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A case of impaired verbalization but preserved gesticulation of motion events

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In most cultures, most of the time, when people talk they gesture. We took advantage of a rare opportunity to explore the relation between the verbalization and gesticulation of motion events by studying Marcel, an English speaker with a unilateral left-hemisphere lesion affecting frontal, parietal, and temporal sectors of the perisylvian cortex. Marcel has intact semantic knowledge of the three major classes of words that are commonly used in English descriptions of motion events—specifically, concrete nouns, action verbs, and spatial prepositions—as well as intact syntactic knowledge of how these word classes are typically combined in the intransitive motion construction (e.g., *The ball rolled down the hill*). However, his ability to retrieve the lexical-phonological structures of these words is severely impaired. Despite this profound anomia, he is still remarkably skilled at producing iconic manual depictions of motion events, as demonstrated in two experiments involving spontaneous gestures and one experiment involving elicited gestures. Moreover, the structural characteristics of Marcel's gestures are clearly sensitive to the idiosyncratic meanings of English verbs and prepositions, and they may also be sensitive to the way motion events are syntactically packaged in the intransitive motion construction. These findings improve our understanding of how some brain-damaged individuals with severe aphasia but without manual apraxia can successfully employ gesture to augment the semantic content of their speech.

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INTRODUCTION

When people talk, they often produce iconic manual gestures that are temporally and informationally coordinated with the concurrent speech. These gestures augment spoken language by encoding in three-dimensional analogue format what can only be orally encoded in one-dimensional digital format. For example, the visuospatial content of a sentence like *The ball rolled down the hill* can be conveyed more vividly if the speaker simultaneously moves a hand in small circles along a downward sloping trajectory. Research on co-speech gesture has increased during the past few years (for reviews see Goldin-Meadow, 2004; Kendon, 2004; McNeill, 2000b, 2005). One major finding is the existence of cross-linguistic variation in gesture systems (e.g., Enfield, 2003; Haviland, 1993; Kita, Danziger, & Stolz, 2001; Kita & Özyürek, 2003; Levinson, 2003; McNeill, 2000a; Özyürek et al., 2005; Wilkins, 2003). An especially interesting form of such variation involves the encoding of motion events. As described below, Kita and Özyürek (2003; see also Özyürek et al., 2005) discovered that the way that motion events are manually structured in co-speech gestures reflects the way that they are lexically and clausally structured in the given language. This constitutes evidence that gestures are not only tightly synchronized with speech, but are often packaged in informational units that correspond with those expressed through the oral modality.

The gestural capacities of brain-damaged individuals have also received increasing attention in recent years. A number of studies have investigated from a primarily clinical perspective how some aphasics can employ gesture as a compensatory strategy to improve their communication (e.g., Ahlsen, 1991; Fex & Mansson, 1998; Feyereisen, 1983; Hanlon, Brown, & Gerstman, 1990; Helm-Estabrooks, Fitzpatrick, & Barresi, 1982; Lott, 1999; Orgassa, 2005; Pashek, 1997; Rodriguez, Raymer, & Rothi, 2006; Schlanger & Freimann, 1979). In addition, several studies have explored from a more theoretical perspective how neuropsychological data can provide a unique source of insight into the underlying nature of the complex interaction between language and gesture (e.g., Barrett, Dore, Hansell, & Heilman, 2002; Carlomagno, Pandolfi, Marini, Di Iasi, & Cristilli, 2005; Cole, Gallagher, & McNeill, 2002; Hadar, Wenkert-Olenik, Krauss, & Soroker, 1998; Hadar & Yadlin-Gedassey, 1994; Lausberg, Cruz, Kita, Zaidel, & Ptito, 2003; Lausberg, Davis, & Rothenhausler, 2000; see also Corina et al., 1992; Marshall, Atkinson, Smulovitch, Thacker, & Woll, 2004). However, it remains the case that very little is known about the specific types of spontaneous co-speech gestures that are produced by brain-damaged individuals with different kinds of linguistic and/or cognitive disturbances.

In this paper we report a severely anomic but nonapraxic aphasic participant—Marcel[1]—who can no longer produce fluent sentences to orally express his intact semantic and syntactic knowledge of how motion events are structured in English, but who can nevertheless produce complex iconic gestures that depict the schematic visuospatial properties of those events. The rest of the Introduction is devoted to elaborating the necessary background for our study: First we review recent research on cross-linguistic covariation between the verbalization and gesticulation of motion events, and then we clarify our main goals and outline the theoretical framework that grounds our investigation. In the *Case History* section we introduce Marcel and summarize his neurological history and neuropsychological status. In the following three sections we present a series of studies that reveal a robust dissociation between impaired verbalization and preserved gesticulation of motion events. Study 1 demonstrates that Marcel is virtually incapable of retrieving the lexical-phonological forms of the three major classes of words that are commonly used in

[1] This case name is based on Marcel Marceau, the world's greatest mime artist. The patient is designated as 2762 in the Iowa Patient Registry (see Methods).

English descriptions of motion events—specifically, object nouns, action verbs, and spatial prepositions—but that he still retains knowledge of the meanings of those words. Study 2 then shows that in certain narrative contexts Marcel's verbalization of motion events is extremely impoverished while his simultaneous gesticulation of the very same motion events is quite rich. Finally, Study 3 demonstrates that in a situation in which Marcel was explicitly instructed to gesticulate the meanings of a large set of carefully selected verbs and sentences, his performance was almost indistinguishable from that of normal comparison subjects. Although the task did not involve co-speech gesture in the strict sense, the results are consistent with the hypothesis that Marcel's gestures, as well as those produced by the normal comparison subjects, were partially influenced by the way that motion events tend to be lexically and clausally packaged in English. We acknowledge, however, that further research would be necessary to confirm this hypothesis. Last of all, in the General Discussion we situate our findings within the context of our theoretical framework and also with respect to neuroscientific research on the underlying brain systems.

Cross-linguistic covariation between the verbalization and gesticulation of motion events

Basic semantic components of motion events

Only a small fraction of the 6,000 + languages in the world have been studied in depth, but it is nevertheless well established that motion events comprise one of the most important and complex semantic domains cross-linguistically (e.g., Narasimhan, 2003; Slobin, 2004; Talmy, 1985, 1991; Wienold, 1995). Typological surveys have shown that most if not all languages treat motion events as having at least four basic semantic components: (a) the *figure*, which is the entity that moves, such as a person, animal, or inanimate object; (b) the *path*, which is where the figure moves relative to its external frame of reference, such as into, onto, or across something; (c) the *manner*, which is how the figure moves relative to its internal frame of reference, such as walking, swimming, or rolling; and (d) the *ground*, which is an entity that serves as a landmark for determining the path, such as the source or goal of motion. To take a simple example, in an ordinary scene in which a man walks across a street, the figure is the man, the path of motion is the trajectory that leads from one side of the street to the other, the manner of motion is walking, and the ground is the street itself.

Cross-linguistic variation in the verbalization of motion events

Although languages worldwide distinguish between the four rudimentary semantic components of motion events described above, they vary systematically in how these components are preferentially encoded. Most of the typological research on this topic has involved sorting languages according to how the path component is encoded, since this component specifies change of location and is therefore often regarded as the core feature of a motion event. Several language types have been distinguished (Slobin, 2004; Talmy, 1985, 1991), but the two that have been studied most intensively are as follows: *satellite-framed languages* (henceforth S-languages) in which path is encoded by a satellite[2] to the verb, and manner is encoded by the verb itself; and *verb-framed languages* (henceforth V-languages), in which path is encoded by the main verb, and manner is encoded by an adverbial adjunct in a syntactically subordinate clause.

In S-languages like English, both manner and path are preferentially encoded in a monoclausal grammatical construction that Goldberg (1995) and Goldberg and Jackendoff (2004) call the

[2] The term "satellite" is defined quite broadly as "any constituent other than a nominal complement that is in a sister relation to the verb root" (Talmy, 1991, p. 486). It therefore encompasses such diverse elements as English verb particles, German separable and inseparable verb prefixes, Russian verb prefixes, Lahu nonhead "versatile verbs", Caddo incorporated nouns, and Atsugewi polysynthetic affixes around the verb root.

Table 1. *The verbalization of motion events in S-languages and V-languages*

	S-language (e.g., English)				*V-language (e.g., Modern Greek)*			
Lexical and clausal packaging	FIGURE	MANNER	PATH	GROUND	FIGURE	PATH	GROUND	MANNER
	[SUBJECT	VERB	SATELLITE	OBJECT]$_{\text{CLAUSE}}$	[SUBJECT	VERB	OBJECT]$_{\text{CLAUSE}}$	[ADVERB]$_{\text{CLAUSE}}$
	The man	walked	across	the street	*O andra* The man	*dieshise* crossed	*to dromo* the street	*perpatontas* walking
Manner granularity	Many fine-grained manner distinctions				Few fine-grained manner distinctions			
Path granularity	Many subtrajectories of complex paths				Few subtrajectories of complex paths			
Rhetorical style	Both manner and path usually expressed				Manner frequently omitted			
Sample languages	Dutch, English, German, Icelandic, Swedish, Polish, Russian, Serbo-Croatian, Ukrainian, Finnish, Hungarian, Mandarin Chinese				French, Italian, Portuguese, Spanish, Moroccan Arabic, Hebrew, Turkish, American Sign Language, Sign Language of the Netherlands			

Note: Generalizations about manner granularity are from Slobin (2003, 2004). Generalizations about path granularity are from Slobin (1996b, 2004). Generalizations about rhetorical style are based on elicited narratives analysed in Berman and Slobin (1994) and Strömqvist & Verhoeven (2004).

intransitive motion construction—for example, *The man walked across the street* (Table 1). The semantic component of manner is easily accessible for encoding because it is realized as the main verb. Every sentence requires a main verb, and with respect to the number of lexical items that a speaker must retrieve, it is just as economical to produce a manner-specific verb like *run* as it is to produce a manner-neutral verb like *go*, so speakers of S-languages effectively get manner "for free" (Slobin, 2003, p. 162). As a result, speakers of S-languages make abundant use of manner verbs in descriptions of motion events, and historically this has led S-languages to develop large lexicons in which the semantic field of manner is intricately partitioned, with many fine-grained idiosyncratic distinctions along multiple dimensions such as motor pattern, visual pattern, rate, and social-emotional evaluation (Table 2). Such specialized manner verbs are not just dictionary entries, but are employed by speakers in a variety of naturalistic and experimental contexts, including picture-elicited oral narrative, spontaneous conversation, creative writing, naming videoclips of motion events, and speeded fluency—that is, listing as many manner verbs as possible within a one-minute time frame (Slobin, 2000, 2003).

V-languages also have a monoclausal intransitive motion construction in which manner is realized as a verb and path as a satellite, but the expressive range of the construction is typically much narrower in these languages than in S-languages. In particular, the construction can only be used to encode motion events if the path is continuous and uninterrupted (e.g., *run toward/away from a building*). If instead the path culminates in the crossing of some kind of boundary, then information about the specific nature of the path cannot be encoded in the form of a satellite (e.g., *run into/out of a building*) but must rather be encoded more prominently as a main-clause verb, forcing the manner component to be shifted to adjunct status in an optional subordinate

Table 2. *Fine-grained partitioning of the semantic field of manner of motion in English, a prototypical S-language*

Rapid motion	bolt, burst, dart, dash, hasten, hurry, race, run, scramble, sprint
Leisurely motion	amble, drift, loiter, mosey, saunter, stroll, wander
Smooth motion	brush, glide, slide, slink, slip, slither
Awkward motion	hobble, limp, lurch, stagger, stumble, trip
Furtive motion	crawl, creep, sidle, skulk, sneak, tiptoe
Manners of walking	march, plod, sashay, step, stride, strut, tramp, trudge, walk
Manners of jumping	bound, jump, leap, spring

Note: Adapted from Slobin (2000).

clause (e.g., *enter/exit a building running*) (Aske, 1989; Slobin & Hoiting, 1994). As a result of this grammatical-semantic constraint, the latter biclausal construction, which is illustrated by the Modern Greek example in Table 1, has a greater frequency of usage than does the former monoclausal construction, as shown by quantitative analyses of narrative data (Berman & Slobin, 1994; Strömqvist & Verhoeven, 2004). Path is highly codable in the biclausal construction because it is mapped onto the main verb slot; manner, however, is "costly" to produce since it requires generating a separate clause, and for this reason it is often omitted entirely (Berman & Slobin, 1994; Strömqvist & Verhoeven, 2004). A historical consequence of this downgrading of manner information is that the manner-verb lexicons of V-languages are generally not as densely differentiated as those of S-languages. For instance, Spanish *escabullirse* does not distinguish between *glide, slide, slip*, and *slither*, and French *bondir* does not distinguish between *jump, leap, bound, spring*, and *skip* (Slobin, 2000, 2003).

Numerous studies across a variety of age groups and discourse genres suggest that the different ways of preferentially packaging motion events in S- and V-languages induce speakers to habitually engage in different patterns of "thinking for speaking"—that is, the cognitive process of figuring out how to put one's thoughts into words, or, more technically, determining how one's nonlinguistic mental representations can be matched with the unique semantic structures encoded by the lexical items and grammatical constructions of one's native language (Slobin, 1987, 1996a, 1996b, 2000, 2003). As alluded to above, speakers of S-languages pay more attention to manner distinctions than do speakers of V-languages. In addition, speakers of S-languages seem to be inclined to think of manner and path as being tightly integrated components of motion events, as if directed motion along a trajectory inherently involves some kind of manner, whereas speakers of V-languages tend to think of the two components as being conceptually more independent. Both of these contrasting forms of language-specific "thinking for speaking" are also visible in co-speech gestures, as described below.[3]

Cross-linguistic variation in the gesticulation of motion events

To investigate cross-linguistic variation in the gestural encoding of motion events, Kita and Özyürek (2003) showed *Canary Row*, an animated cartoon featuring "Sylvester the cat" and "Tweety the bird," to speakers of one S-language (English) and two V-languages (Japanese and Turkish) and then asked them to narrate the story.[4] Analyses were made of the speakers' patterns of concurrent language and gesture while describing two scenes: the "Swinging Event" and the "Rolling Event".

In the Swinging Event, Sylvester and Tweety are across the street from each other in the windows of different high-rise buildings, and in an attempt to catch Tweety, Sylvester swings across the street on a rope; he misses Tweety, however, and crashes into the side of the building instead. Linguistically, English speakers used the verb *swing* to describe the event, but Japanese and Turkish speakers lack a verb for an arc-shaped trajectory (this being one manifestation of how V-languages generally have more impoverished manner-verb inventories than do S-languages), so they described the event by using verbs that are translated roughly as *go, jump, fly*, and *sneak in*. Gesturally, the different participant groups manifested strikingly different performance patterns, presumably because of the differential

[3] Whether the different coding preferences of the two language types have deeper cognitive influences—that is, whether they affect people's nonlinguistic processing of motion events (e.g., similarity judgements, mental imagery, learning, memory, evaluation)—is still an unresolved issue, with some studies supporting this possibility (e.g., Billman & Krych, 1998; Billman, Swilley, & Krych, 2000; Kersten et al., 2006; Oh, 2003) and others leaning against it (e.g., Gennari, Sloman, Malt, & Fitch, 2002; Papafragou, Massey, & Gleitman, 2002, 2006). The new findings reported in the present study do not bear directly on this ongoing debate, since our focus is limited to "thinking for speaking" and its effects on co-speech gesture.

[4] For a detailed description of the cartoon, see the appendix of McNeill (1992).

availability of a verb like *swing*. Almost all of the English speakers used isolated arc gestures that not only represented iconically the shape of Sylvester's trajectory as depicted in the stimulus, but also corresponded to the semantic structure of the verb *swing*. A few English speakers produced an arc gesture together with a straight horizontal gesture, the latter highlighting just the source and goal of the motion event; however, none of them produced an isolated straight gesture. In contrast, less than a quarter of the Japanese speakers, and less than half of the Turkish speakers, produced isolated arc gestures. Instead, the majority of participants in these two groups preferred to use either arc gestures together with straight gestures, or exclusively straight gestures. Kita and Özyürek (2003) argue that while the Japanese and Turkish participants' occasional use of arc gestures may have been influenced by their memory of the dynamic visuospatial stucture of the motion event, their more frequent selection of straight gestures reflected the linguistic packaging of the motion event, specifically the absence of a verb like *swing*.

In the Rolling Event, Sylvester, who has swallowed a bowling ball, has a big round stomach and bottom, and rolls down the street into a bowling alley. Linguistically, English speakers produced one clause expressing both manner and path (usually *roll down*), consistent with the typical S-language pattern; however, Japanese and Turkish speakers produced separate clauses for these two semantic components (the rough equivalent of *descend rolling*), consistent with the typical V-language pattern. Gesturally, the different subject groups exhibited different performance patterns once again, only this time reflecting the different ways of clausally packaging the motion event. English speakers used manner-path conflations alone more often than did Japanese and Turkish speakers—a coding pattern that not only represented iconically the spatiotemporal synthesis of manner and path in the visual stimulus, but also corresponded to the linguistic integration of both semantic components in a single concise clause. Japanese and Turkish speakers, on the other hand, produced separate gestures for manner and path more often than did English speakers, most likely reflecting the encoding of each semantic component in a separate clause. Although many Japanese and Turkish speakers produced manner-path conflations, they tended to do so together with manner-only and/or path-only gestures. As Kita and Özyürek (2003, p. 25) point out, for these speakers "it was not sufficient to have a construal of the event that is similar to the nonlinguistic structure of the Rolling Event. They had to further come up with informational chunks that were more compatible with their linguistic formulation possibilities . . .". These findings suggest that in addition to lexical-semantic resources, another factor that influences the gesticulation of motion events is the way that such events are clausally organized in the given language.

Kita and Özyürek (2003) also discovered that for both the Swinging Event and the Rolling Event, most speakers of all three languages omitted from their verbal narratives, but included in their concurrent gestural expressions, the direction of motion in the stimulus. For both motion events, most speakers manually encoded direction from the perspective of the viewer—that is, as an arm/hand movement with either a leftward or rightward bias, corresponding to the trajectory shown on the video screen. However, some speakers adopted the perspective of the protagonist, so that the gesture was away from the speaker, as if the protagonist's body were mapped onto the speaker's body. These results suggest that another factor influencing co-speech gestures for motion events involves spatial features of the referent scene that are not verbalized.

Kita and Özyürek (2003) argue that their study supports the interface hypothesis, which maintains that the content and organization of co-speech gestures are partially shaped by the following factors (see also Özyürek et al., 2005, for further empirical and theoretical developments):

1. Two distinct levels of linguistic structure:
   a. Lexical-semantic resources.
   b. Syntactic organization.
2. Aspects of spatial representation that are not usually verbalized.

Claims 1a and 1b distinguish the interface hypothesis from the free imagery hypothesis, which holds that gestures are not constrained at all by the representational potential of the language (Krauss, Chen, & Chawla, 1996; Krauss, Chen, & Gottesman, 2000), and Claims 1b and 2 distinguish the interface hypothesis from the lexical semantics hypothesis, which holds that gestures are generated primarily from the meanings of words in the accompanying speech (Butterworth & Hadar, 1989; Hadar & Butterworth, 1997; Schegloff, 1984). While it is true that some gestures do correspond to the meanings of simultaneously expressed words (as in English speakers' narrations of the Swinging Event), it is also the case that gestures are sometimes influenced by linguistic units larger than the word, such as the clause (as shown by the differences between English speakers' and Japanese and Turkish speakers' narrations of the Rolling Event); furthermore, gestures sometimes incorporate spatial information that is not verbalized (as with the exclusively gestural encoding of directionality in all of the narrations of both the Swinging and Rolling Events). Overall, the interface hypothesis is most similar to the growth point theory, which states that the planning of synchronous utterances and gestures involves a complex interplay between linguistic and imagistic thinking (McNeill, 1992, 2000a; McNeill & Duncan, 2000; see also Alibali, Kita, & Young, 2000; Kita, 2000).

Goals and theoretical framework

Our neuropsychological investigation of Marcel had two main goals: first, to explore the specific types of iconic gesture, both spontaneous and elicited, that he is able to produce despite his severe anomia; and second, to evaluate and attempt to explain the degree to which his gestures are structurally similar to those produced by normal English speakers. This investigation was partly inspired by Kita and Özyürek's (2003) discovery of cross-linguistic covariation between the verbalization and gesticulation of motion events, as well as by the interface hypothesis that they invoke to explain their findings. However, the overarching purpose of our investigation was not to assess the validity of the interface hypothesis, but rather to gain further insight into the kind of gestural communication that is still possible in the context of profound aphasia.

Kita and Özyürek (2003) anchor the interface hypothesis in a modified version of Levelt's (1989) model of speech production, but we prefer to ground our investigation in a variant of the linguistic framework developed by Jackendoff (2002), since it is not only more consistent with our theoretical biases but is also more explicit about several points that are relevant to our study, especially regarding the encoding of motion events. Figure 1 shows the multiple cognitive systems that comprise the framework and illustrates how they collectively subserve the concurrent verbalization and gesticulation of a single sentence instantiating the intransitive motion construction—namely, *The ball rolled down the hill.* We have deliberately incorporated into Jackendoff's architecture the system referred to as Gestural Structure (GS) so that we can elucidate several aspects of the complex interaction between language and gesture. As described below, correspondences between structural units in the different cognitive systems are formally indicated by coindexed numerical subscripts, in accord with the notational conventions proposed by Jackendoff.

The meaning of *The ball rolled down the hill* is captured jointly by the two systems at the top of Figure 1—Spatial Structure (SpS) and Conceptual Structure (CS). Jackendoff (2002) argues that the SpS system is involved in categorizing the shape, motion, and layout of objects and substances in space, and that specific units of SpS symbolize geometric/topological patterns that may be thought of as image schemas. In Figure 1 the dashed box that surrounds the whole illustration indicates the entire motion event and is labelled 1. The circle labelled 2 indicates the unit of SpS representing the shape of the ball. The arrow labelled 3 and 4 indicates two units of SpS representing separate but closely related aspects of the ball's path—its downward trajectory (3), and its left-to-right directionality (4). The arrow labelled 5 indicates the unit of SpS representing

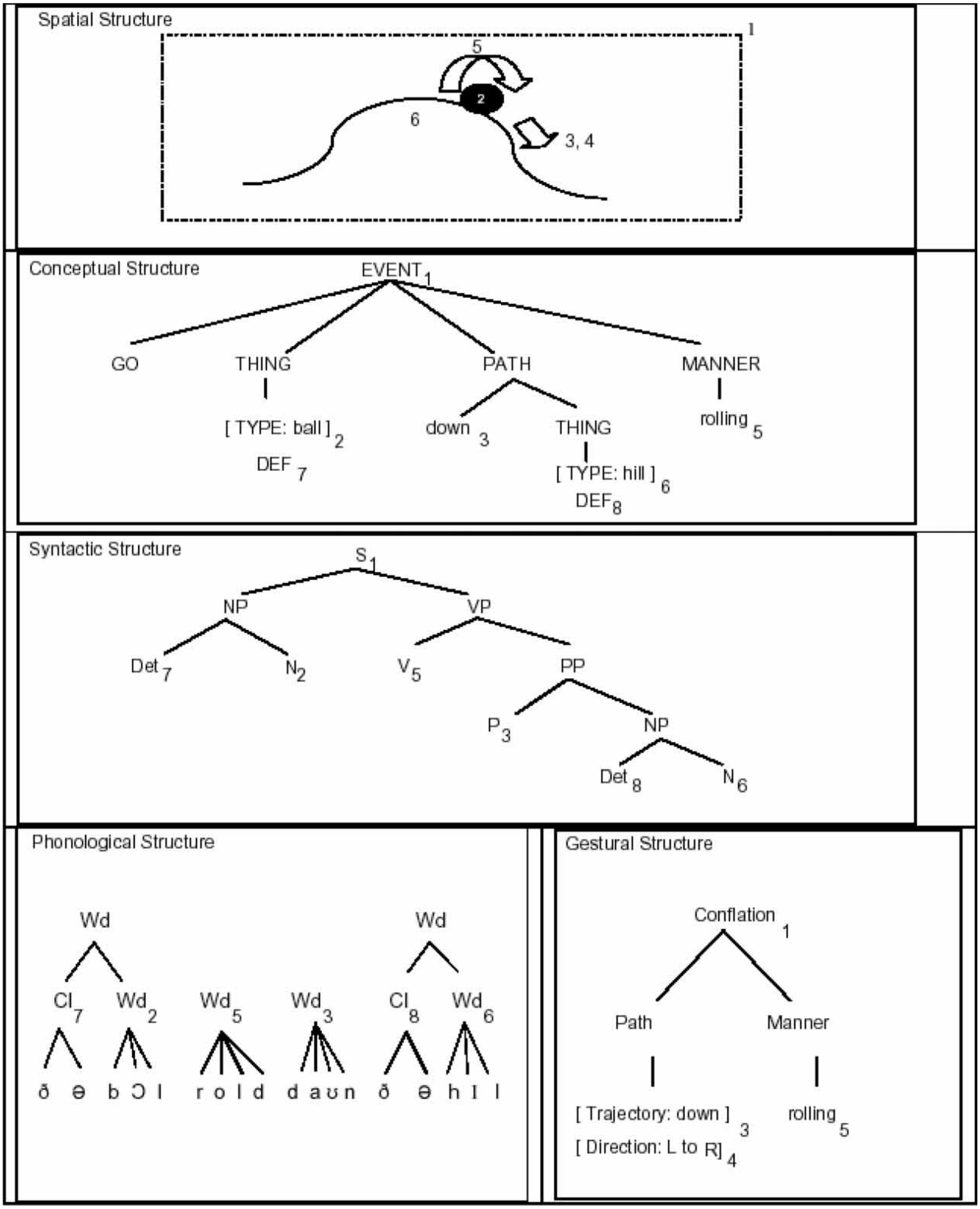

Figure 1. *Functional architecture of the cognitive systems underlying the verbalization and gesticulation of motion events, exemplified by the representation of the sentence* The ball rolled down the hill. *See text for details.*

the rolling pattern of the ball's motion. Finally, the curved line labelled 6 indicates the unit of SpS representing the shape of the hill. Turning to the CS system, Jackendoff (2002) argues that it is the level at which predicate-argument relations, the type-token distinction, presupposition, quantification, and so forth are formulated. In Figure 1 a tree diagram portrays some of the core elements of the CS of *The ball rolled down the hill*. Correspondences between units of SpS and units of CS are indicated by subscripts.

The third system is Syntactic Structure (SS), which is the level at which grammatical categories like noun, verb, and preposition are combined to form larger constituents like phrases, clauses, and sentences. For the sake of simplicity, Figure 1 illustrates the SS of *The ball rolled down the hill* in very generic terms. The whole SS constitutes the syntactic level of the English intransitive motion construction. The fact that English is typologically classified as an S-language is captured in Figure 1 by the following sets of CS–SS correspondences. First, the "down" element in CS is linked with the preposition category in SS (Subscript 3). Given that prepositions are satellites in Talmy's (1985, 1991) and Slobin's (2000, 2003, 2004) terminology, this correspondence indicates that English prefers to express the core path component of motion events with a satellite instead of a verb. Second, the "rolling" element in CS is linked with the verb category in SS (Subscript 5), showing that English reserves the verb position for expressing the manner component of motion events.

The system called Phonological Structure (PS) subserves the oral encoding of motion events. Two hierarchically related representational tiers for *The ball rolled down the hill* are depicted in Figure 1. At the top is morphophonological structure—that is, units for words and clitics. These units are sometimes referred to as lexical-phonological structures, nodes, or forms. They are composed of sequences of phonological segments, as shown in the bottom part of the diagram. Several other sublevels of PS, such as distinctive features, syllabic structure, and prosodic structure, are not shown in Figure 1.

The last system is Gestural Structure (GS), which subserves the manual encoding of motion events. According to the interface hypothesis, GS is partially shaped by the factors described in Claims 1 and 2 above (see section *Cross-linguistic Variation in the Gesticulation of Motion Events*). These multiple sources of influence on GS are illustrated in Figure 1 through multiple sets of correspondences—or interfaces, to use the term favoured by Kita and Özyürek (2003) and also employed frequently by Jackendoff (2002)—between certain units of GS and certain units of SpS, CS, and SS. Claim 1a—that is, that GS is influenced by language-specific lexical-semantic resources—is illustrated by the following two sets of correspondences between SpS and CS on the one hand and GS on the other: First, the "down" units in SpS and CS are associated with the "down" unit in GS (Subscript 3); and second, the "rolling" units in SpS and CS are associated with the "rolling" unit in GS (Subscript 5). Claim 1b—that is, that the gestural packaging of motion events often mirrors the syntactic packaging of motion events—is shown by the correspondence between the sentence unit in SS, which embraces within a single compact clause both the manner verb and the path preposition, and the conflation unit in GS, which similarly embraces within a single integrated gesture both the manner component and the path component (Subscript 1). Finally, Claim 2—that is, that iconic gestures sometimes express spatial information that is not simultaneously expressed in speech—is captured by the fact that the path component of GS is specified as having left-to-right directionality, a feature that reflects the directionality shown in SpS (Subscript 4) but is not encoded in CS, SS, or PS.

It would be remiss not to make two additional points about our conception of the GS system. First, the main reason why a manner-path conflation is shown in Figure 1 is that Kita and Özyürek (2003) found that when the English speakers in their study narrated the Rolling Event, this is the type of gesture that they produced most often, usually in isolation (i.e., without also producing separate manner-only and/or path-only gestures, thus distinguishing these speakers from the Japanese and Turkish speakers) and in synchrony with a monoclausal expression including the manner verb *roll* and the path preposition *down*. But while this constitutes evidence that language-specific factors—in this case, the clausal packaging of motion events—influence the content and organization of co-speech gestures, it is also important to note that the interaction between language and gesture allows for a great deal of flexibility. For instance, during their narrations of the Rolling Event, a few of the English speakers in Kita and Özyürek's study produced exclusively manner-only gestures, a few produced exclusively path-only gestures, and a few did not produce any gestures at all. Second, it is well established that gesture is closely coordinated with speech not only representationally but also temporally; that is, when people express certain thoughts in three-dimensional analogue format through co-speech gestures, their manual movements are tightly synchronized with the expression of the same (or very similar) thoughts in one-dimensional digital format through words (McNeill, 1992). For example, when stutterers repeatedly produce just the initial syllable of a word that they are struggling to articulate, their gestures typically remain time locked with their dysfluent speech (Mayberry & Jacques, 2000; see also the experiments involving delayed auditory feedback reported by McNeill, 1992). Both of these points are relevant to our analysis of Marcel's co-speech gesticulation of motion events, as will become clear below.

CASE HISTORY

Neurological background

Marcel is a 40-year-old, fully right-handed (+100 on the Geschwind-Oldfield scale) man with 13 years of education. All of his first-degree relatives are right-handed. He earned average to above-average grades in school and worked for several years as a salesperson. In August, 1996, he suffered a unilateral left-hemisphere traumatic brain injury (TBI) during an automobile accident. He sustained a depressed skull fracture and an epidural and subdural hematoma, which required surgical intervention. He made an excellent neurological recovery, and by one year after lesion onset, his neurological status was entirely normal save for aphasia. He developed posttraumatic seizures, which have been well controlled with medication (Tegretol). Marcel's lesion is depicted in Figure 2, which shows a three-dimensional reconstruction using Brainvox (Damasio & Frank, 1992) based on a magnetic resonance imaging (MRI) scan conducted 2/20/02. The damage affected the posterior inferior frontal gyrus, the inferior precentral and postcentral gyri, part of the inferior parietal operculum, most of the superior temporal gyrus, and a small portion of the posterior middle temporal gyrus. The lesion is remarkably superficial, however, being almost completely confined to cortex and sparing almost all of the underlying white matter. In fact, even in some of the cortical regions that appear to be damaged and in which there is abnormal signal on the MRI scan, there may be some preservation of neural function, and this would help explain Marcel's neurological status: He has no motor or sensory defects and, as noted, no neurological defects whatsoever outside of his aphasia (including absence of anosmia). Apart from the left-sided cortical injury, there is no indication of any other brain damage.

General neuropsychological assessment

Table 3 shows Marcel's performance on standardized neuropsychological tests that are routinely used in the Benton Neuropsychology Laboratory. The data provide a detailed overview of his mental capacities (for descriptions of the tests, see Tranel, 1996, in press). Marcel has intact orientation, is completely attentive to the examination, and makes appropriate efforts to respond. He frequently resorts to attempts at writing responses, when the oral modality fails. (These attempts, in conjunction with paralinguistic gestures, often enhance the overall effectiveness of his communication, because the listener can

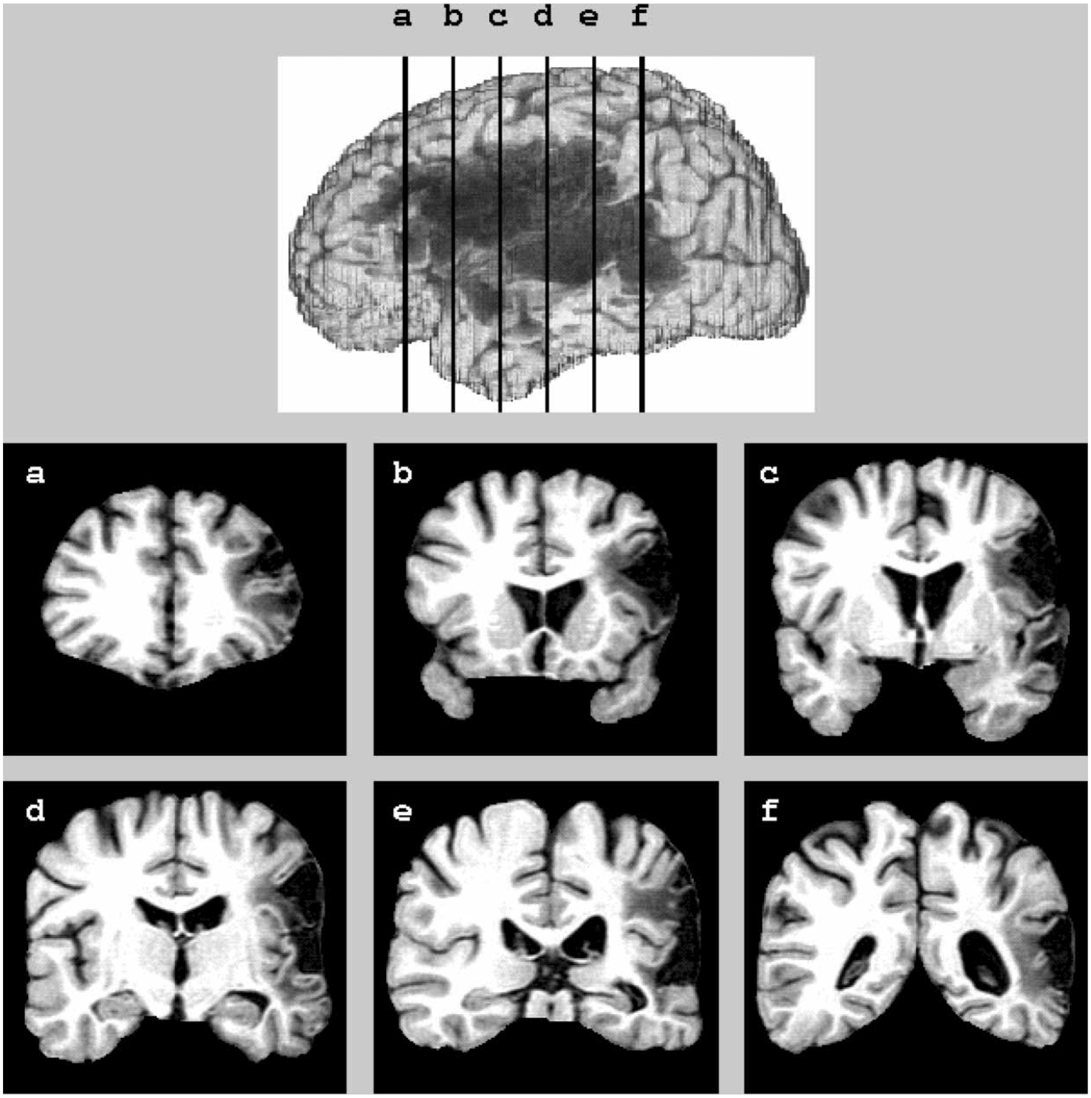

Figure 2. *Lesion reconstruction for Marcel from an MRI scan. See text for details.*

frequently guess his intentions based on a combination of his gestures and the letters he produces in writing. However, his actual written output is as severely impaired as his spoken output: Most of the time, he can write only the first letter of the word that he is attempting to produce; on rare occasions he might produce two or three letters. He almost never produces a complete word via writing. In short, his ability to produce word forms via writing is profoundly disrupted, essentially to the same magnitude as his spoken word production.) On formal assessment, his performance IQ was average (verbal IQ was not assessed, due to his aphasia). Scores on most of the subtests from the WAIS-III were in the average range, within expectations based on his

Table 3. *Neuropsychological assessment of Marcel*

Test/Function	*Score*	*Interpretation*
Orientation		
Time	−0	Intact
Place and personal information	6/6	Intact
Intellect		
Wechsler Adult Intelligence Scale−III		
Performance IQ	91	Average
Picture Completion	9	Average
Digit Symbol-Coding	6	Low average
Block Design	9	Average
Matrix Reasoning	11	Average
Picture Arrangement	9	Average
Object Assembly	13	High average
Anterograde memory for visuospatial material		
Benton Visual Retention Test (#correct/#errors)	8/3	Normal
Complex Figure Test: Delayed Recall (#/36)	17.5	Normal
Visuospatial perception/ construction		
Facial Discrimination (percentile)	15	Low average
Judgement of Line Orientation (percentile)	57	Average
Hooper Visual Organization Test (#/30)	28.5	High average
Complex Figure Copy (#/36)	34	High average
Clock Drawing Test	1/1	Intact
Language		
Multilingual Aphasia Examination (percentiles)		
Controlled Oral Word Association	<1	Very defective
Visual Naming	<1	Very defective
Sentence Repetition	<1	Very defective
Token Test	<1	Very defective
Aural Comprehension	16	Low average
Reading Comprehension	59	Average
Boston Diagnostic Aphasia Examination		
Boston Naming (#/60)	3	Very defective
Responsive Naming (#/30)	7	Very defective
Reading (#/10)	10	Average
Praxis		
Buccofacial (#/5)	5	Intact
Intransitive Limb (#/5)	5	Intact
Transitive Limb (#/5)	5	Intact
Whole Body (#/5)	5	Intact
Executive function		
Trail Making Test: Part A	37 sec	Average
Trail Making Test: Part B	113 sec	Low average

educational and occupational background. Anterograde memory for visuospatial material was normal (again, verbal memory was not assessed due to his aphasia). In the domains of visuospatial perception and construction, his scores ranged from "low average" to "high average". Outside of language-related deficits, there was no indication of impairments in higher order reasoning and planning abilities, nor was there any indication of changes in personality, social functioning, or emotional regulation (as assessed with standard tests and interviews; see Tranel, Bechara, & Denburg, 2002, for details regarding the test instruments).

Marcel's speech is very nonfluent and effortful, but not dysarthric or aprosodic. His sentence production is moderately agrammatic, as suggested by clinical observations as well as by informal analyses of the narratives that he provided in Study 2. His comprehension of conversational speech is well preserved, and he readily understands test instructions and is able to cooperate fully and validly with assessment procedures. Evaluation of linguistic abilities with the Multilingual Aphasia Examination (MAE) and the Boston Diagnostic Aphasia Examination (BDAE) revealed multiple defects, consistent with his severe aphasia. He achieved a "low average" score on a simple measure of aural comprehension from the MAE and "average" scores on two measures of reading; otherwise, his scores were mostly very impaired. Marcel has no impairments in buccofacial praxis or gestural praxis, as determined by standard tests from the BDAE.

STUDY 1: ANOMIA FOR NOUNS, VERBS, AND PREPOSITIONS

The general neuropsychological assessment revealed that Marcel has impaired production but relatively intact comprehension of spoken words. The purpose of this study was to investigate more specifically his naming and semantic knowledge for the three major word classes that are commonly used in English descriptions of motion events: object nouns, action verbs, and spatial prepositions

Method

First, Marcel was shown 110 pictures (either line drawings or photographs) of objects belonging to the following six categories: animals ($n = 18$), fruits/vegetables ($n = 16$), tools/utensils ($n = 35$), human body parts ($n = 30$), vehicles ($n = 5$), and musical instruments ($n = 6$). For each stimulus, he was asked to say the correct name of the object. If naming was inaccurate or absent, he was prompted to generate specific descriptions of the stimuli. These were scrutinized to determine whether they conveyed sufficient information about the object to warrant scoring the response as a correct identification—that is, as adequate retrieval of semantic knowledge. For details concerning the scoring procedure, see Damasio, Tranel, Grabowski, Adolphs, and Damasio (2004).

Next, Marcel was given a battery of six tests that evaluate production, comprehension, and semantic analysis of a wide range of action verbs that vary along multiple conceptual and grammatical dimensions. These tests are only described briefly here because complete details are available elsewhere (Fiez & Tranel, 1997; Kemmerer, Tranel, & Barrash, 2001).

- *Naming* ($n = 100$): For each item, the participant is shown a photograph of an action, and the task is to name it with a specific verb or else with one of a small set of verbs considered to be acceptable responses based on normative data.
- *Word–Picture Matching* ($n = 69$): For each item, the participant is shown a written verb together with photographs of two actions, and the task is to determine which action the verb describes.
- *Picture Attribute* ($n = 72$): For each item, the participant is shown photographs of two actions, and the task is to indicate which action satisfies a particular value for a single attribute—for example, which one makes the loudest sound.
- *Word Attribute* ($n = 62$): This test parallels the Picture Attribute Test, but the stimuli are written verbs instead of photographs.
- *Picture Comparison* ($n = 24$): For each item, the participant is shown photographs of three actions, and the task is to ascertain which action is different from the other two—for example, in one item the pictures show a person *wrapping* a box with paper, a person *wrapping* her wrist with a cloth, and a person *drying* a plate with a towel.
- *Word Comparison* ($n = 44$): This test parallels the Picture Comparison Test, but the stimuli are written verbs instead of photographs, and the two associated verbs have one of four types of semantic relation—synonymy, antonymy, hyponymy, or cohyponymy.

Finally, Marcel was given a battery of four tests that assess production, comprehension, and semantic analysis of 12 spatial prepositions (*on, in, around, through, above, below, over, under, in front of, in back of/behind, beside/next to, between*). As with the verb tests, these tests are only described briefly here because complete details are available elsewhere (Kemmerer & Tranel, 2000; Tranel & Kemmerer, 2004). The tests focus on locative rather than path prepositions; however, the meanings of the latter often incorporate those of the former (e.g., *into* and *onto* derive from *in* and *on*).

- *Naming* ($n = 80$): For each item, the participant is shown a photograph of two (sometimes three) objects in a particular spatial relationship, and the task is to name the spatial relationship with a specific preposition or else with one of a small set of prepositions considered to be acceptable responses based on normative data.
- *Word–Picture Matching* ($n = 50$): For each item, the participant is shown a written preposition together with photographs of three spatial relationships, and the task is to determine which spatial relationship the preposition describes.
- *Odd One Out* ($n = 45$): For each item, the participant is shown photographs of three spatial relationships, and the task is to ascertain which spatial relationship is different from the

other two—for example, in one item the pictures show a boy *on* a tricycle, a sign *on* a wall, and eggs *in* a carton.[5]

- *Verification* ($n = 44$): For each item, the participant is shown a written preposition together with line drawings of two (sometimes three) abstract shapes in a particular spatial relationship, and the task is to indicate whether the preposition correctly describes the depicted spatial relationship.

Results

The results for all three batteries of tests are shown in Table 4. For object nouns, Marcel exhibited a robust dissociation between severely impaired spoken naming (mean = 6.3%) and well-preserved semantic knowledge (mean = 95%). Interestingly, for the objects that he could not name, he sometimes demonstrated accurate recognition by producing not only verbal descriptions (e.g., drill → "make hole") but also pantomimes of appropriate motion patterns. For action verbs, his spoken naming was extremely poor (2%), yet his average score on the tests evaluating semantic knowledge was normal (89.1%). Although his score on the Word Comparison Test was below normal (70%), this probably reflects disproportionate difficulty with certain processing requirements that are unique to that test, as opposed to impaired knowledge of the meanings of action verbs (Kemmerer et al., 2001). Turning to spatial prepositions, the same dissociation emerged once again. His spoken naming was profoundly defective (12.5%), but his average performance on the tests assessing semantic knowledge was within normal limits (85.3%). He was mildly impaired on the Odd One Out Test (76%), but his score on the Matching Test was high (96%), and he was also within the normal range on the Verification Test (84%), suggesting relatively intact knowledge of the meanings of spatial prepositions.

Discussion

The results clearly indicate that Marcel is virtually incapable of orally producing all three classes of words—object nouns, action verbs, and spatial prepositions—but has little trouble retrieving the appropriate semantic knowledge. Quantitative analyses of his spoken naming errors were not conducted; however, the vast majority of his errors were omissions. He made a number of semantic paraphasic naming responses, but few phonological paraphasic errors, suggesting that the primary deficit involves activating the appropriate lexical-phonological structures from lexical-semantic input (Dell, Lawler, Harris, & Gordon, 2004; Hillis, 2001; Laine, Tikkala, & Juhola, 1998; Ruml, Caramazza, Shelton, & Chialant, 2000). We consider the relation between Marcel's linguistic deficit and his lesion in the General Discussion.

STUDY 2: SPONTANEOUS VERBALIZATION AND GESTICULATION OF MOTION EVENTS

Although Marcel has great difficulty expressing himself through the oral modality, it was apparent to us from our very first encounters with him that he could convey his thoughts remarkably well through the skillful use of iconic gesture. To explore the types of spontaneous co-speech gestures that he is capable of producing despite his profound anomia, we conducted two experiments. In the first experiment, we investigated his simultaneous verbalization and gesticulation of the Swinging and Rolling Events in *Canary Row* and compared his performances with those of the normal English, Japanese, and Turkish speakers studied by Kita and Özyürek (2003). In the

[5] The format of this test is analogous to that of the Picture Comparison Test in the verb battery. It is noteworthy that although neither of these tests requires the processing of lexical-phonological structures, both of them probably do require knowledge of lexical-semantic structures, some of which may be unique to English. For example, *on* applies to spatial relationships involving both horizontal support by virtue of gravity (as in the picture of a boy on a tricycle) and vertical support by virtue of attachment (as in the picture of a sign on a wall); however, many other languages employ different morphemes for these two types of spatial relationship (Kemmerer, 2006b; Levinson & Meira, 2003).

Table 4. *Marcel's performance on tests assessing picture naming and semantic knowledge of concrete nouns, action verbs, and spatial prepositions, as compared with data from normal participants*

		Picture naming		*Semantic knowledge*	
Category/Test	*n*	*Normals*	*Marcel*	*Normals*	*Marcel*
Concrete nouns					
animals	18	95.7 (3.1)	0	91.9 (2.8)	89
fruits & vegetables	16	94.3 (3.7)	8	92.6 (3.9)	81
tools & utensils	35	97.2 (3.9)	3	96.2 (3.3)	100
human body parts	30	98.1 (1.2)	27	100	100
vehicles	5	97.4 (2.0)	0	98.4 (2.1)	100
musical instruments	6	96.9 (4.5)	0	96.3 (3.4)	100
Mean		96.6	6.3	95.9	95
Action verbs					
naming	100	85.2 (5)	2	–	–
word–picture matching	69	–	–	92.1 (4.6)	96
picture attribute	72	–	–	91.7 (4.8)	92
word attribute	62	–	–	94.8 (3.6)	100
picture comparison	24	–	–	83.6 (8.3)	87.5
word comparison	70	–	–	88.7 (8.1)	70
Mean		85	2	90.2	89.1
Spatial prepositions					
naming	80	93.3 (6.6)	12.5	–	–
word–picture Matching	50	–	–	99.4 (1.2)	96
odd one out	45	–	–	95.2 (6.5)	76
verification	44	–	–	91.6 (8.9)	84
Mean		93.3	12.5	95.4	85.3
Overall mean		91.7	6.9	93.8	89.8

Note: For Marcel the cells indicate percentage correct; for the normal participants they indicate mean percentage correct with standard deviations in parentheses. The normative data derive from various publications from our laboratory; see text for details.

second experiment, we investigated his simultaneous verbalization and gesticulation of 12 motion events portrayed in the wordless picture book *Frog, Where Are You?* (Mayer, 1969) and compared his performances with those of a group of normal English speakers. In both experiments, we expected that Marcel's verbalization would be severely impaired but that his gesticulation would be quite elaborate. In addition, we wanted to address the question of the extent to which his gestures would be structurally similar to those produced by normal English speakers and hence possibly influenced by the way that motion events tend to be lexically and clausally packaged in this particular S-language. We report both experiments together in this section because they employed similar methods and yielded similar results.

STUDY 2A: *CANARY ROW*

Method

On three separate occasions, Marcel watched *Canary Row* on a computer monitor and then told the story to a listener who had been waiting in another room. He was not explicitly instructed to supplement his narratives with gestures, so the gestures that he did produce were completely spontaneous. Marcel's performances were recorded with a camcorder. His narratives were transcribed, and his co-speech gestures were categorized as follows according to the same criteria as those used by Kita and Özyürek (2003). For the Swinging Event, a gesture was treated as an "arc" if its trajectory was downward concave and as "straight" if its trajectory was purely lateral. For the Rolling Event, a gesture was treated as "manner only" if it iconically represented just the circular nature of the rolling, as "path only" if it iconically represented just the trajectory of the rolling, and as a "conflation" if it iconically represented the superimposition of both semantic components. Gesture classifications were initially conducted by the second author and were subsequently checked, with 100% agreement, by the first author.

Results and discussion

The results are shown in Table 5. Across all three trials of the Swinging Event, Marcel never used either the verb *swing* or the preposition *across* in his oral descriptions, but he nevertheless produced isolated arcs in his concurrent gestures. For example, on Trial 2 he said "He go here, and bird, and back home" and simultaneously made two arc gestures. The first one was synchronized with the utterance "He go here" and had a leftward direction, and the second one was synchronized with the utterance "and back home" and had a rightward direction; more precisely, it represented what Marcel apparently imagined to be Sylvester's intention, namely to swing back to his own building after capturing Tweety. The fact that Marcel produced isolated arc gestures on every trial converges with the predominant pattern exhibited by Kita and Özyürek's (2003) English speakers and diverges from that exhibited by their Turkish and Japanese speakers. The English speakers' arc gestures were partially influenced by the lexical-semantic structure of *swing*, a verb that has no counterpart in either Japanese or Turkish. However, because Marcel never said *swing*, it is impossible to know whether he activated the meaning of this verb, and hence it is also impossible to know whether his arc gestures were influenced by that meaning; after all, they could have been determined solely by the dynamic visuospatial structure of the motion event in the stimulus. The point is simply that the proper interpretation of Marcel's arc gestures is rendered especially difficult because his anomia consistently prevented him from saying *swing*.

Table 5. *Marcel's concurrent linguistic and gestural encoding of the Swinging and Rolling Events in three separate trials*

Event	*Trial*	*Speech*	*Gesture*
Swinging	1	Whoosh, run there	Arc
	2	He go here, and bird, and back home	Arc (twice)
	3	Bird right there, and he misses, bam!	Arc
Rolling	1	He . . . down, whoa!	Manner-only rolling gesture during pause after "He," followed by path-only sloping gesture synchronized with "down".
	2	He run run run	Conflation comprised of a rolling manner component and a lateral path component.
	3	He . . . uh uh uh go down down down	Manner-only rolling gesture during pause after "He," followed by path-only sloping gesture synchronized with "down down down".

Across the three trials of the Rolling Event, Marcel never uttered the verb *roll*, but he did use the preposition *down* several times. In the manual modality, he consistently produced complex iconic gestures. On Trial 2, for instance, he produced a conflation in which the manner component represented rolling, and the path component represented a lateral trajectory. This performance was similar to that of Kita and Özyürek's (2003) English speakers. On Trials 1 and 3 he produced gestural sequences that were almost identical to each other. Concurrently with saying "He", Marcel initiated a manner-only rolling gesture and sustained it in a stationary position in front of his body during a long pause. Then at the same time that he said "down" in Trial 1 and "go down down down" in Trial 3, he abruptly terminated the manner-only gesture and produced a path-only gesture with a downward sloping trajectory representing the direction of Sylvester's motion. These two performances accord more with the predominant pattern exhibited by Kita and Özyürek's (2003) Japanese and Turkish speakers than with the predominant pattern exhibited by their English speakers. However, it is possible that Marcel's non-English-typical gesticulation derived in part from his impaired verbalization. On each of the two trials, during the lengthy pause between "He" and "down", Marcel may have been searching in vain for the lexical-phonological form of the manner verb *roll*. Because he was presumably concentrating on just the manner component of the Rolling Event, he only encoded that component in his concurrent gesture (Christenfeld, Schachter, & Bilous, 1991). After aborting the lexical-phonological search, he apparently shifted his attention to the path component of the Rolling Event, since he simultaneously produced *down* in the oral modality and a sloping gesture in the manual modality. Although this line of explanation is admittedly speculative, it is consistent with the well-established principle that during co-speech gesture the manual modality is usually tightly synchronized with the oral modality. Marcel's sudden word-finding difficulty forced him to interrupt what would be, for a normal English speaker, a rapid process of assembling a simple sentence like *He rolled down the hill*, in which the semantic components of manner and path are mapped onto the grammatical categories of verb and preposition within a single concise clause (see Figure 1). Moreover, this interruption in the normal flow of linguistic processing may have been partly responsible for his production of separate manner-only and path-only gestures instead of an English-typical isolated conflation.

STUDY 2B: *FROG, WHERE ARE YOU?*

Method

Study 2A provided initial evidence that Marcel has a dissociation between impaired verbalization and preserved gesticulation of motion events. However, that experiment was limited insofar as only two motion events were used as stimuli. To further investigate the types of spontaneous co-speech gestures that he is capable of producing despite his severe anomia, we asked him to narrate the wordless picture book *Frog, Where Are You?* (Mayer, 1969), which portrays in black-and-white drawings the adventures of a boy and his dog as they wander through a forest searching for his pet frog who escaped from a jar during the night while he was sleeping. This book has been used to elicit "frog stories" from speakers of over 70 languages and 13 different language families worldwide, and some of the most important discoveries about the contrasts between S- and V-languages, especially with respect to the encoding of motion events, have come from these investigations (Berman & Slobin, 1994; Strömqvist & Verhoeven, 2004).[6] However, no systematic data are available regarding the types of spontaneous co-speech gestures that are associated with English frog stories.[7] For this reason, we compared Marcel's behaviour with that of 12 normal English speakers with the following demographic characteristics: age (M = 29.7 years, SD = 6.8); education (M = 14.8 years, SD = 1.7); male/female gender ratio (7/5); preponderance of right-handedness (100%). As in Study 2A, we anticipated that Marcel's oral narrative would be extremely poor but that his concurrent gesticulation would be highly expressive. For the normal participants, on the other hand, we expected that their descriptions of motion events would contain roughly the same amount of fine-grained

[6] All of the drawings comprising *Frog, Where Are You?* are reproduced in Berman and Slobin (1994) and Strömqvist and Verhoeven (2004).

[7] But see Ibarretxe-Antunano (2004) for an analysis of the gestural expression of manner and path in Basque frog stories, and see Clark (2004) for a broad overview of the many forms of mimesis that speakers of various languages employ in their frog stories.

manner and path information that has been reported in previous studies of English frog stories (Berman & Slobin, 1994; Slobin, 1996a, 1996b, 1997, 2000). However, we were unable to formulate precise predictions about these participants' gestures because, as indicated above, we are not aware of any previous studies have directly addressed this topic. Indeed, the current study may begin to fill this gap in the literature.

Frog, Where Are You? consists of 24 drawings that we henceforth refer to as frames. We photocopied each frame and then inserted the pages in a notebook. At the beginning of each testing session, the participant was given the notebook and was instructed to look through the pictures and become familiar with the plot of the story. Next, the participant was asked to narrate the story in as much detail as possible, but also in a natural fashion. Throughout the task, the relevant pages of the notebook were kept open and in full view on a table. We adopted this procedure in order to reduce the participant's memory load and maximize the likelihood that the participant would describe all of the events that we were interested in. Care was taken to ensure that the participant was seated comfortably and had ample space for arm and hand movements; however, the participant was not explicitly encouraged to gesture, so all of the gestures that were produced were completely spontaneous. Each participant's performance was recorded with a camcorder. Data analyses focused on the verbalization and, when available, gesticulation of 12 specific motion events implied by certain frames. Each participant's description of each event was transcribed, and any accompanying gestures were coded according to the following conventions. A gesture was classified as "manner only" if it was judged as representing exclusively the manner in which the figure moves with respect to its own object-centred frame of reference (e.g., waving both arms up and down to represent an owl flying). A gesture was classified as "path only" if it was judged as representing exclusively the path that the figure traverses relative to an environmental or ground-centred frame of reference (e.g., moving a hand downward to represent falling). Finally, a gesture was classified as a "conflation" if it was judged as simultaneously representing both manner and path (e.g., wiggling the index and middle fingers to represent walking, while simultaneously moving the hand laterally to represent the trajectory of motion). Gesture classifications were initially conducted by the second author and were subsequently checked by the first author; there were few disgreements, and they were resolved through collaborative data analysis.

Results and discussion

The normal participants produced informationally rich narratives comparable in detail to previously reported English frog stories (Berman & Slobin, 1994; Slobin, 1996a, 1996b, 1997, 2000). In striking contrast, however, these participants produced virtually no co-speech gestures to augment their descriptions. Altogether we observed only three gestures, all of which were classified as path only, and all of which were produced concurrently with utterances that expressed path but not manner. Given that the vast majority of English speakers in Kita and Özyürek's (2003) study spontaneously produced iconic co-speech gestures to enhance their descriptions of the Swinging and Rolling Events in *Canary Row*, it is quite surprising that the normal participants in our study did not produce a wealth of gestures while narrating the 12 key motion events in *Frog, Where Are You?* The reason for this discrepancy is not clear, but one possibility is that the different behavioural results were due to the different types of stimuli. Because the motion events in *Canary Row* are represented dynamically, in real time, whereas those in *Frog, Where Are You?* are represented statically, as line drawings, the former may be more conducive to gestural portrayal than the latter. Another possibility is that the different behavioural results were due to the different story-telling circumstances. For *Canary Row*, the task was to narrate the cartoon from memory, and this may have facilitated gesticulation as a way of enhancing both spatial thinking and spatial communication (Goldin-Meadow, 1999;

McNeill, 1992); however, for *Frog, Where Are You?*, the task was to narrate the story while the frames depicting the various events were in full view, and this may have dissuaded the participants from gesturing. We would like to point out, though, that we have also elicited frog stories from normal participants when the entire plot had to be recalled from memory, and we have not observed a significant increase in gesticulation under those circumstances. Thus, we consider the first explanation proposed above to be more plausible than the second.

Consistent with the severity of his aphasia, Marcel's oral narrative contained very little in the way of overt lexical content. However, his storytelling technique was nevertheless astonishingly good. He often overcame his word-finding problems by creatively substituting other expressions (e.g., he regularly referred to the frog as "little green man" and "green stuff" while producing hopping movements with his hand). Moreover, he was able to bring the fictional world to life by skilfully employing a wide range of mimetic devices (Clark, 2004), including quotation, sound symbolism, intonation, tone of voice, facial expression, and gesture. Table 6 shows his simultaneous verbalization and gesticulation of the 12 motion events (see also Figure 3, which corresponds to Event 1 in Table 6). His only manner verb was *run* (produced three times), and his only path preposition was *down* (produced twice), but he also encoded path information with the verb *fall* (produced twice) and the verb *back* (produced in the unusual utterance *He backs*, which describes the boy falling backward from the tree). In direct opposition to the normal participants, however, he produced at least one co-speech gesture, and sometimes two, for every single event. Structurally, these gestures were a mixture of manner-only, path-only, and conflation types, and for a number of events they both complemented and supplemented his speech. Thus, for Events 3 and 4 he said *fall* while also producing falling (i.e., path-only) gestures, and for Events 5 and 10 he said *run* while also producing running (i.e., conflation) gestures. For several other events, though, Marcel communicated almost exclusively through the manual modality. Thus, for Event 7 he was completely unable to produce a verb, but he represented the owl's movement quite vividly by producing a wing-flapping (i.e., manner-only) gesture.

Discussion of Studies 2A and 2B

As we predicted, in his narrations of both *Canary Row* and *Frog, Where Are You?*, Marcel's verbalization was extremely impoverished, yet his spontaneous gesticulation was quite rich. In fact, this dissociation between the two communicative modalities was manifested for every motion event that we investigated. For the Swinging and Rolling Events in *Canary Row*, Marcel's gestures were often similar to those produced by Kita and Özyürek's (2003) normal English speakers. However, his anomia frequently made it impossible for us to determine whether his gestures were partially influenced by language-specific factors. For instance, there were several occasions when he produced the expected (i.e., English-typical) gesture without difficulty, but was unable to simultaneously articulate the corresponding verb, thereby making it unclear whether the shape of the gesture may have been partly driven by activation of the verb's meaning. There were also several occasions when his anomia interfered with the smooth, rapid production of a complete clause, which in turn may have affected the organization of his gesticulation, preventing it from potentially reflecting syntactic structure.

The data from *Frog, Where Are You?* do not take us any further beyond the data from *Canary Row* regarding the question of the degree to which Marcel's spontaneous gesticulation of motion events is English-typical in the narrow sense of being partially influenced by language-specific semantic and syntactic factors. One serious limitation is that the normal participants produced surprisingly few co-speech gestures that could serve as a basis for comparison. Equally if not more important, though, is that apart from the fact that a few of Marcel's gestures corresponded with, and hence may have been partially motivated by, the meanings of the words

Table 6. *Marcel's concurrent linguistic and gestural encoding of 12 motion events in* Frog, Where Are You?

			Gesture	
	Event	*Speech*	*Type*	*Content*
1	Frog escapes from jar.	So he is like, [shhhh,] he gone.	C + M	RH represents walking while left index finger represents stealth by being placed against mouth. (See Figure 3.)
2	Dog pokes head in jar.	[He went down.]	P* + G	RH represents the dog poking his head in the jar while LH represents the circular opening of the jar.
3	Dog falls from window.	Then dog he fall, [tut tut tut.]	P*	RH represents falling.
4	Beehive falls from tree.	Bees' home, it [fall.]	P*	BH crash down on table.
5	Bees chase dog.	[Dog, he run. Bee too, mmmmmm.]	C* + C*	RH represents running while LH represents chasing.
6	Boy falls from tree.	Boy, [he backs . . .]	P*	Marcel leans backward while raising his arms in the air.
7	Owl emerges from hole in tree.	[Big bird, he . . .]	M	Marcel spreads out his arms and flaps them like wings.
8	Owl flies down at boy.	He, like, [look down at boy.]	C	BH represent the owl fluttering toward the boy.
9	Boy falls over deer's antlers.	[He moves down to . . .]	P*	LH represents the trajectory of the boy's motion.
10	Deer runs toward edge of cliff, carrying boy.	[He run, he run, right here.]	C* + G	RH represents running while LH represents edge of cliff (back of hand is horizontal and fingers are bent downward).
11	Boy falls off deer's antlers into water.	[Aaaaan water.] [Bam!]	P, C	LH represents falling. Then BH crash down on table and quickly move up and outward to represent water splashing.
12	Boy stretches over log.	So, [he went there.]	P*	BH represent the trajectory of the boy's motion.

Note: Abbreviations: [] = beginning and end of gesture; C = conflation; M = manner only; P = path only; G = ground entity; * = gesture conveys information also found in speech; RH = right hand; LH = left hand; BH = both hands.

(especially verbs and prepositions) that he simultaneously produced, the vast majority of his gestures have no discernable semantic or syntactic influences, since his verbalization was so impoverished. Indeed, it is now quite apparent that from a theoretical perspective, Marcel's robust dissociation between impaired verbalization and preserved gesticulation has both a positive side and a negative side. On the one hand, it reveals that when the oral modality of communication is profoundly disrupted, the manual modality can still be used to convey a substantial amount of information, including spatial information about motion events. On the other hand, the paucity of Marcel's verbal output makes it nearly impossible to determine whether his co-speech gestures are partially shaped by knowledge of how motion events tend to be lexically and clausally packaged in English.

In Study 3 we used a different approach to address the challenging issue of whether Marcel is able to produce gestures that are structurally similar to those produced by normal English speakers. In particular, we asked the participants to perform a series of tasks, including gesture tasks, with a set of carefully selected verbs and sentences that encode various kinds of motion events in written form.

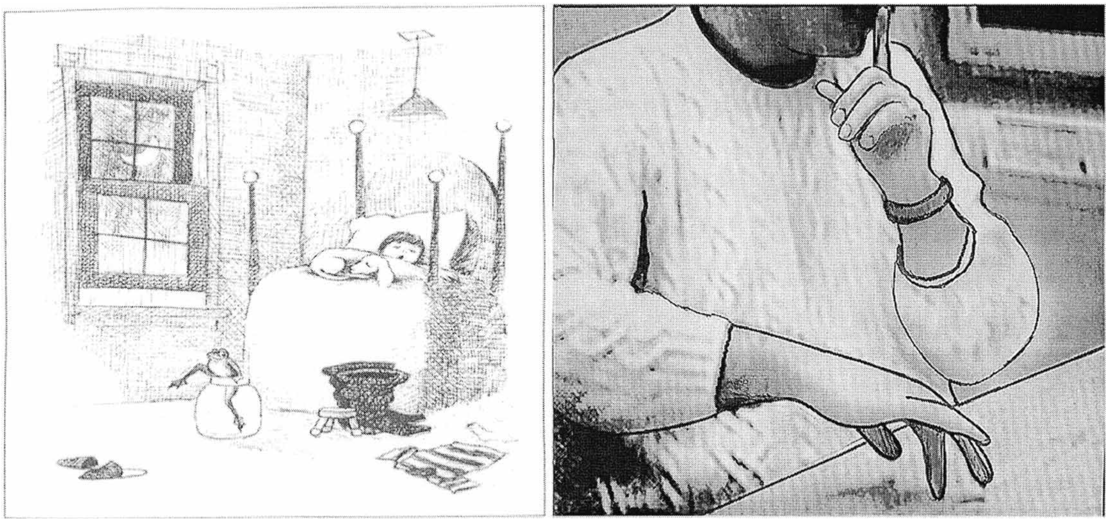

Figure 3. *Left panel: A frame from* Frog, Where Are You?, *in which the frog escapes from the jar. Right panel: Marcel's gesticulation of the event shown in the frame. See Event 1 in Table 6 for transcriptions of his concurrent speech and gesture.*

STUDY 3: ELICITED VERBALIZATION AND GESTICULATION OF MOTION EVENTS

According to the interface hypothesis and the broader theoretical framework that we outlined in the section *Goals and Theoretical Framework*, the co-speech gesticulation of motion events is influenced not only by visuospatial factors but also by two distinct levels of linguistic structure: (a) lexical-semantic resources, such as the idiosyncratic meanings of manner verbs and path prepositions; and (b) syntactic organization, such as whether the semantic components of manner and path are expressed in the same clause or in different clauses. Thus, as shown in Figure 1, if an English speaker says *The ball rolled down the hill* and simultaneously produces a gesture, the gesture tends to involve rotating an index finger while moving the hand along a downward sloping trajectory. The rotation of the finger partly reflects the meaning of *roll*, the downward sloping trajectory of the hand partly reflects the meaning of *down*, and the conflation of both elements within a single gesture partly reflects the integration of the verb and preposition within a single clause. In this study we explored in greater detail, with Marcel as well as with a group of normal English speakers, the possible influences of language-specific semantic and syntactic factors on the gesticulation of motion events. Before elaborating the methods and predictions of the study, however, we first discuss pertinent aspects of the English intransitive motion construction.

According to the constructionist approach to language, grammatical constructions consist of morphological and syntactic patterns that are often associated with certain schematic meanings, or sometimes with polysemous networks of closely related meanings (e.g., Croft, 2001; Culicover & Jackendoff, 2005; Goldberg, 1995, 2003, 2006; Jackendoff, 1997, 2002; Kay & Fillmore, 1999; Michaelis & Ruppenhofer, 2001). The prototypical meaning of the intransitive motion construction can be rendered informally as "X goes along a path by means of some manner of movement" (Goldberg & Jackendoff, 2004). The overall motion event consists of two subevents: (a) the object-centred motion of the figure in some manner, details of which are conveyed by the content of the verb; and (b) the environment-centred motion of the figure along a path, details of which are conveyed by the content of the prepositional phrase. The function of the construction is to synthesize these two independent subevents by uniting the local frame of reference defining within-object motion with the global frame of reference defining translational motion (Pinker, 1989, pp. 182–183). Thus, *The dancer whirled across the aisle* can be paraphrased roughly as "The dancer crossed the aisle by means of whirling".

The intransitive motion construction licenses many different classes of verbs (Levin, 1993), including "roll" verbs (e.g., *roll, bounce, glide, drift, float*), "run" verbs (e.g., *run, jump, walk, crawl, slither*), and verbs of substance emission (e.g., *ooze, gush, spurt, bubble, spill*). However, one of its most intriguing features is that it also allows verbs of sound emission (e.g., *squeal, whistle, roar, buzz, creak*), as in *The car squealed around the corner* (Goldberg, 1995; Goldberg & Jackendoff, 2004; Levin & Rappaport Hovrav, 1996). When these verbs occur in isolation, they do not encode any kind of spatial displacement, so when they occur in the intransitive motion construction, the general idea of motion must be supplied by the construction itself, since the final interpretation of the sentence is something like "X goes along a path while emitting a sound as a result of the motion" (for further elaboration of this point, see Goldberg & Jackendoff, 2004). Note that this constructional meaning is somewhat different from the prototypical one described above, since it specifies not that the figure traverses a path by means of moving in some manner, but rather that the figure traverses a path and consequently emits a sound. This notion of a causal linkage between the movement and the sound is actually a crucial semantic constraint, as shown by the oddness (at least for many English speakers) of sentences like *The car honked around the corner* in which the designated sound emission is not produced by the motion but is merely an accompaniment.

In this study we compared participants' gestural (and sound symbolic) responses to the following types of orthographically presented stimuli: (a) verbs from the "roll", "run", and "sound emission" classes; and (b) intransitive motion sentences that contain not only those verbs, but also prepositions encoding particular paths, and nouns encoding particular figure and ground entities. We expected the responses to the isolated verbs to reflect just the meanings of those verbs, whereas we expected the responses to the complete sentences to reflect both the verb meanings and the preposition meanings, as well as the syntactic integration of the words within a single clause. The specific methods and predictions are elaborated in full below.

Method

Participants

In addition to Marcel, 12 normal comparison participants were tested on an individual basis. All of them were free of neurological or psychiatric disease, were native speakers of English, and participated voluntarily. They had the following demographic characteristics: age (M = 27.4 years, SD = 5.6); education (M = 16.6 years, SD = 3.7); male/female gender ratio (6/6); preponderance of right-handedness (100%). None of these individuals had participated in Study 2.

Verb and sentence conditions

The experimental tasks were divided into two conditions, one involving verbs and the other involving sentences. Participants' responses in both conditions were recorded with a camcorder.

In the verb condition, which was administered first, each participant was shown, in random order, 22 verbs printed in capital letters on 5 × 3-inch index cards. These verbs were drawn from the following three semantically and syntactically defined classes, based on Levin's (1993) taxonomy:

- "roll" verbs: roll, spin, whirl
- "run" verbs: walk, limp, march, run, sprint, crawl, slither, somersault, bounce, jump, leap
- "sound emission" verbs: screech, squeal, whistle, buzz, roar, creak, groan, rumble

For each verb, the participant was asked to perform two consecutive tasks: (a) say it out loud; and (b) either manually pantomime or vocally imitate its meaning, depending on whether it specifies a kind of motion or a kind of sound emission.

In the sentence condition, the participant was shown, in random order, 36 sets of 5 × 3-inch index cards. Each set consisted of four cards on which words were printed in capital letters according to the following specifications: Two cards had simple noun phrases composed of a definite determiner followed by a noun (e.g., THE DANCER and THE AISLE); one card had one of the verbs from the previous condition, but in the past tense (e.g., WHIRLED); and one card had a path preposition (e.g., ACROSS). Thus, the cards in each set could be arranged to form a semantically coherent and syntactically well-formed sentence instantiating the intransitive motion construction (e.g., [THE DANCER] [WHIRLED] [ACROSS] [THE AISLE]). There were two versions of the sentences containing "roll" and "run" verbs, with the different versions varying only in the identity of the path preposition (e.g., the second version of the sentence just mentioned was [THE DANCER] [WHIRLED] [DOWN] [THE AISLE]). In contrast, there was just one sentence corresponding to each of the "sound emission" verbs. For each of the 36 items in the sentence condition, the examiner first laid the cards down on a table in front of the participant in a random order that did not constitute a natural sentence and then asked the participant to perform three consecutive tasks: (a) rearrange the cards into a natural sentence (henceforth we refer to this as the sentence anagram task); (b) say the sentence out loud; and (c) gesticulate the meaning of the sentence, adding sound symbolism if appropriate. For both the verb condition and the sentence condition, gestural responses were coded as manner only, path only, or conflation, according to the same criteria as those used in Study 2B. Gesture classifications were initially conducted by the second author and were subsequently checked, with 100% agreement, by the first author.

Before describing our precise predictions, we would like to highlight the fact that for each item in both the verb condition and the sentence condition, the gesture task came immediately (i.e., a few seconds) after the speech task. The reason we did not ask the participants to perform the speech and gesture tasks simultaneously is that we suspected that Marcel's severe dysfluency in the oral modality would have engendered similar, time-locked dysfluency in the manual modality, just as it apparently did in Study 2, most clearly in two of his three narrations of the Rolling Event.

By administering the two tasks sequentially, we were able to circumvent the negative effects of such crossmodal "yoking", since our main goal was to create an experimental situation in which we could observe the possible language-specific influences of the lexical and clausal packaging of motion events on Marcel's (and the normal participants') gestural packaging of the very same motion events, independent of the oral modality. We are aware, however, that our study does not actually involve co-speech gesture because the oral and manual channels of communication were not synchronized, and in the Discussion we address certain theoretical issues regarding this point.

Predictions

We expected the normal comparison participants to read aloud the verbs and sentences without any difficulty. Also, in the sentence anagram task, we expected them to prefer to arrange the cards in the form of sentences that instantiate the intransitive motion construction, which presumably has a much higher frequency, and hence a greater degree of cognitive entrenchment, than alternative constructions such as locative inversion (e.g., *Across the aisle whirled the dancer*). On the other hand, Marcel was predicted to have great difficulty with the reading aloud tasks, given his severe impairment in retrieving the lexical-phonological forms of words. However, he was predicted to perform well in the sentence anagram task, not only because the sentences are syntactically quite simple, but also because he achieved scores in the "average" range on two separate measures of reading ability in standardized aphasia tests (see Table 3).

With regard to the tasks requiring gesticulation and/or sound imitation, the normal participants were predicted to exhibit systematic types of similarities and differences in their responses to the various classes of verbs and corresponding sentences. Marcel was predicted to perform in similar ways, because although the tasks require intact knowledge of the relevant semantic and syntactic structures, they do not require access to lexical-phonological structures. Specific predictions for each class of verbs and corresponding constructions are elaborated below and summarized in Table 7.

"Roll" verbs and sentences

Levin (1993) includes 18 verbs in her "roll" class. The three verbs that we drew from this class—*roll, spin*, and *whirl*—all refer to motion events in which the figure revolves around an axis; however, *roll* seems to be used more often than either *spin* or *whirl* to designate motion events that also involve displacement of the figure along an unspecified or default path. In other words, if something is rolling, it is most likely rolling in some direction, whereas if something is spinning or whirling, it can more easily be imagined as doing so in one place. Hence we expected that in the verb condition the participants would tend to gesticulate the meanings of these three verbs somewhat differently. In particular, *roll* would typically elicit conflations in which the manner component is encoded by rotating a finger, and the path component is encoded by simultaneously moving the arm/hand in a default lateral direction, whereas *spin* and *whirl* would typically elicit manner-only gestures.

When these three verbs occur in sentences that instantiate the intransitive motion construction, the prototypical meaning of which is roughly "X goes along a path by means of some manner of movement", we predicted that the participants would tend to gesticulate the overall sentence meanings with conflations, the same way that Kita and Özyürek's (2003) English speakers did for the Rolling Event in *Canary Row.* Because the intransitive motion construction employs a single compact clause to synthesize two subevents—one involving the local, object-centred manner of motion expressed by the verb, and the other involving the global, environment-centred translational motion expressed by the preposition—the participants should prefer to use a single compact conflation gesture that also synthesizes the same two subevents by simultaneously encoding both manner and path components— manner with the identical hand/finger movement elicited by the verb in isolation, and path with a directional arm/hand movement corresponding to the meaning of the preposition (although sometimes the complete gestural encoding of the path component may require introducing the other hand to represent the ground entity, since this entity often serves as a reference point for defining the path). For the sentence pairs that vary only in the nature of the path preposition (e.g., *The dancer whirled across the aisle* and *The dancer whirled down the aisle*), we predicted that the participants would produce conflations in which the manner component is constant but the path component varies to accommodate the different prepositional meanings.

"Run" verbs and sentences

Levin (1993) includes 124 verbs in her "run" class, and we used 11 of them. The first eight verbs—*walk, limp, march, run, sprint, crawl, slither*, and *somersault*—refer to idiosyncratic manners of motion that typically bring about some kind of global displacement of the figure relative to its environment, but none of them inherently expresses the direction of the path. Hence we predicted that, as with *roll*, in the verb condition the participants would most likely produce conflations in which the foregrounded manner component is encoded by idiosyncratic hand/finger movements while the backgrounded path component is simultaneously encoded by a default lateral arm/hand movement. The remaining three verbs—*bounce, jump*, and *leap*—do not highlight any particular type of object-internal manner of motion of the figure (apart from the fact that the last two verbs typically involve certain kinds of leg actions), but they do designate paths that usually involve the gravitationally defined vertical axis. Hence we predicted that in the verb condition the participants

Table 7. *Predicted gestural responses to isolated motion verbs and to corresponding sentences instantiating the intransitive motion construction*

	Verbs		*Sentences*	
	Stimulus	*Gesture*	*Stimulus*	*Gesture*
"Roll"	1. roll	C (DP)	a. The ball rolled down the hill.	C (PP)
			b. The ball rolled towards the hill.	C (PP)
	2. spin	M	a. The top spun into the table.	C (PP)
			b. The top spun around the table.	C (PP)
	3. whirl	M	a. The dancer whirled across the aisle.	C (PP)
			b. The dancer whirled down the aisle.	C (PP)
"Run"	1. walk	C (DP)	a. The boy walked from the river.	C (PP)
			b. The boy walked along the river.	C (PP)
	2. limp	C (DP)	a. The man limped across the room.	C (PP)
			b. The man limped around the room.	C (PP)
	3. march	C (DP)	a. The soldiers marched out of the camp.	C (PP)
			b. The soldiers marched around the camp.	C (PP)
	4. run	C (DP)	a. The girl ran into the car.	C (PP)
			b. The girl ran around the car.	C (PP)
	5. sprint	C (DP)	a. The athlete sprinted around the track.	C (PP)
			b. The athlete sprinted along the track.	C (PP)
	6. crawl	C (DP)	a. The baby crawled around the chair.	C (PP)
			b. The baby crawled under the chair.	C (PP)
	7. slither	C (DP)	a. The snake slithered underneath the table.	C (PP)
			b. The snake slithered off the table.	C (PP)
	8. somersault	C (DP)	a. The clown somersaulted into the box.	C (PP)
			b. The clown somersaulted over the box.	C (PP)
	9. bounce	P (V)	a. The ball bounced across the street.	P (V + H)
			b. The ball bounced down the street.	P (V + H)
	10. jump	P (V)	a. The boy jumped across the puddle.	P (V + H)
			b. The boy jumped into the puddle.	P (V + H)
	11. leap	P (V)	a. The insect leapt into the box.	P (V + H)
			b. The insect leapt over the box.	P (V + H)
"Sound emission"	1. screech	S	The train screeched into the station.	P + S
	2. squeal	S	The car squealed around the corner.	P + S
	3. whistle	S	The bullet whistled past John's head.	P + S
	4. buzz	S	The fly buzzed around the room.	P + S
	5. roar	S	The rocket roared into the sky.	P + S
	6. creak	S	The elevator creaked up to the 3rd floor.	P + S
	7. groan	S	The old man groaned up the stairs.	C (PP) + S
	8. rumble	S	The truck rumbled down the street.	C (PP) + S

Note: Abbreviations: M = manner only; P = path only; C = conflation; DP = conflation with a default path; PP = conflation with a preposition-specific path; V = vertical; H = horizontal; S = sound symbolism.

would tend to gesticulate the meanings of these verbs with path-only gestures involving up-and-down arm/hand movements.

In the sentence condition, the items containing the first eight verbs were expected to elicit conflations in which the manner component is essentially the same as that in the verb condition, but the path component is no longer an inconspicuous default but is instead a precise trajectory reflecting the unique meaning of the preposition. Indeed, the predicted nature of the path component is the critical difference between the verb and sentence conditions for these eight verbs (see Table 7). As for the items containing the last three verbs, we anticipated that they would elicit path-only gestures in which the path is elaborated not only along the vertical axis, as stipulated by the verb, but also along the horizontal axis, according to the specific direction indicated by the preposition. For example, *The ball bounced across the street* might be gesticulated by using one hand to represent the street while simultaneously using the other hand to represent a sequence of bouncing movements that go not only up and down but also laterally across the first hand.

"Sound emission" verbs and sentences

Levin (1993) includes 119 verbs in her "sound emission" class, and we used 8 of them. We pointed out above that although verbs of this type do not imply any motion whatsoever on the part of the figure, they can freely occur in the intransitive motion construction, yielding an interpretation something like "X goes along a path while emitting a sound as a result of the motion". For example, *The old man groaned up the stairs* can be paraphrased roughly as "The old man went up the stairs while emitting a groaning sound as a result of the motion". In the verb condition we predicted that when the participants were asked to vocally imitate the sounds designated by these verbs, they would generally do so without any accompanying manual gestures. However, in the sentence condition we predicted that the participants would produce multimodal displays, using their arms and hands to make various types of iconic gestures, and simultaneously using their vocal apparatus to generate the same kind of sound symbolism that they demonstrated in the verb condition. Thus, a participant might respond to *The old man groaned up the stairs* by simultaneously wiggling two fingers (to indicate walking), directing the hand along an upward sloping trajectory (to indicate ascending stairs), and groaning (to indicate the noise caused by the movement).

As noted above, we predicted that Marcel would perform like the normal comparison participants on the gesticulation and sound imitation tasks.

Results

As predicted, the normal comparison participants were error free in reading aloud the verbs and sentences, and they arranged all of the sentences according to the syntactic structure of the intransitive motion construction.[8] Marcel also performed as predicted in the reading aloud tasks and in the sentence anagram task. As shown in the "Speech" column in Tables 8, 9, and 10, his lexical-phonological retrieval was severely impaired. In the verb condition he produced only 5 (22.7%) of the 22 verbs, and in the sentence condition he read aloud just a few words of only 6 (16.7%) of the 36 sentences. On the other hand, as shown in the "Syntax" column in Tables 8, 9, and 10, he arranged 33 (91.7%) of the 36 sentences in terms of the intransitive motion construction, revealing preserved syntactic knowledge of how motion events are clausally packaged in this construction.

Turning to the data on gesture and sound symbolism, most of the predictions were confirmed. Table 8 presents the results for the "roll" verbs and corresponding sentences. As predicted, in the verb condition the majority of normal participants produced conflations with default paths for *roll* and produced manner-only gestures for both *spin* and *whirl* (Figure 4). Marcel manifested exactly the same preferences. Also as predicted, in the sentence condition the normal participants produced conflations with preposition-specific paths for all of the sentences (Figure 5). Marcel also produced conflations with preposition-specific paths for four of the six sentences.

Table 9 presents the results for the "run" verbs and corresponding sentences. In the verb condition, all of the normal participants produced conflations with default paths for the first seven

[8] Because the first 5 participants exhibited perfect consistency in the sentence anagram task, we did not administer this task to the remaining 7 participants; instead we simply showed them the properly arranged sentences and then administered the other tasks.

Table 8. *Results for "roll" verbs and sentences*

									Gesture			
									Normal participants			
Stimuli			*NP*	*V*	*P*	*NP*	*Syntax Marcel*	*Speech Marcel*	*M*	*P*	*C*	*Marcel*
Verbs	1	roll						/ro/	25%	–	75% (DP)	C (DP)
	2	spin						–	83%	–	17% (DP)	M
	3	whirl						–	75%	–	25% (DP)	M
Sentences	1a		The ball	rolled	down	the hill	+	fall down	8%	–	92% (PP)	C (PP)
	1b		The ball	rolled	towards	the hill	–	ball rolled all here	–	–	100% (PP)	C*
	2a		The top	spun	into	the table	–	–	–	–	100% (PP)	–
	2b		The top	spun	around	the table	+	–	–	–	100% (PP)	C (PP)
	3a		The dancer	whirled	across	the aisle	+	–	–	–	100% (PP)	C (PP)
	3b		The dancer	whirled	down	the aisle	+	–	–	–	100% (PP)	C (PP)

Note: Marcel's performances are shown for the syntax (i.e., sentence anagram), speech, and gesture tasks. The normal participants' performances are shown for the gesture tasks, with cells indicating the percentage of participants who produced the given type of response. Abbreviations and symbols are as follows. Columns for "Stimuli": NP = noun phrase; V = verb; P = preposition. Column for "Syntax": plus sign = correct assembly of sentence; minus sign = incorrect assembly of sentence. Columns for "Gesture": M = manner only; P = path only; C = conflation; DP = conflation with a default path; PP = conflation with a preposition-specific path; asterisk = conflation with a path component that does not conform to the meaning of the preposition in the sentence.

Table 9. *Results for "run" verbs and sentences*

									Gesture			
									Normal participants			
Stimuli			*NP*	*V*	*P*	*NP*	*Syntax Marcel*	*Speech Marcel*	*M*	*P*	*C*	*Marcel*
Verbs	1	walk						walk	–	–	100% (DP)	C (DP)
	2	limp						–	–	–	100% (DP)	C (DP)
	3	march						–	–	–	100% (DP)	C (DP)
	4	run						run	–	–	100% (DP)	C (DP)
	5	sprint						run fast	–	–	100% (DP)	C (DP)
	6	crawl						crawl	–	–	100% (DP)	C (DP)
	7	slither						–	–	–	100% (DP)	C (DP)
	8	somersault						–	67%	–	33% (DP)	C (DP)
	9	bounce						bounce	–	33% V, 67% V + H	–	P (V + H)
	10	jump						jump	–	33% V, 67% V + H	–	P (V + H)
	11	leap						–	–	100% V + H	–	P (V + H)
Sentences	1a		The boy	walked	from	the river	+	–	–	–	100% (PP)	C (PP)
	1b		The boy	walked	along	the river	+	walk	–	–	100% (PP)	C (PP)
	2a		The man	limped	across	the room	+	–	–	–	100% (PP)	C (PP)
	2b		The man	limped	around	the room	+	–	–	–	100% (PP)	C*
	3a		The soldiers	marched	out of	the camp	+	–	–	–	100% (PP)	C*
	3b		The soldiers	marched	around	the camp	+	–	–	–	100% (PP)	C (PP)
	4a		The girl	ran	into	the car	+	–	–	–	100% (PP)	C (PP)
	4b		The girl	ran	around	the car	+	–	–	–	100% (PP)	C (PP)
	5a		The athlete	sprinted	around	the track	+	–	–	–	100% (PP)	C (PP)
	5b		The athlete	sprinted	along	the track	+	–	–	–	100% (PP)	C (PP)
	6a		The baby	crawled	around	the chair	+	–	–	–	100% (PP)	C (PP)
	6b		The baby	crawled	underneath	the chair	+	–	–	–	100% (PP)	P
	7a		The snake	slithered	underneath	the table	+	–	–	–	100% (PP)	C (PP)
	7b		The snake	slithered	off	the table	+	–	–	–	100% (PP)	C (PP)
	8a		The clown	somersaulted	into	the box	+	–	–	–	100% (PP)	C (PP)
	8b		The clown	somersaulted	over	the box	+	–	–	–	100% (PP)	C (PP)
	9a		The ball	bounced	across	the street	+	–	–	100% V + H	–	P (V + H)
	9b		The ball	bounced	down	the street	+	down	–	100% V + H	–	P (V + H)
	10a		The boy	jumped	across	the puddle	+	run	–	100% V + H	–	P (V + H)
	10b		The boy	jumped	into	the puddle	+	–	–	100% V + H	–	P (V + H)
	11a		The insect	leapt	into	the box	+	into	–	100% V + H	–	P (V + H)
	11b		The insect	leapt	over	the box	+	–	–	100% V + H	–	P (V + H)

Note: Marcel's performances are shown for the syntax (i.e., sentence anagram), speech, and gesture tasks. The normal participants' performances are shown for the gesture tasks, with cells indicating the percentage of participants who produced the given type of response. Abbreviations and symbols are as follows. Columns for "Stimuli": NP = noun phrase; V = verb; P = preposition. Column for "Syntax": plus sign = correct assembly of sentence; minus sign = incorrect assembly of sentence. Columns for "Gesture": M = manner only; P = path only; C = conflation; DP = conflation with a default path; PP = conflation with a preposition-specific path; asterisk = conflation with a path component that does not conform to the meaning of the preposition in the sentence; V = vertical; H = horizontal.

Table 10. *Results for "sound emission" verbs and sentences*

									Gesture and sound symbolism				
									Normal participants				
			NP	*V*	*P*	*NP*	*Syntax Marcel*	*Speech Marcel*	*M*	*P*	*C*	*S*	*Marcel*
Verbs	1	screech						–	–	–	–	+	S
	2	squeal						–	–	–	–	+	–
	3	whistle						–	–	–	–	+	Pantomime
	4	buzz						–	–	–	–	+	S
	5	roar						–	–	–	–	+	–
	6	creak						/kri/	–	–	–	+	–
	7	groan						–	–	–	–	+	–
	8	rumble						–	–	–	–	+	S
Sentences	1		The train	screeched	into	the station	+	–	–	75%	25% (PP)	+	P
	2		The car	squealed	around	the corner	+	–	–	100%	–	+	P + S
	3		The bullet	whistled	past	John's head	–	fast	–	100%	–	+	P + S
	4		The fly	buzzed	around	the room	+	–	–	100%	–	+	P + S
	5		The rocket	roared	into	the sky	+	–	–	100%	–	+	P + S
	6		The elevator	creaked	up to	the 3rd floor	+	–	–	83%	17% (PP)	+	P + S
	7		The old man	groaned	up	the stairs	+	–	–	25%	75% (PP)	+	C (PP) + S
	8		The truck	rumbled	down	the street	+	–	–	8%	92% (PP)	+	C (PP) + S

Note: Marcel's performances are shown for the syntax (i.e., sentence anagram), speech, gesture, and sound symbolism tasks. The normal participants' performances are shown for the gesture and sound symbolism tasks, with cells indicating the percentage of participants who produced the given type of response. Abbreviations and symbols are as follows. Columns for "Stimuli": NP = noun phrase; V = verb; P = preposition. Column for "Syntax": plus sign = correct assembly of sentence; minus sign = incorrect assembly of sentence. Columns for "Gesture and sound symbolism": M = manner only; P = path only; C = conflation; PP = conflation with a preposition-specific path; S = appropriate sound symbolism.

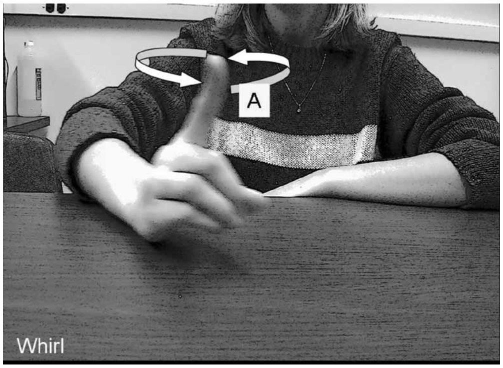

Figure 4. *Gesticulation of the meaning of the verb* whirl. *The arrows labelled "A" indicate the manner of motion, in this case circular motion around the major axis of the figure entity.*

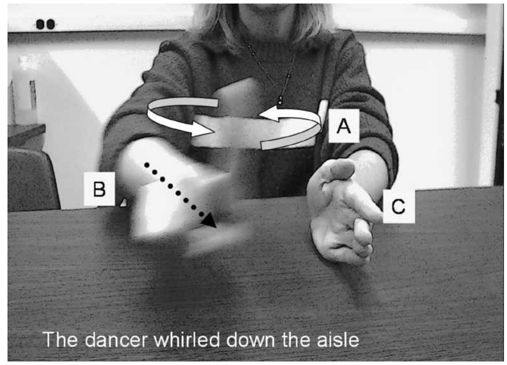

Figure 5. *A normal participant's gesticulation of the meaning of the sentence* The dancer whirled down the aisle. *Rotation of the finger represents the manner of motion (A); simultaneous movement of the hand away from the body represents the path of motion (B); and the stationary configuration of the other hand represents the ground entity (C). The conflation of manner and path in a single integrated gesture may reflect the tight syntactic packaging of both semantic components within a single compact clause.*

verbs, just as predicted; however, for the eighth verb—*somersault*—two thirds of them produced manner-only gestures instead. Marcel produced conflations with default paths for all eight verbs.[9] Regarding the next three verbs—*bounce, jump*, and *leap*—the normal participants produced, either preferentially or exclusively, gestures involving both vertical and horizontal axes, and Marcel performed the same way. These findings disconfirm our prediction that all three of these verbs would elicit exclusively vertical path gestures (see Table 7). Shifting to the sentence condition, all of the normal participants produced conflations with preposition-specific paths—as opposed to default paths—for all of the sentences containing the first eight verbs, as expected (Figure 6). Marcel also produced such gestures for all but three of these sentences.

Table 10 presents the results for the "sound emission" verbs and corresponding sentences. In the verb condition the normal participants had no trouble vocally imitating the sounds designated by all of the verbs; however, Marcel vocally imitated the sounds of only three verbs, and he seemed to be somewhat puzzled by several of the others. Neither the normal participants nor Marcel produced manual gestures in this condition. On the other hand, in the sentence condition all of the normal participants produced multimodal gestural and sound-symbolic displays, just as predicted. Marcel did so too; in fact, he included the appropriate sound-symbolic element in all but one of his responses, apparently because the nature of this element was made clear to him by the sentence context. In the sentence condition there are two major patterns.

[9] Experiments involving picture drawing and sentence–picture matching have shown that many action verbs that do not lexically encode a specific path are nevertheless conceptually associated with a left-to-right directionality (Chatterjee, Maher, & Heilman, 1995; Chatterjee, Southwood, & Basilico, 1999; see also Altmann, Saleem, Kendall, Heilman, & Gonzalez Rothi, 2006; Chatterjee, 2001). For this reason, we analysed the directionality of the default path component of the conflations that the participants produced for the first seven verbs in the verb condition. Except for *crawl*, 90% of the paths were manually expressed with a right-to-left directionality; for *crawl*, only 46% of the paths had this directionality, and the remainder had a directionality straight out from the body (see Figure 6). All of the participants used exclusively their right hand to produce the gestures under discussion, so the right-to-left preference probably reflects the most natural way to execute right-handed path gestures, given the motor constraints of the task. Interestingly, from the perspective of an observer facing the gesturer, such gestures appear to have a left-to-right directionality, which is consistent with the visuospatial bias documented by Chatterjee and coworkers.

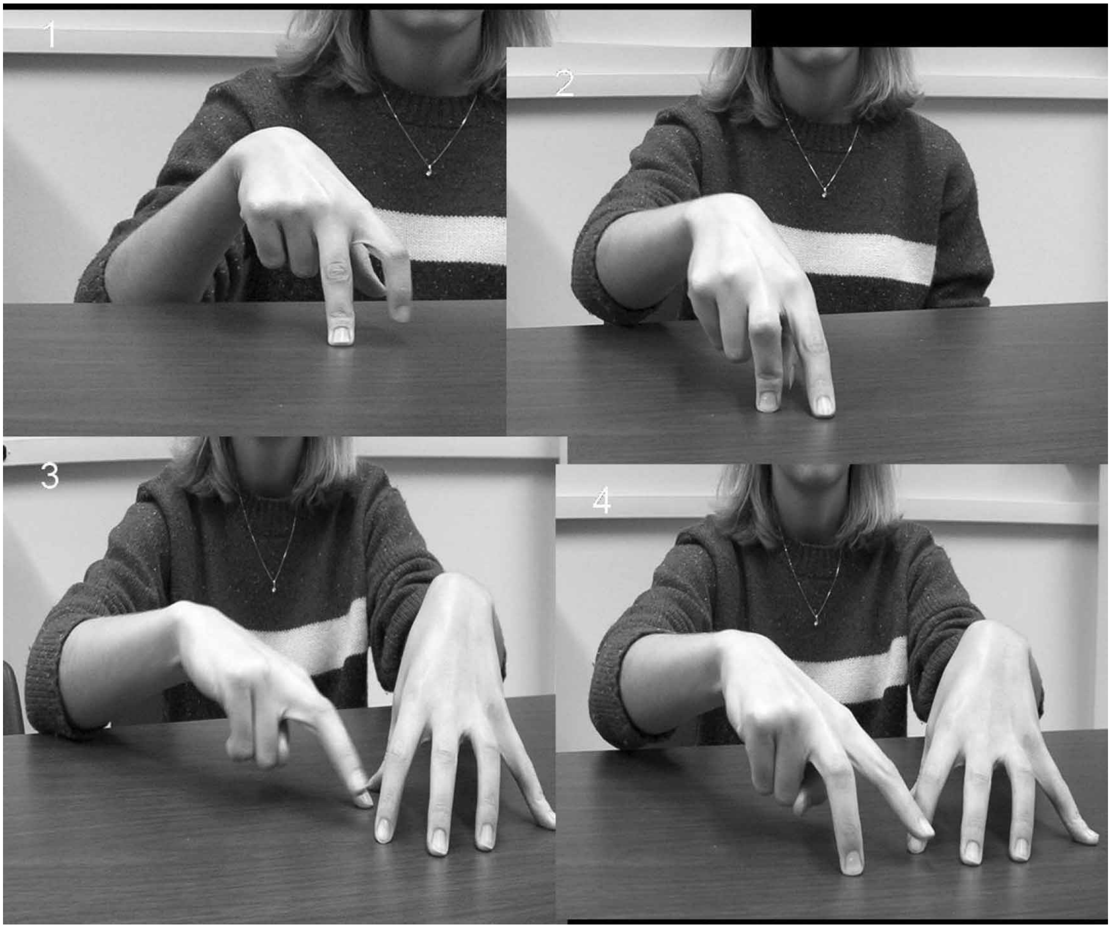

Figure 6. *A normal participant's gesticulation of the meaning of the verb* crawl *in isolation (Panels 1 and 2), in the sentence* The baby crawled under the chair *(Panel 3), and in the sentence* The baby crawled around the chair *(Panel 4). Manner–path conflations are produced in all cases, but a default path (defined relative to the body) is employed when gesticulating the meaning of the verb in isolation, whereas distinct preposition-specific paths (defined relative to the ground entity represented by the other hand) are employed when gesticulating the meaning of the verb in each sentence context.*

First, for Items 1 through 6, the normal participants produced, either preferentially or exclusively, preposition-specific path-only gestures accompanied by verb-specific sound symbolism, and Marcel performed the same way. Second, for Items 7 and 8, the majority of normal participants produced conflations with preposition-specific path components accompanied by verb-specific sound symbolism, and again Marcel performed the same way.

Discussion

Marcel's performance compared to that of the normal participants

The normal participants performed perfectly on the verbalization and sentence anagram tasks, and virtually all of their gestural and sound-symbolic responses were consistent with our predictions. Regarding Marcel, as in Studies 1 and 2, his ability to access the lexical-phonological structures of words was profoundly impaired. However, he performed extremely well in the sentence anagram task. This finding is important because it constitutes evidence that, although he was moderately agrammatic, he nevertheless had intact knowledge of the basic syntactic structure of the intransitive motion construction. The status of this knowledge was left vague in Study 2 because the data were obtained exclusively through the phonological modality, which we had already established as being disrupted. However, by including the sentence anagram task in the current study, we were able to probe Marcel's syntactic knowledge through the orthographic modality instead and thereby demonstrate that he still had a fundamental understanding of how motion events are clausally packaged in the intransitive motion construction. The most impressive finding of all is that Marcel's gestures were remarkably similar to those of the normal participants. He even modulated his gestures in the same ways that they did across the verb and sentence conditions, and also across most of the paired items in the sentence condition—that is, the items that varied only with respect to the path preposition (e.g., *The dancer whirled across the aisle* vs. *The dancer whirled down the aisle*). This study therefore goes beyond Study 2 insofar as it shows that in a carefully controlled experimental situation, Marcel was able to manually encode very specific motion events with gestures that were structurally indistinguishable from those generated by normal English speakers.

Language-specific influences on the gesticulation of motion events

Semantic factors. When the participants were asked to gesticulate the meanings of isolated verbs from the "roll" and "run" classes, they produced appropriate manner-only, path-only, and conflation gestures that represented in analogue visuospatial format just the core aspects of those meanings, often emphasizing the most salient semantic features while downplaying the less salient ones—for example, using certain idiosyncratic finger movements to indicate the highly specific manner component of *limp* while simultaneously directing the hand along an inconspicuous lateral trajectory to indicate a default path. In contrast, when the participants were asked to gesticulate the meanings of sentences containing not only the same verbs from the "roll" and "run" classes but also particular path prepositions, they produced more semiotically complex gestures that incorporated the independent semantic contributions of the different lexical items, usually by elaborating the path components of the gestures in preposition-specific ways—for example, gesticulating the meaning of *The man limped around the room* by producing the same finger movements that were elicited by *limp* in isolation, but this time simultaneously directing the hand along a prominent path reflecting the unique meaning of *around* (see Figure 6). The participants' responses to the "sound emission" verbs and sentences were also clearly influenced by language-specific semantic factors. As Goldberg and Jackendoff (2004) point out, in a sentence like *The train screeched into the station*, the verb only expresses the kind of sound generated by the figure's motion; the basic idea that a motion event occurred comes not from the verb itself but from the construction as a whole, with the nature of the path being supplied by the preposition *into.* The fact that motion per se is a clause-level rather than a verb-level semantic property of the sentence was reflected in the participants' gestural and sound-symbolic responses, because when they were shown the verb *screech* in isolation, they produced vocal imitations but no manual gestures whatsoever, whereas when they were shown the sentence containing the verb, they not only made similar vocal imitations but also manually encoded the train's path by moving a flat hand laterally with decreasing speed; furthermore, 25% of the participants simultaneously moved their hand side to side to indicate effortful braking—a more complex gesture that we classified as a manner–path conflation.

Syntactic factors. While there can be no question that the participants' gestures were strongly influenced by the meanings of the verbs and sentences that were used as stimuli, it is much more difficult to determine whether their gestures in the sentence condition were also influenced by the syntactic structure of the intransitive motion construction.

Given that this is an issue of considerable theoretical interest, it warrants close attention.

As already noted, syntactic influences would be manifested in the *organization* rather than the *content* of gestures. In particular, the syntactic integration of a manner verb and a path preposition within a single compact clause would be reflected in the manual integration of both semantic components within a single conflation gesture. We found that the participants produced conflations for all 6 sentences with “roll” verbs and for 16 of the 22 sentences with “run” verbs, so it is possible that the organization of these gestures was partly due to syntactic factors. However, for 2 of the 6 conflation-eliciting sentences with “roll” verbs, and for 14 of the 16 conflation-eliciting sentences with “run” verbs, the participants also produced conflations in response to just the corresponding verbs in the separate verb condition. The main difference between the conflations in the verb and sentence conditions was that in the latter condition the specific content of the path component was modulated according to the unique meaning of the preposition. But this is obviously an effect of semantics, not syntax. Even though the conflations that were elicited by the isolated verbs had inconspicuous default path components, the simple fact that the verbs did elicit conflations is important, because this makes it impossible to determine whether the basic organization of the gestures that the participants produced for the corresponding sentences was influenced by the meanings of the verbs, by the syntactic structure of the intransitive motion construction, or by both of these factors operating together. On the other hand, for 4 of the 6 conflation-eliciting sentences with “roll” verbs (namely those with *spin* and *whirl*), and for 2 of the 16 conflation-eliciting sentences with “run” verbs (namely those with *somersault*), the participants produced manner-only gestures in response to just the corresponding verbs in the separate verb condition. Hence the conflations in the sentence condition were presumably not due to the meanings of the verbs and may instead have been influenced by syntactic structure.[10]

One of the reasons that we included “sound emission” verbs in our experiment was that they can freely occur in the intransitive motion construction, and we expected that the sentences containing them would elicit complex iconic gestures that depict the movement of the figure—a prediction that was strongly confirmed. For six of the eight sentences, the gestures were path-only in character, reflecting both the general idea of motion specified by the construction and the particular spatial trajectory specified by the preposition. However, for the last two sentences (namely *The old man groaned up the stairs* and *The truck rumbled down the street*), the gestures appeared to be genuine manner−path conflations. In each case, the manner component presumably derived from the participants’ inferences about the way the figure moved, since that information was not overtly expressed in the sentence. Nevertheless, it is not inconceivable that the conflational organization of the gestures was partly influenced by syntactic factors.

So far we have argued that the results are consistent with the hypothesis that many of the conflations that the participants produced in the sentence condition were influenced by syntactic factors. It is not clear, however, whether this type of influence was actually present. A potential problem is that the results may have been affected by the fact that for each item the gesture task lagged behind the speech task by a few seconds, so that oral and manual encoding were sequential instead of simultaneous. This may be important for the following reason: In situations involving the true co-speech gesticulation of motion events, the principal mechanism by which gestural

[10] When we designed this experiment, we examined Levin’s (1993) taxonomy of over 3,000 English verbs very carefully in order to find motion verbs that might elicit manner-only gestures, but we found very few, and most of them were in the “rotation around an axis” subclass of the “roll” class. Indeed, it is interesting that even though *somersault* belongs to the “run” class, it elicited predominantly manner-only gestures in the verb condition, perhaps because it designates figure-internal rotation without any necessary translational movement relative to the environment, just like *spin* and *whirl.*

structure is sometimes influenced by syntactic structure may involve synchronous bindings between corresponding information units in different cognitive systems (Singer, 1999). As pointed out by Kita and Özyürek (2003; see also Özyürek et al., 2005), it is well established that the clause is a basic unit of syntactic processing, and this appears to be what drives the gesture system to have a corresponding unit at a similar level of hierarchical organization. In Figure 1, this aspect of the simultaneous verbalization and gesticulation of the sentence *The ball rolled down the hill* is formalized by means of coindexation between the sentence unit in Syntactic Structure (SS), which subsumes within a single clause both the manner verb and the path preposition, and the conflation unit in Gestural Structure (i.e., GS), which subsumes within a single gesture both the manner component and the path component. During online production, these structural correspondences are usually computed rapidly and unconsciously, and the underlying synchronous bindings are effective for only a brief span of time.

How might these considerations be relevant to our study? Given that the speech and gesture tasks were performed sequentially, it may be that the critical synchronous bindings between high-level units of SS and GS were not established. And if they were not, then it seems unlikely that the conflational organization of the observed gestures was directly influenced by the syntactic organization of the sentences that were used as stimuli. On the other hand, we would like to emphasize that each sentence was clearly visible throughout the gesture task, and that all 36 sentences had exactly the same syntactic structure. These aspects of the experimental procedure may have increased the chances that the syntactic structure was active, to some degree, in the participant's working memory while the appropriate gestures were being programmed, thereby allowing for the possibility of direct influence. We are aware, however, that this proposal is quite speculative.

In this context, it is noteworthy that Goldin-Meadow, McNeill, and Singleton (1996) conducted a study in which English speakers were asked to describe a series of action vignettes in two conditions: First, they were instructed to simply talk about the events, but they also produced a number of spontaneous co-speech gestures; and second, they were instructed to manually portray the events with iconic gestures and avoid talking. The investigators found that the gestures in the two conditions had qualitatively different structural characteristics. These findings seem to present a more serious challenge to the view that the gestures produced by our participants in the sentence condition were partially shaped by syntactic factors. However, the strength of this challenge may be diminished by the fact that the stimuli in Goldin-Meadow et al.'s study were purely visuospatial in format, whereas the stimuli in our study were written sentences with inherent syntactic structure. As suggested above, it may not be trivial that those sentences were always visible and that the syntactic structure was always the same.[11]

For the sake of argument, let us suppose that the conflational organization of the participants' gestures in the sentence condition was not influenced by syntactic structure. This would imply that the organization reflected a kind of a default strategy. Such a view seems to have considerable merit, since it is reasonable to assume that the most natural way to gesticulate motion events is with conflations that iconically simulate the real-world spatiotemporal synthesis of manner and path. Indeed, this is presumably why Kita and Özyürek's (2003) Japanese and Turkish speakers produced not only separate manner-only and

[11] In another relevant study, Hammond and Goldin-Meadow (2002) found that when English-speaking adults were asked to create gestures in response to visuospatial stimuli, they consistently employed a non-English ordering pattern; however, when they were asked to create gestures in response to written text, they did not manifest a dominant ordering pattern, but some of them followed the English order. These results support the view that different types of stimuli elicit different types of gestures, and most importantly for present purposes, the findings also indicate that written linguistic stimuli sometimes (but not always) elicit syntactically homologous language-specific gestures.

path-only gestures (in accord with the syntactic realization of these two semantic components in distinct clauses), but also a number of conflations, while narrating the Rolling Event in *Canary Row.* Senghas, Kita, and Özyürek (2004) obtained indirect support for the "default conflation hypothesis" by showing that deaf people who were first exposed to the emerging Nicaraguan Sign Language (NSL) before 1984 tended to produce conflations when gesticulating motion events in *Canary Row*, whereas deaf people who were first exposed to NSL between 1984 and 1993 tended to produce separate manner-only and path-only movements when gesticulating the same events. According to Senghas et al., these findings suggest that the initial cohort of children who began building NSL in the late 1970s preferred the holistic conflation strategy for manually encoding motion events, and that later cohorts shifted to the more discrete combinatorial strategy. However, a different picture emerges from Zheng and Goldin-Meadow's (2002) comparison of the "home sign" communicative systems invented independently by American and Chinese deaf children who have not been exposed to any conventional language model. They found that both groups of children used conflations in a very small percentage of their gesticulations of motion events: "The American deaf children combined Path and Manner within a single characterizing gesture in 16% of their action characterizing gestures; the Chinese deaf children did so in 15% of theirs" (p. 154). Thus, it is not clear whether conflations really are the default strategy for manually encoding motion events in analogue format.

One way to evaluate the "default conflation hypothesis" would be to investigate aphasic but nonapraxic speakers of V-languages like Japanese and Turkish who are impaired at using language-specific factors, especially syntactic structure, to guide their gestural packaging of motion events. The hypothesis predicts that these individuals would produce predominantly conflations and hence would behave more like normal English speakers than like normal Japanese and Turkish speakers. Another approach—one that would be more feasible in terms of participant recruitment—would be to conduct an experiment similar to the one reported here, but with normal Japanese and Turkish speakers and with written sentences that encode manner and path in separate clauses, following the typical V-language pattern. For each sentence, the participants would be instructed to first say it out loud and then pantomime its meaning. The key question is whether the participants would tend to gesticulate manner and path separately, reflecting syntactic organization, or together, reflecting a default conflation strategy.

In summary, our data are consistent with the possibility that many of the conflations that the participants produced in the sentence condition were influenced by the syntactic structure of the intransitive motion construction. However, we cannot exclude the alternative possibility that the organization of those gestures was *not* influenced by syntactic factors, but was instead a reflection of a default strategy for manual encoding motion events. Caution is definitely warranted here, but we remain impressed by the close homology between gestural structure and syntactic structure in the participants' responses.

GENERAL DISCUSSION

Marcel's dissociation between impaired verbalization and preserved gesticulation of motion events can be understood in the context of the theoretical framework that we introduced in the section *Goals and Theoretical Framework*. In what follows, we discuss the multiple cognitive systems comprising the model shown in Figure 1, focusing on their status for Marcel at both neuropsychological and neuroanatomical levels of analysis.

Spatial Structure (SpS) and Conceptual Structure (CS)

Studies 1 and 3 provide strong evidence that Marcel has intact knowledge of the meanings of object nouns, action verbs, and spatial prepositions, certainly at the level of SpS, and probably also at the level of CS. Below we consider each of these three word classes separately.

Object nouns

As shown in Figure 2, Marcel's unilateral left-hemisphere lesion affected the posterior inferior frontal gyrus, the inferior precentral and postcentral gyri, part of the inferior parietal operculum, most of the superior temporal gyrus, and part of the posterior middle temporal gyrus. However, the lesion spares the neural structures that have been linked most strongly with the meanings of the various classes of object nouns that were included in Study 1. There is now a substantial body of literature on the neural correlates of conceptual knowledge of concrete entities (for recent reviews from different perspectives, see Caramazza & Mahon, 2006; Kemmerer, in press; Thompson-Schill, Kan, & Oliver, 2006). Although much remains controversial, there is increasing support for the following two hypotheses: First, the different sensory properties encoded by object nouns depend on modality-specific cortical regions that are anatomically adjacent to, or even overlapping with, the regions that are engaged during the perception of those properties (e.g., Goldberg, Perfetti, & Schneider, 2006, in press; James & Gauthier, 2003; Kan, Barsalou, Solomon, Minor, & Thompson-Schill, 2003; Kellenbach, Brett, & Patterson, 2001; Martin & Chao, 2001; Simmons & Barsalou, 2003); second, correlations between the different sensory properties encoded by object nouns are captured by conjunctive units residing in anterior temporal regions, most likely the perirhinal cortex (Bright et al., in press; Davies, Graham, Xuereb, Williams, & Hodges, 2004; Taylor, Moss, Stamatakis, & Tyler, 2006). All of these neural structures are intact for Marcel.

Action verbs

A growing body of research suggests that the meanings of action verbs depend to a large extent on certain sectors of the frontal and temporal lobes (for reviews see Kemmerer, 2006a; Pulvermüller, 2005; for pertinent behavioural studies see Borreggine & Kaschak, in press; Boulenger, Roy, Paulignan, Deprez, Jeannerod, & Nazir, in press; Glenberg & Kaschak, 2002; Kaschak et al., 2005; Zwaan & Taylor, 2006). First, there is increasing evidence that motoric aspects of the meanings of action verbs are subserved by motor-related structures in the frontal lobes, especially in the left hemisphere. Several studies employing a variety of techniques have shown that verbs encoding face actions (e.g., *bite*), arm/hand actions (e.g., *punch*), and leg/foot actions (e.g., *kick*) differentially engage the corresponding ventrolateral, dorsolateral, and dorsomedial sectors of somatotopically mapped primary motor and premotor regions (Buccino, Riggio, Melli, Binkofski, Gallese, & Rizzolatti, 2005; Hauk, Johnsrude, & Pulvermüller, 2004; Hauk & Pulvermüller, 2004; Pulvermüller et al., 2005a, 2005b; Tettamanti et al., 2005). In addition, lesion studies have found that damage in the left premotor/prefrontal region often disrupts knowledge of the meanings of action verbs (Bak & Hodges, 2003; Bak, O'Donovan, Xuereb, Boniface, & Hodges, 2001; Bak et al., 2006; Kemmerer & Tranel, 2003; Tranel, Kemmerer, Adolphs, Damasio, & Damasio, 2003). Marcel's lesion includes the left posterior inferior frontal gyrus, but the other frontal regions just described are largely if not entirely preserved.

Second, there is also evidence that the visual motion patterns encoded by action verbs depend on the left posterior lateral temporal cortex. Several functional neuroimaging studies employing tasks that require the semantic processing of action verbs (Kable, Kan, Wilson, Thompson-Schill, & Chatterjee, 2005; Kable, Lease-Spellmeyer, & Chatterjee, 2002; see also Martin, Ungerleider, & Haxby, 2000; Wu, Morganti, & Chatterjee, 2004) have found activation in regions of the the left posterior lateral temporal cortex that lie anterior and dorsal to area MT, which is located in the posterior lateral occipito-temporal cortex and is critically involved in visual motion perception (Malikovic et al., in press). Two other functional neuroimaging studies ostensibly found associations between action verb processing and area MT itself (Damasio et al., 2001; Tranel, Martin, Damasio, Grabowski, & Hichwa, 2005); however, the observed activation foci may actually lie anterior and dorsal to area MT (as defined by Malikovic et al., in press), in which case they would be similar to those reported by Kable et al. (2002, 2005). Furthermore, damage in this cortical territory, or in the subjacent white matter, can impair conceptual knowledge of the kinds of actions encoded by verbs (Tranel et al., 2003). Marcel's lesion included a portion of the posterior middle temporal gyrus but appears to have spared, or only minimally affected, the lateral temporal regions that may support the types of visual motion patterns that are encoded by action verbs.

Spatial prepositions

Very little research has addressed the neuroanatomical correlates of the meanings of spatial prepositions, but the available evidence suggests that the left supramarginal gyrus is a critical structure (for a review see Kemmerer, 2006b). This region is activated when participants name static spatial relationships with appropriate prepositions like *in, on*, etc. (Damasio et al., 2001; see also Emmorey et al., 2002; MacSweeney et al., 2002). In addition, damage to this region frequently impairs performance on tasks that evaluate knowledge of the spatial meanings of these words (Kemmerer, 2005; Kemmerer & Tranel, 2000, 2003; Tranel & Kemmerer, 2004). Marcel's lesion spared most of the left supramarginal gyrus, which explains his well-preserved knowledge for spatial prepositions.

Syntactic Structure (SS)

Recent studies suggest that the morphosyntactic processing of grammatical categories like noun and verb may be supported by cortical structures in and around Broca's area (for a review see Caramazza & Shapiro, 2004). In addition, there is growing evidence that the left Rolandic operculum, caudally adjacent to Broca's area, contributes to the assembly of argument structure constructions during sentence production (Haller, Radue, Erb, Grodd, & Kircher, 2005; Indefrey et al., 2001; Indefrey, Hellwig, Herzog, Seitz, & Hagoort, 2004). Marcel's lesion affected all of these areas, so it is initially surprising that he nevertheless performed well on the sentence anagram task in Study 3. The discrepancy is mitigated, however, by the following considerations. First, as already noted, separate analyses of Marcel's narrative discourse indicate that he is moderately agrammatic, so it is likely that his preserved ability to perform the anagram task reflects the simplicity of the syntactic structure of the intransitive motion construction. Second, severe agrammatism usually requires damage to not only the cortex but also the underlying white matter (Mohr, 1976), but Marcel's lesion is almost entirely cortical.

Phonological Structure (PS)

Studies 1, 2, and 3 all indicate that Marcel has tremendous difficulty producing the spoken forms of words. This is entirely what one would expect, given that his brain damage encompasses frontal and temporal regions that are well established as subserving various aspects of PS (for reviews see Hickok & Poeppel, 2004; Indefrey & Levelt, 2000, 2004). Most importantly, the lesion affected the left posterior superior temporal gyrus and sulcus—areas that have been implicated in phonological code retrieval during picture naming, according to Indefrey and Levelt's (2004) meta-analysis.

Gestural Structure (GS)

Despite his profound deficit in orally describing motion events, Marcel is still remarkably skilled at programming iconic manual depictions of motion events at the level of GS, as demonstrated not only in Study 2, which focused on spontaneous co-speech gestures, but also, and even more convincingly, in Study 3, which focused on elicited gestures. These findings contribute significantly to the literature on how some brain-damaged individuals with severe aphasia but without manual apraxia can successfully employ gesture to augment the semantic content of their speech (e.g., Ahlsen, 1991; Fex & Mansson, 1998; Feyereisen, 1983; Hanlon et al., 1990;

Helm-Estabrooks et al., 1982; Lott, 1999; Pashek, 1997; Schlanger & Freimann, 1979). In addition, given that our investigation was grounded in recent research on cross-linguistic covariation in the verbalization and gesticulation of motion events, it adds a new theoretical perspective to the literature on how neuropsychological data can help illuminate the underlying nature of the complex interaction between language and gesture (e.g., Barrett et al., 2002; Carlomagno et al., 2005; Cole et al., 2002; Hadar et al., 1998; Hadar & Yadlin-Gedassey, 1994; Lausberg et al., 2003; Lausberg et al., 2000; see also Corina et al., 1992, and Marshall et al., 2004).

Perhaps the most interesting outcome of this investigation is that, as shown in Study 3, when Marcel's gestural packaging of motion events is released from the constraints imposed by his word-finding problems in the oral modality, it is exactly like that of normal English speakers. Moreover, because the systems of SpS, CS, SS, and GS appear to be intact for Marcel (at least regarding the types of cognitive structures considered in this study), it is possible that his English-typical gesticulation of motion events in Study 3 was partially influenced by the same language-specific semantic and syntactic factors that Kita and Özyürek (2003; see also Özyürek et al., 2005) have argued to be operative for normal speakers. These factors are illustrated in Figure 1 as correspondences between particular units of GS on the one hand, and particular units of SpS, CS, and SS on the other. Additional research would be necessary, however, to confirm one rather problematic aspect of this hypothesis—namely, that the specific conflational organization of Marcel's gestures (as well as those of the normal participants) in the sentence condition in Study 3 was influenced by the syntactic structure of the intransitive motion construction. The alternative possibility, which warrants further investigation, is that the organization reflected a kind of default strategy based on purely iconic principles.

Despite this point of uncertainty, it is noteworthy that our case study of Marcel converges with several other studies that provide evidence for a very close relation between language and gesture, especially co-speech gesture. For example, Ramachandran and Blakeslee (1998, p. 41) report that a woman who was born without arms but experienced phantom limbs felt that her phantoms were "frozen" when she walked but gesticulated when she talked. In addition, Cole et al. (2002) describe the case of I.W., a man who lost proprioception and the sense of touch from the neck down, but who gradually learned to control his posture and limb movements through arduous visually guided attention. I.W.'s body schema is so dependent on visual input that one day when he was standing in his mother's kitchen and the lights suddenly went out, he immediately collapsed onto the floor because his major frame of reference for monitoring the configuration of his body was abruptly cut off (Cole, 1995). Remarkably, despite the fact that I.W.'s instrumental and locomotor actions require constant visual supervision, he is able to produce spontaneous co-speech gestures *even when he cannot see his hands*. Although his gestures are topokinetically degraded (i.e., inaccurate with respect to precise distance relations), they are morphokinetically normal (i.e., properly structured in terms of handshapes). Cole et al. (2002, p. 59) maintain that IW's performance supports the view that co-speech gesture is "primarily part of communicative action rather than a form of motor behaviour"—a statement that alludes to the many ways in which the content and organization of GS is influenced by SpS, CS, and SS, as shown in Figure 1.

Given that co-speech gesture appears to be tightly interwoven with language, the question naturally arises as to whether its underlying neural circuitry is partially distinct from that which subserves other kinds of limb praxis such as pantomiming how to use certain tools. Marcel can easily produce both language-related and non-language-related gestures. But if the neural substrates of these two types of limb praxis are partially distinct, then it should be possible for them to be impaired independently of each other by focal lesions. As far as we know, however, no studies have systematically explored this issue. Non-language-related gesture is associated with a complex network of bilateral frontal, parietal, and temporal structures (for a recent attempt to integrate neuropsychological and functional neuroimaging perspectives, see Peigneux et al., 2004). But research on the specific neuroanatomical correlates of co-speech gesture has barely begun (e.g., Lausberg et al., 2003; Lausberg et al., 2000; McNeill, 1992). Hopefully this intriguing topic will receive greater attention in the near future.

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