of temporal sequences correlate with writing direction, but this is just the beginning of a complete explanation for the discrepancy between left/right mappings in diagrams and gestures and front/back metaphors for time in language (see Torralbo, Santiago, & Lupiáñez, 2006 for discussion). One concern with invoking writing direction as an explanation is that Tversky, Kugelmass, and Winter (1991) observed culture-specific space-time mappings even in kindergarten aged children, who presumably had very little experience with reading and writing. Another concern with this explanation, or any theory of conceptual structure that relies on reading and writing, is that the great majority of people throughout history who could talk and think have been illiterate: how have they learned to structure their temporal concepts?

Whatever the source of the left-to-right space-time mapping in English speakers' gestures, its existence should be of interest for evaluating Conceptual Metaphor as a theory of mental representation. The programme of Conceptual Metaphor Theory is to infer how people think about abstract concepts from the way they talk about them. Our gesture data support Conceptual Metaphor in a very broad sense: people seem to spatialize time. However, since people don't talk about time in terms of left-right space (and *do* talk about time in terms of front/back space), there is no simple way to use linguistic data to predict the findings of our studies. Other behavioral research on the spatial basis of temporal thinking suggests that the structure of our non-linguistic mental representations of time can be predicted from the spatiotemporal metaphors in our native languages. Boroditsky (2001) found evidence that English speakers conceptualize temporal sequences horizontally, the way they talk about them. By contrast Mandarin speakers, who often talk about time as if it flows along a vertical spatial axis, also appear to think about temporal sequences as vertical. Casasanto, et al. (2004) showed that whereas some languages tend to use linear spatial metaphors for duration (e.g., English: *a long time*), other languages prefer to talk about time as if it were a substance accumulating in 3-dimensional space (e.g., Spanish: *mucho tiempo*). Performance on non-linguistic time estimation tasks revealed that speakers of different languages relied differentially on mental representations of distance or volume, as predicted by the prevalence of distance and volume metaphors in their native languages. Findings such as these suggest that language provides a window onto our non-linguistic mental representations of time. The studies we present here, however, suggest that there may be systematic differences between our linguistic and image schematic time representations. Making inferences about the mental representation of temporal sequences based on linguistic metaphors may be more like looking through a prism than through a window onto the mind.

Setting this issue aside, on the whole our findings converge with the growing number of psychological experiments that suggest mental representations of physical space underlie our conceptualizations of abstract domains, including *time*, *number*, and *social status* (Boroditsky, 2000, 2001; Casasanto & Boroditsky, 2003; Casasanto, et al., 2004; Dehaene, Bossini, & Giraux, 1993; Meier

& Robinson, 2003; Richardson, et al., 2003; Schubert, 2005; Torralbo, Santiago, & Lupiáñez, 2006). Our data also help to arbitrate a debate about the significance of these findings. Although they appear to support Conceptual Metaphor Theory, the results of least some of these studies are amenable to an alternative interpretation: perhaps mental representations in abstract domains simply share representational resources with the domain of space. The idea that a common mental magnitude metric underlies multiple domains was proposed by Meck and Church (1983) to explain *time* and *number* representation in animals. This proposal has since been extended to humans and expanded in scope. Walsh (2003), for example, proposes that the domains of *time*, *space*, and *number* all share a common metric (cf. Boroditsky, 2000), and Chiao, Bordeaux, & Ambady (2004) have suggested that such a metric may also subserve our mental representations of social rank. If so, then behavioral studies showing effects of space on judgments of time, number, rank, or other abstract domains may demonstrate intimate connections among these domains, but do not show that people use spatial representations metaphorically to instantiate abstract concepts. Rather, people may use a general-purpose magnitude metric to construct scalar representations in a variety of domains, including *space*, *time*, *number*, *value*, *intelligence*, *rank*, etc. These magnitude representations may not be spatial, but merely space-like.

The finding that people gesture metaphorically, and that these gestures have functional consequences, argues in favor of the metaphorical use of space. In order to plan and execute gestures, speakers must form spatio-motor representations in the mind. The specificity of temporal gestures, in particular, argues against the possibility that gestures are manifestations of a more general magnitude metric: how could a non-spatial metric distinguish *left* from *right*? The finding that people use spatio-motor representations does not rule out the possibility that people also form non-spatial magnitude metrics in order to conceptualize a *long* meeting or a *high* price, but our data do complicate this proposal: why should people form the spatio-motor representations that their metaphorical gestures reveal if the magnitude of *duration* or *value* is fundamentally represented by a non-spatial metric? One plausible explanation would be that time and value are conceptualized in terms of a general magnitude metric, and only spatialized for the sake of communicating. This suggestion is hard to maintain, however, given the evidence we present that metaphorical gestures often serve cognitive but not communicative functions for the speaker.

Experiments on metaphorical gestures help to address two outstanding questions in the literature: *do gestures serve primarily communicative or internal cognitive functions*, and *how does gesture interact with speech production?* Our data show that the answer to the first question depends, in part, on the kind of gestures under consideration: whereas both literal and metaphorical spatial gestures help gesturers to formulate words or concepts, only literal spatial gestures appear to be designed with communicative intent. Different types of gestures such as *emblems, deictics*, *iconics*, *metaphorics*, and *beat* gestures may lie along a continuum from the principally communicative to the principally cognitive in function for the speaker. A separate issue not addressed by our present experiments concerns the communicative benefits of different gesture types for the *recipient* (see Cienki, 2005 and Lozano & Tversky, 2005 for discussion).

The second question has generally been framed as *what stage of speech production does gesture influence – word finding or conceptual planning for speech?* (Alibali, Kita, & Young, 2000; Krauss, 1998; Krauss & Hadar, 1999; cf. Lozano & Tversky, 2005). While previous studies suggest that literal spatial gestures are involved both in accessing lexemes (Krauss, 1998) and in packaging information into speech-appropriate units (Alibali, Kita, & Young, 2000), our findings suggest another role for gestures and directed motor movements. In Experiment 6, the schema congruity of motor movements interacted with the meanings of abstract words even though participants were reading them in a non-communicative setting, and had no need to package conceptual information into speech. This raises the possibility that gestures influence speech not because they are an intrinsic component of speech production (cf., McNeill & Duncan, 2000), but rather because they help people to conceptualize things with literal or metaphorical spatial content -- whether of not they choose to talk about them. Our data suggest that activating the motor programs that give rise to gestures also reinforces the spatio-motor schemas that underlie concrete and abstract word meanings. These motor programs may be partly constitutive of the concepts, themselves (Barsalou, 1999; Goldstone & Barsalou, 1998). As such, gesture may influence *thinking for speaking* by virtue of influencing literal and metaphorical spatial thinking, more generally.

Conclusions

In summary, these experiments showed that: (1) speakers produced spontaneous gestures consistent with both the literal and metaphorical spatial content of the stories they told. (2) This was true even when they expressed abstract ideas without using any spatial language. (3) Both the rates of metaphorical gesturing and the proportions of schema congruent gestures were equivalent whether speakers expressed abstract ideas using spatial language (e.g., *my team's rank fell*) or non-spatial language (e.g., *my team's rank got worse*). (4) Preventing gestures increased disfluencies during speech with both literal and metaphorical spatial content (whether or not speakers used spatial language), but not during speech with non-spatial content. (5) Gestures expressing literal spatial ideas appear to serve an internal cognitive function for the speaker, and also tend to be designed for the listener. (6) Gestures expressing abstract, metaphorically spatial ideas do not appear to be designed for the listener, but do appear to serve an internal function for the speaker, facilitating access to spatial words or concepts. (7) Although establishing the precise role of gesture in thinking and speaking is an ongoing project, the present studies suggest that gestures and other motor movements play a role in instantiating abstract concepts that transcends any role they may play in communicating these concepts or packaging them for speech.

Gesture research helps to clarify the meaning of linguistic metaphors for theories of mental representation. In turn, studies of metaphor in the mind and hands elucidate the interrelations of gesture, thought, and language.

Acknowledgments

This research was supported by an NRSA post-doctoral fellowship to DC. A preliminary report on these studies appeared in Casasanto, D. and S. Lozano. *Metaphor in the Mind and Hands* in Proceedings of 28th Annual Conference of the Cognitive Science Society, 2006. Vancouver, BC. We thank Lindsay Garlock, Svetlana Nabieva, and Jane Solovyeva for help collecting and coding data, and also thank Lera Boroditsky, Herb Clark, Teenie Matlock, Laura Staum, and Barbara Tversky for helpful discussions.

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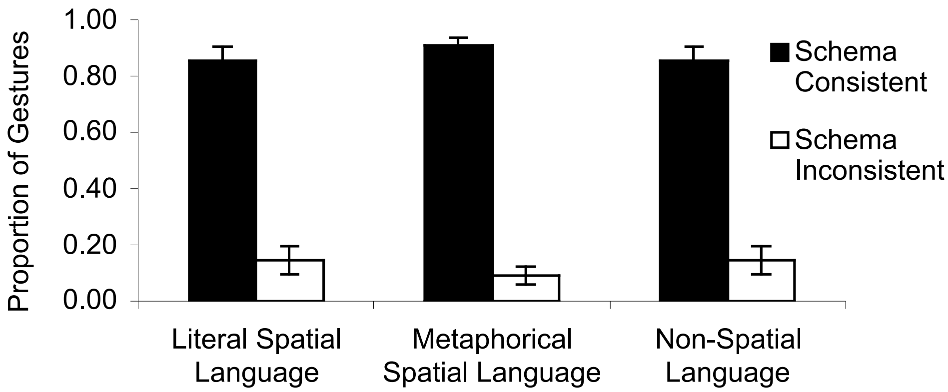

Figure 1. Results of Experiment 1. The proportion of schema consistent gestures was equivalent across all conditions. Bars indicate Standard Error.

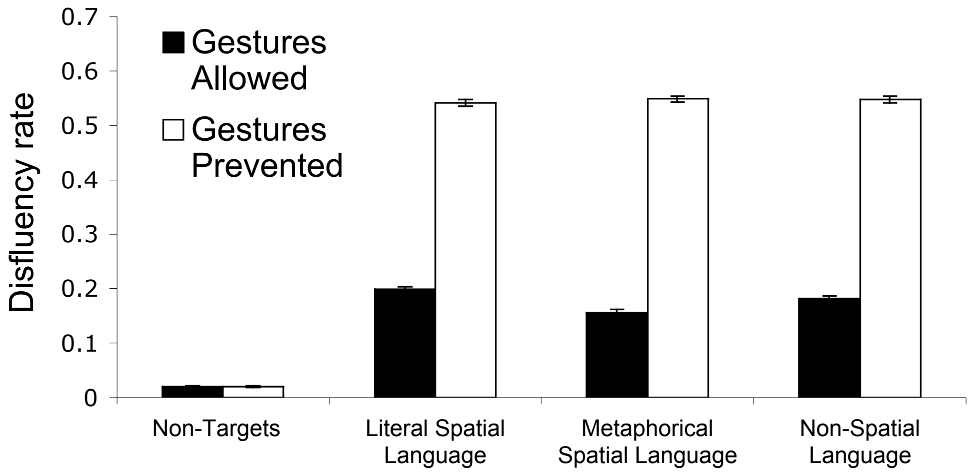

Figure 2: Rates of verbal disfluency with gestures allowed (Experiment 1) and gestures prevented (Experiment 2). Bars indicate Standard Error.

Figure 3: Disfluency rates during schema congruent marble movements (Experiment 3), free gesturing (Experiment 1), gesture prevention (Experiment 2), and schema incongruent marble movements (Experiment 3). Bars indicate Standard Error.

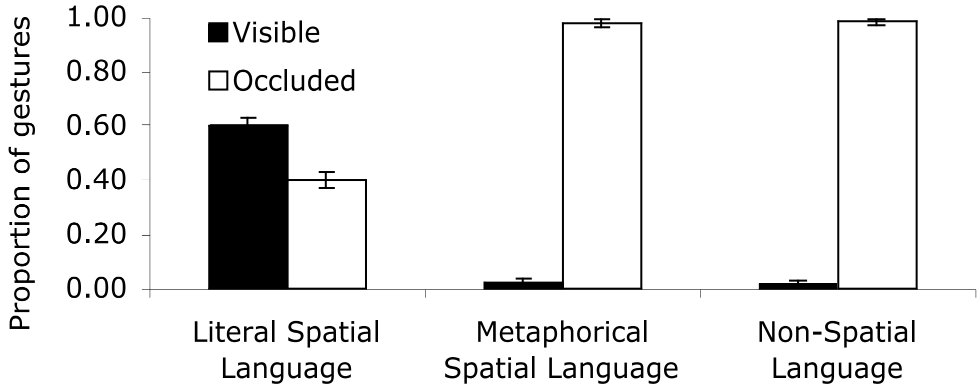

Figure 4: Results of Experiment 4. Proportions of visible and occluded gestures. Bars indicate Standard Error.

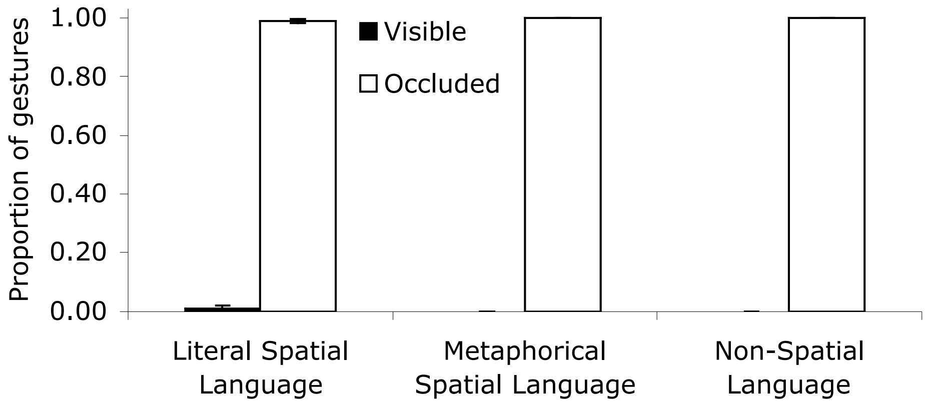

Figure 5: Results of Experiment 5. Proportions of visible and occluded gestures. Bars indicate Standard Error.

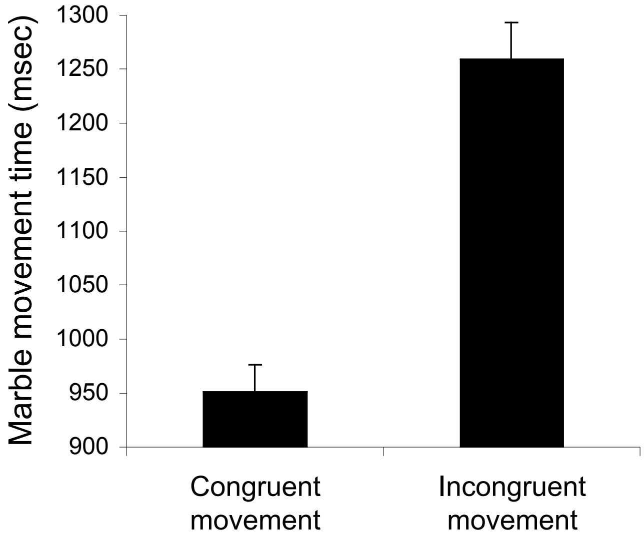

Figure 6a: Time to make schema congruent and schema incongruent marble movements (Experiment 6). Bars indicate Standard Error.

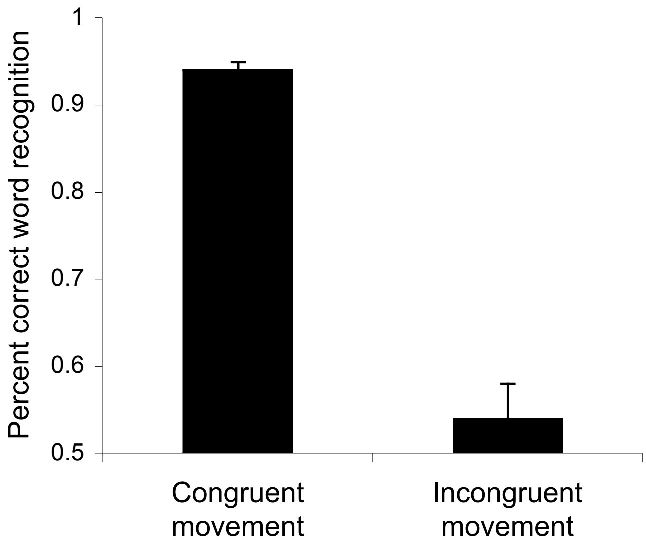

Figure 6b: Correct recognition for words seen during schema congruent and schema incongruent marble movements (Experiment 6). Bars indicate Standard Error.