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10

Action verbs, argument structure constructions, and the mirror neuron system

David Kemmerer

10.1 Introduction

This chapter reviews recent evidence that the linguistic representation of action is grounded in the mirror neuron system. Section 10.2 summarizes the major semantic properties of action verbs and argument structure constructions, focusing on English but also considering cross-linguistic diversity. The theoretical framework is Construction Grammar, which maintains that the argument structure constructions in which action verbs occur constitute basic clausal patterns that express basic patterns of human experience. For example, the sentence *She sneezed the napkin off the table* exemplifies the Caused Motion Construction, which has the schematic meaning "X causes Y to move along path Z," and the sentence *She kissed him unconscious* exemplifies the Resultative Construction, which has the schematic meaning "X causes Y to become Z" (Goldberg, 1995).

Section 10.3 addresses the neuroanatomical substrates of action verbs and argument structure constructions. A number of neuroimaging and neuropsychological studies are described which suggest that different semantic properties of action verbs are implemented in different cortical components of the mirror neuron system, especially in the left hemisphere: (1) motoric aspects of verb meanings (e.g., the type of action program specified by *kick*) appear to depend on somatotopically mapped primary motor and premotor regions; (2) agent–patient spatial–interactive aspects of verb meanings (e.g., the type of object-directed path specified by *kick*) appear to depend on somatotopically mapped parietal regions; and (3) visual manner-of-motion aspects of verb meanings (e.g., the visual movement pattern specified by *kick*) appear to depend on posterior middle temporal regions. In addition, several neuropsychological studies are described which suggest that the meanings of argument structure constructions are implemented in left perisylvian cortical regions that are separate from, but adjacent to, those for verb meanings.

Action to Language via the Mirror Neuron System, ed. Michael A. Arbib. Published by Cambridge University Press.

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Finally, Section 10.4 broadens the discussion of action verbs and argument structure constructions by briefly considering the emergence of language during ontogeny and phylogeny.

10.2 Action verbs and argument structure constructions

10.2.1 Action verbs

Causal complexity

Although many verbs refer to abstract states and events (e.g., *exist, remain, increase, elapse*), the prototypical function of verbs in all languages is to denote physical actions, that is, situations in which an agent, such as a person or animal, engages in certain kinds of bodily movement (Croft, 1991). For this reason, and also because action is a prominent theme throughout the current volume, I will focus exclusively on action verbs. Most contemporary semantic theories assume that conceptions of space, force, and time constitute the foundation of the meanings of action verbs, and that an especially important dimension of semantic variation involves causal complexity (e.g., Pinker, 1989; Jackendoff, 1990; Van Valin and LaPolla, 1997; Croft, 1998; Rappaport Hovrav and Levin, 1998). The simplest verbs, which are usually intransitive, represent events in which an agent performs an activity that does not necessarily bring about any changes in other entities (e.g., *sing, laugh, wave, jog*). Other verbs, which are usually transitive, are more complex insofar as they express activities that do affect other entities in certain ways, such as by inducing a change of state (e.g., *slice, engrave, purify, kill*) or a change of location (e.g., *pour, twist, load, smear*), either through direct bodily contact or by means of a tool.

Semantic classes

In addition to the basic organizing factor of causal structure, the meanings of action verbs can be analyzed and compared in terms of the various semantic fields that they characterize. Levin (1993) sorted over 3000 English verbs (the majority of which are action verbs) into approximately 50 classes and 200 subclasses. Representative classes include verbs of throwing (e.g., *fling, hurl, lob, toss*), verbs of creation (e.g., *build, assemble, sculpt, weave*), and verbs of ingesting (e.g., *eat, gobble, devour, dine*). The verbs in a given class collectively provide a richly detailed categorization of the relevant semantic field by making distinctions, often of a remarkably fine-grained nature, along a number of different dimensions. For instance, verbs of destruction are distinguished by the composition of the entity to be destroyed (e.g., *tear* vs. *smash*), the degree of force (e.g., *tear* vs. *rip*), and the extent of deformation (e.g., *tear* vs. *shred*). The verbs in a given class are also organized according to principled semantic relations such as the following: synonymy, in which two verbs have nearly identical meanings (e.g., *shout* and *yell*); antonymy, in which two verbs have opposite meanings (e.g., *lengthen* and *shorten*); hyponymy, in which one verb is at a higher taxonomic level than another (e.g., *talk* and *lecture*); and cohyponymy, in which two verbs are at roughly the same taxonomic level (e.g., *bow* and *curtsey*) (Fellbaum, 1998).

Cross-linguistic diversity

Another important point about the meanings of action verbs is that they vary considerably across the 6000+ languages of the world. One manifestation of this variation involves the distinctions that are made within particular semantic fields or, as they are sometimes called, conceptual spaces. For example, Lakoff and Johnson (1999, p.576) describe several idiosyncratic differences in how languages carve up the conceptual space of hand actions:

- In Tamil, *thallu* and *ilu* correspond to English *push* and *pull*, except that they connote a sudden action as opposed to a smooth continuous force.
- In Farsi, *zadan* refers to a wide range of object manipulations involving quick motions – e.g., snatching a purse or strumming a guitar.
- In Cantonese, *mit* covers both pinching and tearing. It connotes forceful manipulation by two fingers, yet is also acceptable for tearing larger items when two full grasps are used.

A more systematic case of cross-linguistic variation in verb semantics derives from two different clausal patterns for encoding the manner and path components of motion events (Talmy, 1985). As shown below, in some languages (e.g., English, German, Russian, Swedish, and Chinese) manner is preferentially encoded by a verb and path by a preposition (or a similar grammatical category), whereas in other languages (e.g., French, Spanish, Japanese, Turkish, and Hindi) path is preferentially encoded by a verb and manner by an optional adverbial expression in a syntactically subordinate clause:

English: The dog ran$_{\text{MANNER}}$ into$_{\text{PATH}}$ the house.
French: Le chien est entré dans la maison en courant.
"The dog entered$_{\text{PATH}}$ the house by running$_{\text{MANNER}}$."

As a result of this fundamental difference, the inherently graded conceptual space of manner-of-motion is usually more intricately partitioned in languages of the former type than in languages of the latter type (Slobin, 2003). Thus, English distinguishes between *jump, leap, bound, spring*, and *skip*, but all of these verbs are translated into French as *bondir*; similarly, English distinguishes between *creep, glide, slide, slip*, and *slither*, but all of these verbs are translated into Spanish as *escabullirse*. Specialized manner verbs like these are not just dictionary entries, but are actively employed by English speakers in a variety of naturalistic and experimental contexts, including oral narrative, spontaneous conversation, creative writing, naming videoclips of motion events, and speeded fluency, i.e., listing as many manner verbs as possible in 1 minute (Slobin, 2003). In addition, recent research suggests that the cross-linguistic differences in semantic maps for manner-of-motion influence co-speech gesture (Kita and Özyürek, 2003; D. Kemmerer *et al*., unpublished data) and lead to non-trivial differences in perceptual tuning and long-term memory for subtle manner details of motion events (A. W. Kersten *et al*., unpublished data; Oh, 2003).

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10.2.2 Argument structure constructions

The relation between verbs and constructions

Many action verbs occur in a wide range of argument structure constructions. For example, even though *kick* is usually considered to be a prototypical transitive verb, it occurs in at least nine distinct active-voice constructions (Goldberg, 1995):

(1) Bill kicked the ball.
(2) Bill kicked the ball into the lake.
(3) Bill kicked at the ball.
(4) Bill kicked Bob the ball.
(5) Bill kicked Bob black and blue.
(6) Bill kicked Bob in the knee.
(7) Bill kicked his foot against the chair.
(8) Bill kicked his way through the crowd.
(9) Horses kick.

These sentences describe very different kinds of events: (1) simple volitional bodily action directed at an object, (2) causing an object to change location, (3) attempting to contact an object, (4) transferring possession of an object, (5) causing an object to change state, (6) inducing a feeling in a person by contacting a part of their body, (7) causing a part of one's own body to contact an object, (8) making progress along a path by moving in a particular manner, and (9) having a tendency to perform a certain action. According to Construction Grammar and related theories (e.g., Goldberg, 1995, 2003; Croft, 2001; Jackendoff, 2002; Croft and Cruse, 2004), argument structure constructions are clausal patterns that are directly associated with specific meanings, and the interpretation of a sentence is in large part the outcome of a division of labor between the meaning of the construction and the meaning of the verb.[1] For instance, the *X's way* construction consists of a particular syntactic structure – roughly "Subject Verb *X's way* Oblique" – that is paired with a particular semantic structure – roughly "X makes progress along a path by V-ing." Thus, in a sentence like *Bill kicked his way through the crowd*, the general concept of "motion of the subject referent along a path" comes from the *X's way* construction itself, and the more specific notion of "forceful leg action" comes from *kick*. Table 10.1 shows how each of the sentences with *kick* listed in (1)–(9) above instantiates a construction that designates an idealized event type.

The meanings of these constructions are quite abstract and hence bear an interesting resemblance to the "minimal scenes" described by Itti and Arbib (this volume). As Goldberg (1998, p.206) points out, "we do not expect to find distinct basic sentence types that have semantics such as something turning blue, someone becoming upset, something turning over." This is because specific events like these do not happen frequently enough to warrant incorporation into a language's morphosyntactic design.

[1] The process of integrating verbs and constructions is, not surprisingly, quite complex. See Goldberg (1995) for an introduction.

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Table 10.1 *Examples of English argument structure constructions*

Construction	Form	Meaning	Example
1. Transitive	Subject Verb Object	X acts on Y	Bill kicked the ball.
2. Caused motion	Subject Verb Object Oblique	X causes Y to move along path Z	Bill kicked the ball into the lake.
3. Conative	Subject Verb Oblique_{at}	X attempts to contact Y	Bill kicked at the ball.
4. Ditransitive	Subject Verb Object_1 Object_2	X causes Y to receive Z	Bill kicked Bob the ball.
5. Resultative	Subject Verb Object Complement	X causes Y to become Z	Bill kicked Bob black and blue.
6. Possessor ascension	Subject Verb Object $\text{Oblique}_{in/on}$	X contacts Y in/on body-part Z	Bill kicked Bob in the knee.
7. $\text{Contact}_{against}$	Subject Verb Object $\text{Oblique}_{against}$	X causes Y to contact Z	Bill kicked his foot against the chair.
8. *X's way*	Subject Verb *X's way* Oblique	X makes progress by performing action	Bill kicked his way through the crowd.
9. Habitual	Subject Verb	X performs action habitually	Horses kick.

The Grammatically Relevant Semantic Subsystem Hypothesis (GRSSH)

Research along these lines has led to what Pinker (1989) calls the Grammatically Relevant Semantic Subsystem Hypothesis (GRSSH), which maintains that a distinction exists between two large-scale components of meaning: (1) a set of fairly abstract semantic features that are relevant to grammar insofar as they tend to be encoded by closed-class items as well as by morphosyntactic constructions; and (2) an open-ended set of fairly concrete semantic features that are not relevant to grammar but instead enable open-class items to express an unlimited variety of idiosyncratic concepts. This distinction is illustrated by the ditransitive construction, which at the highest level of schematicity means "X causes Y to receive Z," but which also (as is true of many argument structure constructions) has several additional semantic restrictions, one of which is that while verbs of instantaneous causation of ballistic motion are acceptable (e.g., *I kicked/tossed/rolled/bounced him the ball*), verbs of continuous causation of accompanied motion are not (e.g., **I carried/hauled/lifted/dragged him the box*) (Pinker, 1989).[2] According to the GRSSH, the ditransitive construction is sensitive to the relatively coarse-grained contrast between the two sets of verbs, but is not sensitive to the more

[2] Pinker (1989, p.358) points out, however, that some speakers find the sentences with verbs of accompanied motion to be acceptable, which suggests that there are dialectal or idiolectal differences in dativizability.

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fine-grained contrasts between the verbs within each set – i.e., between *kick, toss, roll*, and *bounce* on the one hand, and between *carry, haul, lift*, and *drag* on the other.

Morphosyntax

Since the main focus of this chapter is on semantics, I will only make a few points concerning the morphosyntactic aspects of argument structure constructions (for a more detailed exposition, see Croft, 2001). As shown in Table 10.1, the form of these constructions is specified in terms of phrasal units that are arrayed around a verb according to syntactic relations like subject, object, and oblique. These phrasal units are assumed to have internal hierarchical structures captured by other (families of) constructions, such as the NP (noun-phrase) construction, the PP (prepositional phrase) construction, and so forth. With respect to grammatical categories like noun, verb, and adjective, the fact that the members of each category exhibit widespread distributional mismatches across constructions suggests that they fractionate into subclasses that comprise a vast multidimensional network or inheritance hierarchy with broad categories at the top and narrow ones at the bottom. For example, all English nouns can serve as the subject NP of a sentence, but "subject NP" is just one construction, and further investigation leads to a proliferation of subclasses of nouns with varying constructional distributions, such as pronouns, proper nouns, count nouns, and mass nouns, each of which breaks down into even smaller and quirkier groupings – e.g., proper nouns for days of the week and months of the year require different spatially based prepositions when used in expressions for temporal location (*on*/**in Saturday*, *in*/**on August*; cf. Kemmerer, 2005). As for English verbs, they all inflect for tense/aspect in main clauses, but again this is a construction-specific property justifying only the category that Croft (2001) calls "morphological verb," and closer scrutiny reveals that, as mentioned above, verbs display a tremendous range of distributional diversity, with approximately 50 classes and 200 subclasses based on combined semantic and syntactic factors (Levin, 1993). Finally, there are apparently no distributional criteria that justify a single overarching adjective category in English, as suggested by facts like the following. Some adjectives are both attributive and predicative (*the funny movie, that movie is funny*) whereas others are only attributive (*the main reason*, **that reason is main*) or only predicative (**the asleep student, that student is asleep*). Moreover, when multiple adjectives occur prenominally, their linear order is determined primarily by which of several semantically and pragmatically defined subclasses they belong to, thus accounting for why it is grammatical to say *the other small inconspicuous carved jade idols* but not **the carved other inconspicuous jade small idols* (Kemmerer, 2000b; Kemmerer *et al.*, in press).

Three constructions

To further clarify the nature of argument structure constructions as well as the GRSSH, I will briefly describe two constructional alternations (the locative alternation and the body-part possessor ascension alternation) and one morphological construction (reversative *un-* prefixation). I will concentrate on semantic issues, and will return to all three constructions later, in the section on neuroanatomical substrates.

First, the locative alternation is illustrated by the constructions in (10) and (11):

(10) (a) Sam sprayed water on the flowers.
(b) Sam dripped water on the flowers.
(c) *Sam drenched water on the flowers.
(11) (a) Sam sprayed the flowers with water.
(b) *Sam dripped the flowers with water.
(c) Sam drenched the flowers with water.

Functionally, these two constructions encode different subjective construals of what is objectively the same type of event. Human cognition is remarkably flexible, and we are able to take multiple perspectives on events by allocating our attention to the entities in various ways (Tomasello, 1999). If I see Sam spraying water on some flowers, I can conceptualize the water as being most affected, since it changes location from being in a container to being on the flowers, or I can conceptualize the flowers as being most affected, since they change state from being dry to being wet. The construction in (10) captures the first kind of perspective since it has the schematic meaning "X causes Y to go to Z in some manner," whereas the construction in (11) captures the second kind of perspective since it has the schematic meaning "X causes Z to change state in some way by adding Y." Semiotically, the two constructions signal these different perspectives by taking advantage of a general principle that guides the mapping between syntax and semantics, namely the "affectedness principle," which states that the entity that is syntactically expressed as the direct object is interpreted as being most affected by the action (Gropen *et al*., 1991). *Spray* can occur in both constructions because it encodes not only a particular manner of motion (a substance moves in a mist) but also a particular change of state (a surface becomes covered with a substance). However, *drip* and *drench* are in complementary distribution, largely because each constructional meaning is associated with a network of more restricted meanings that are essentially generalizations over verb classes (Pinker, 1989; Goldberg, 1995). One of the narrow-range meanings of the first construction is "X enables a mass Y to go to Z via the force of gravity," and this licenses expressions like *drip/dribble/pour/spill water on the flowers* and excludes expressions like **drench water on the flowers*. Similarly, one of the narrow-range meanings of the second construction is "X causes a solid or layer-like medium Z to have a mass Y distributed throughout it," and this licenses expressions like *drench/douse/soak/saturate the flowers with water* and excludes expressions like **drip the flowers with water*.

Second, the body-part possessor ascension alternation is illustrated by the constructions in (12) and (13):

(12) (a) Bill hit Bob's arm.
(b) Bill broke Bob's arm.
(13) (a) Bill hit Bob on the arm.
(b) *Bill broke Bob on the arm.

Like the locative alternation, the body-part possessor alternation provides two constructions for expressing different subjective construals of the same objective type of event – an event that basically involves something contacting part of someone's body. Also like the locative alternation, the body-part possessor alternation places restrictions on which verbs are acceptable, except that here the most interesting restrictions apply to just the second construction, which is traditionally called the ascension construction because the possessor NP – *Bob* in (13) – has "ascended" out of the modifier position in the complex NP of the first construction. Consider, for example, the following sentences: *Bill hit/bumped/tapped/whacked Bob on the arm* vs. **Bill broke/cracked/fractured/shattered Bob on the arm*. There is not yet a completely satisfactory account of the precise semantic criteria that determine which verbs can occur in the construction, but one feature that appears to be relevant is "contact" (Kemmerer, 2003). Although both constructions make reference to physical contact, this feature is more prominent in the ascension construction. It is explicitly marked by a locative preposition (typically *on* or *in*) that introduces the body-part NP. Even more crucially, all of the verbs that can occur in the construction belong to classes that specify contact: verbs of touching (e.g., *caress, kiss, lick, pat, stroke*); verbs of contact by impact, which fractionate into three subclasses – "hit" verbs (e.g., *bump, kick, slap, smack, tap*), "swat" verbs (e.g., *bite, punch, scratch, slug, swipe*), and "spank" verbs (e.g., *bonk, clobber, flog, thrash, wallop*); verbs of poking, i.e., forceful contact by means of a sharp object (e.g., *jab, pierce, poke, prick, stick*); and verbs of cutting, i.e., forceful contact causing a linear separation in the object (e.g., *cut, hack, scrape, scratch, slash*) (Levin, 1993).[3] On the other hand, most of the verbs that cannot occur in the ascension construction belong to a class called "break" verbs (e.g., *break, rip, smash, splinter, tear*). These verbs do not necessarily entail contact but instead focus on just the change of state – the transformation of structural integrity – that an entity undergoes. Another important point is that although both of the constructions shown in (12) and (13) describe events involving bodily contact, they package the information differently. In accord with the affectedness principle mentioned above in the context of the locative alternation, the non-ascension construction focuses more on the body part than the person since the body part is mapped onto the direct object position (*Bill hit Bob's arm*), whereas the ascension construction focuses more on the person than the body part since the person is mapped onto this privileged syntactic position (*Bill hit Bob on the arm*). More specifically, the ascension construction conveys the impression that what is really being affected is the person as a sentient being – in other words, the person's inner sensations, thoughts, or feelings – and that this happens because a particular part of the person's body is contacted in some manner. Support for this aspect of the constructional meaning comes from the observation that the direct object of this construction must refer to an animate entity, as shown below (Wierzbicka, 1988):

[3] "Carve" verbs, which constitute a subclass of verbs of cutting (Levin, 1993), are somewhat problematic because although all of them denote contact, some do not occur naturally in the ascension construction (e.g., **The dentist drilled me in my tooth*). This issue is discussed briefly by Kemmerer (2003).

(14) (a′) The puppy bit Sam on the leg.
(a″) *The puppy bit the table on the leg.
(b′) Sam touched Kate on the arm.
(b″) *Sam touched the library on the window.
(c′) A rock hit Sam on the head.
(c″) *A rock hit the house on the roof.

The ascension construction therefore appears to have a schematic meaning that can be paraphrased rather loosely as follows: "X acts on person Y, causing Y to experience something, by contacting part Z of Y's body."

Third, reversative *un-* prefixation is a morphological construction that licenses some verbs but not others. Thus, one can *unlock* a door, *unwind* a string, *unwrap* a CD, *untwist* a wire, *untie* a shoe, and *unbutton* a shirt, but one cannot **unpress* a doorbell, **undangle* a bag, **unfluff* a pillow, **unhide* a present, or **unboil* a pot of water. According to a recent analysis by Kemmerer and Wright (2002), most of the verbs that allow reversative *un-* fall into two broad classes described by Levin (1993) as "combining/attaching" verbs (which further subdivide into five subclasses) and "putting" verbs (which further subdivide into seven subclasses). Both classes share the property of designating events in which an agent causes something to enter a constricted, potentially reversible spatial configuration. These semantic constraints are revealed in an especially striking way by the different uses of the verb *cross*: one can cross one's arms and then uncross them (because a constricted spatial configuration is created and then reversed), but if one crosses a street and then walks back again, it would be strange to say that one has uncrossed the street (because no constricted spatial configuration is involved). The reversative *un-* prefixation construction may therefore be restricted to verbs which have a schematic meaning something like "X causes Y to enter a constricted, potentially reversible spatial configuration relative to Z." No single verb encodes this idealized meaning, which is why the meaning is a purely constructional one. Yet many verbs have specific meanings that are compatible with this semantic template, and they are the ones that are allowed to occur in the construction.

Cross-linguistic diversity

As with action verbs, argument structure constructions vary greatly across languages in both form and meaning. Even a phenomenon as seemingly trivial as possessor ascension is manifested in such a wide variety of ways cross-linguistically that it has been the topic of book-length studies (Castillo, 1996; Chappell and McGregor, 1996). An especially instructive example of cross-linguistic constructional diversity involves causatives, broadly conceived. Many languages (including English; see Wierzbicka, 1998) have two or more causative constructions, and there is usually if not always a semantic difference between them involving at least one of the following nine parameters (Dixon, 2000):

- State/action: does a causative construction apply equally to state verbs and action verbs?
- Transitivity: does it apply equally to intransitive, transitive, and ditransitive verbs?
- Control: does the causee usually have or lack control of the induced activity?

- Volition: does the causee do it willingly or unwillingly?
- Affectedness: is the causee partially or completely affected?
- Directness: does the causer act directly or indirectly?
- Intention: does the causer achieve the result intentionally or accidentally?
- Naturalness: does the process happen fairly naturally (the causer only instigating it)?
- Involvement: is the causer (not just the causee) involved in the induced activity?

In addition, there are numerous language-specific restrictions (i.e., constraints unique to particular languages). For instance, in Nivkh a causer must be animate, so that one cannot say something like *The mist made us stay in the village*, but must instead resort to a non-causative construction such as *We stayed in the village because of the mist*.

10.3 Neuroanatomical substrates

In an illuminating discussion of the meanings of action verbs like *walk, jog, limp, strut*, and *shuffle*, Jackendoff (2002, p.350) argues that because they differ only in the manner of self-locomotion, the subtle semantic contrasts between them should probably be characterized directly in modality-specific visuospatial and motoric representational formats. In an effort to promote interdisciplinary cross-talk on issues like this, he then writes: "I hope researchers on vision and action might be persuaded to collaborate in the task." In this section I show that such collaboration is not only taking place, but is already yielding results that support Jackendoff's view. The section is organized in three parts. First, I summarize the Convergence Zone (CZ) theory and the Similarity-in-Topography (SIT) principle, which together comprise a model of the organization of conceptual knowledge in the brain. Second, I review research which suggests that (consistent with CZ theory and the SIT principle) the mirror neuron system contributes substantially to the representation of action concepts, including those encoded by verbs. Finally, I consider the neural correlates of the semantic and morphosyntactic aspects of argument structure constructions, concentrating on the following two findings from a series of neuropsychological studies that addressed the three constructions described above: focal brain damage can impair constructional meanings independently of verb meanings (consistent with the GRSSH), yet the lesion data suggest that constructional meanings are nevertheless implemented in cortical areas that are close to those that implement verb meanings (consistent with CZ theory and the SIT principle).

10.3.1 Convergence Zone (CZ) Theory and the Similarity-in-Topography (SIT) Principle

Several competing theories are currently available regarding the organization of conceptual knowledge in the brain (for reviews see Martin and Caramazza, 2003; Caramazza and Mahon, 2006). The framework that I adopt here is Convergence Zone theory (Damasio, 1989; Damasio *et al*., 2004). It assumes that the various instances of a conceptual category are represented as fluctuating patterns of activation across modality-specific feature maps in primary and early sensory and motor cortices. These representations are experienced as explicit images, and they change continuously under the influence of external and internal inputs. For example, watching a dog run across a field generates transient activation patterns in multiple visual feature maps dedicated to coding information about shape, color, texture, size, orientation, distance, and motion. All of the instances of a conceptual category share certain properties that are neurally manifested as similar patterns of activation across feature maps. These commonalities are captured by "conjunctive neurons" (Simmons and Barsalou, 2003) in "convergence zones" (CZs: Damasio, 1989) that reside in higher-level association areas. CZs are reciprocally connected with feature maps, thereby enabling both recognition and recall. In addition, CZs exist at many hierarchical levels such that modality-specific CZs represent particular sensory and motor categories, while cross-modal CZs conjoin knowledge across modalities. Thus, to return to the example of watching a dog run across a field, the following stages of processing can be distinguished: first, activation patterns across visual feature maps are detected by modality-specific CZs that store purely visual knowledge about dogs; these modality-specific CZs then feed forward to a cross-modal CZ for the more general concept of a dog; next, the cross-modal CZ triggers the engagement of related modality-specific CZs in other knowledge domains; finally, the various modality-specific CZs may, depending on the task, generate explicit representations across the appropriate feature maps – e.g., auditory images of what dogs typically sound like, motor images of how one typically interacts with them (like reaching out and petting them), somatosensory images of how their fur feels, and so on. The evocation, whether conscious or unconscious, of some part of the large number of such neuronal patterns, over a brief lapse of time, constitutes activation of the conceptual knowledge pertaining to the category of entities at hand, namely dogs. More generally, CZ theory treats concept retrieval as a process of partial re-enactment or simulation of the sensorimotor states engendered by direct exposure to various instances of the given category (see also Barsalou, 2003; Barsalou *et al*., 2003).

Functionally comparable CZs are neuroanatomically distributed within brain regions that are optimally situated for processing the given type of information. For example, research that has been guided by CZ theory suggests that CZs for animals – a conceptual domain that depends heavily on visual information – are implemented primarily in the right mesial–occipital/ventral–temporal region and the left mesial–occipital region (Tranel *et al*., 1997, 2003a; Damasio *et al*., 2004), whereas CZs for actions – a conceptual domain that depends heavily on motor programming and the perception of biological motion patterns – are implemented primarily in the left premotor/prefrontal region, the left inferior parietal region, and the left posterior middle temporal region, areas that participate in the mirror neuron system, as described in detail below (Damasio *et al*., 2001; Tranel *et al*., 2003b).

Simmons and Barsalou (2003) recently extended CZ theory by adding the Similarity-in-Topography (SIT) principle, which is a conjecture regarding the organization of conjunctive neurons in CZs: "The spatial proximity of two neurons in a CZ reflects the similarity of the features they conjoin. As two sets of conjoined features become more similar, the conjunctive neurons that link them lie closer together in the CZ's spatial topography." Simmons and Barsalou explore the implications of this principle for the neural representation of object concepts. In the next two sections, I show that it also has explanatory and predictive value in considering the neural representation of the kinds of action concepts that are encoded by verbs and argument structure constructions.

10.3.2 Action verbs

During the past few years, evidence has been accumulating for the view that the mirror neuron system supports not only non-linguistic action concepts in both monkeys and humans, but also the meanings[4] of language-specific action verbs. Here I provide a brief and selective review of this evidence. The discussion is organized around the relevant frontal, parietal, and temporal brain regions that together form a complex circuit (Keysers and Perrett, 2004); in addition, for each region the following three types of data are addressed in turn: monkey data, human non-linguistic data, and human linguistic data.

Frontal regions

Area F5 in the macaque brain contains neurons that represent a wide range of action types (Rizzolatti *et al.*, 1988). As Rizzolatti *et al.* (2000, p.542) put it:

> F5 is a store of motor schemas or . . . a "vocabulary" of actions. This motor vocabulary is constituted by "words", each of which is represented by a set of F5 neurons. Some words indicate the general goal of an action (e.g., grasping, holding, tearing); others indicate the way in which a specific action must be executed (e.g., precision grip or finger prehension); finally, other words are concerned with the temporal segmentation of the action into motor acts, each coding a specific phase of the grip (e.g., hand opening, hand closure).[5]

Crucially, many of these neurons discharge during both execution and observation of actions; they are called mirror neurons because the observed action seems to be reflected in the motor representation of the same action (Gallese *et al.*, 1996; Rizzolatti *et al.*, 1996a). Mirror neurons discharge even when the goal of the observed action is not visible but has recently been visible (Umiltà *et al.*, 2001). Moreover, some mirror neurons in the macaque discharge in response to presentation of either the sight or the sound of an action (Kohler *et al.*, 2002). In addition, there is evidence for mirror neurons representing oral actions (Ferrari *et al.*, 2003), but as yet no evidence for mirror neurons representing foot actions. Finally, a recent study found that neurons in the primary motor cortex of the macaque brain also have mirror properties (Raos *et al.*, 2004).

[4] Here and in what follows, only semantic structures are addressed, not phonological structures.

[5] Rizzolatti *et al.*'s vocabulary metaphor is quite provocative, but it should not be taken too literally. The cross-linguistic variation in verbs for hand actions described earlier (p. 349) suggests that the motor aspects of those verb meanings may be neurally implemented in language-specific CZs at a somewhat higher level of the motor hierarchy. See Gallese and Lakoff (2005) for an in-depth neurocognitive analysis of the concept of "grasping," with valuable discussion of pertinent linguistic issues, and see Mahon and Caramazza (2005) for a critique.

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Turning to humans, a rapidly growing literature suggests that non-verbal action concepts depend on certain motor-related sectors of the frontal lobes. First, from the perspective of neurophysiology, experiments utilizing transcranial magnetic stimulation (TMS) have shown that motor evoked potentials recorded from a person's muscles are facilitated when the person observes either intransitive (non-object-directed) or transitive (object-directed) hand actions (Fadiga *et al*., 1995). Second, from the perspective of functional neuroimaging, many important discoveries have recently been made, including the following:

- Broca's area, the human homologue of monkey F5 (Arbib and Bota, this volume), is activated during execution, observation, and imitation of hand actions, especially those involving complex finger movements (e.g., Rizzolatti *et al*., 1996b; Decety *et al*., 1997; Iacoboni *et al*., 1999).
- The human mirror system is somatotopically organized – specifically, observation of both intransitive and transitive face, arm/hand, and leg/foot actions engages premotor areas in a somatotopic manner (e.g., Buccino *et al*., 2001; Wheaton *et al*., 2004), which is consistent with the SIT principle.
- The human mirror system has motor components only for types of actions that people are capable of performing (Buccino *et al*., 2004).
- For action concepts that are within its repertoire, the human mirror system responds robustly even to degraded stimuli – e.g., point-light displays of people moving in particular ways (Saygin *et al*., 2004a).

Third, from the perspective of neuropsychology, several lesion studies with large cohorts of brain-injured patients have found that damage in the left premotor/prefrontal region impairs conceptual knowledge of actions (Tranel *et al*., 2003b; Saygin *et al*., 2004b).

As with action concepts in general, there is increasing evidence that the meanings of action verbs – more precisely, the semantic features that specify the motoric aspects of the designated actions – are subserved by motor-related structures in the frontal lobes, especially in the left hemisphere (although the right hemisphere may also contribute; see Neininger and Pulvermüller, 2003). Studies employing high-density electroencephalography (e.g., Hauk and Pulvermüller, 2004), functional magnetic resonance imaging (fMRI) (Hauk *et al*., 2004; Tettamanti *et al*., 2005), magnetoencephalography (Pulvermüller *et al*., 2005a), and TMS (Buccino *et al*., 2005; Pulvermüller *et al*., 2005b) indicate 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 inferior, dorsolateral, and dorsal–midline sectors of somatotopically mapped motor and premotor regions. These findings support the provocative notion that the motoric aspects of the meanings of action verbs are not part of an abstract symbolic representation in the brain (like the neural analogue of a dictionary entry), but are instead linked with the same frontal cortical structures that subserve action execution and observation. Further evidence for this view comes from studies indicating that damage in the left premotor/prefrontal disrupts knowledge of the meanings of action verbs (e.g., Bak *et al*., 2001; Bak and Hodges, 2003; Kemmerer and Tranel, 2003). However, as yet no neuropsychological studies have directly tested the hypothesis that the meanings of verbs for face, arm/hand, and leg/foot actions should be differentially impaired by lesions affecting the pertinent somatotopically mapped motor regions (but see Kemmerer and Tranel (2000) for a preliminary investigation).

Parietal regions

In the macaque brain, mirror neurons in area F5 receive input from an inferior parietal area called PF (Rizzolatti and Luppino, 2001). This area contains neurons that are also mirror-like, firing during production as well as perception of particular types of transitive (object-directed) hand actions (Gallese *et al*., 2002). These neurons appear to be especially sensitive to the intended goal of a complex action (Fogassi *et al*., 2004).

The most impressive evidence that the human mirror system encompasses parietal structures comes from the frequently cited fMRI study by Buccino *et al*. (2001), which demonstrated that observation of transitive (object-directed) face, arm/hand, and leg/foot actions engages not only the frontal lobes but also the parietal lobes in a somatotopic manner. Additional evidence comes from the lesion study by Tranel *et al*. (2003b), which found that damage in the left inferior parietal cortex, especially the supramarginal gyrus (SMG), impairs knowledge of action concepts. Also relevant are lesion studies that have linked ideational apraxia – a disorder affecting the ideas or concepts underlying skilled movements – with damage in the left parieto-occipital junction (see Johnson-Frey (2004) for a review). Finally, mechanistic knowledge about the proper manipulation of tools has been associated with the left SMG (e.g., Boronat *et al*., 2005).

Turning to action verbs, a recent fMRI study by Tettamanti *et al*. (2005) found that when subjects listened to transitive sentences describing object-directed face, arm/hand, and leg/foot actions, the left inferior parietal cortex was activated in a somatotopic manner, consistent with Buccino *et al*.'s (2001) findings. In addition, an earlier study employing positron emission tomography (PET) (Damasio *et al*., 2001) found that activation in the left SMG was significantly greater for naming actions performed with tools (e.g., *write*) than without tools (e.g., *wave*), which fits the data mentioned above relating this region to conceptual knowledge for tool manipulation. Presumably all of the verbs in Damasio *et al*.'s (2001) tool condition were transitive, in line with the studies by Tettamanti *et al*. (2005) and Buccino *et al*. (2001); however, the authors did not indicate what proportion of the verbs in their non-tool condition were intransitive. Nevertheless, the data from all three functional neuroimaging studies lead to the intriguing prediction that lesions in the left inferior parietal cortex should impair semantic knowledge of transitive verbs (especially those encoding instrumental actions) to a significantly greater extent than semantic knowledge of intransitive verbs. While dissociations between these two large categories of verbs have been reported (e.g., Thompson *et al*., 1997; Jonkers, 2000; Kemmerer and Tranel, 2000), the lesion correlates have not yet been carefully investigated. Finally, it is noteworthy that a recent fMRI study by Wu *et al*. (2004) found activation in the left inferior parietal cortex during attentive processing of the path component, as opposed to the manner component, of motion events. Although English

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preferentially encodes path information in prepositions like *into, out of, upward*, and *downward*, there are a few pure path verbs like *enter, exit, ascend*, and *descend* (all derived historically from Latin), and there are also some manner verbs that include spatial goal-oriented details – e.g., one subclass of "putting" verbs focuses on actions in which a substance is caused to move forcefully against the surface of an object in such a way that it ultimately has an idiosyncratic shape "on" the object (*smear, dab, streak, smudge*, etc.), whereas another subclass of "putting" verbs focuses on actions in which a flexible object extended in one dimension is caused to move along a circular path so that its final spatial configuration is "around" another object (*coil, wind, twirl*, *spin*, etc.) (Levin, 1993; Pinker, 1989). Thus, it is possible that the parietal activation reported by Wu *et al.* (2004) reflects these kinds of semantic features (see also Kemmerer and Tranel, 2003; Tranel and Kemmerer, 2004).

Temporal regions

In the dorsal stream of the macaque brain, the superior temporal sulcus (STS) receives input from area MST and projects to F5 via PF (Rizzolatti and Matelli, 2003). Within the STS, functionally specialized neurons respond to different types of face, limb, and whole-body motion not only when the stimuli are presented in full view but also when they are presented in point-light displays (see Puce and Perrett (2003) for a review). For example, one single-cell recording study identified a neuron that discharges vigorously during observation of a person dropping an object but not during observation of the same bodily movement without the object or during observation of the object motion alone (Keysers and Perrett, 2004; Barraclough *et al*., 2005). Like F5 neurons, STS neurons continue to fire even when an agent has moved behind an occluder (Baker *et al*., 2001) and also when the typical sounds associated with certain actions are detected (Barraclough *et al*., 2005).

In humans, activation occurs in area MT and in areas along the superior temporal gyrus and STS during observation of biological motion patterns (again, see Puce and Perrett (2003) for a review). Activation in these regions can be elicited by point-light displays of real motion (Beauchamp *et al*., 2003), by static images of implied motion (Kourtzi and Kanwisher, 2000; Senior *et al*., 2000), and by motion-related sounds (Lewis *et al*., 2004). Evidence that the left MT region contributes to conceptual knowledge of actions comes from Tranel *et al*.'s (2003a) lesion study, which found that damage to the white matter beneath this region severely disrupts that knowledge.

Regarding action verbs, numerous functional neuroimaging studies suggest that the visual motion patterns encoded by different verbs are represented in the left posterior middle temporal cortex anterior to area MT. This region is engaged by various tasks requiring the semantic processing of action verbs (see Martin *et al.* (2000) for a review; see also Damasio *et al*., 2001; Kable *et al*., 2002). In addition, area MT is activated significantly more when subjects use noun–verb homophones (e.g., *comb*) as verbs to name static pictures of implied actions than when subjects use them as nouns to name objects in the same pictures (Tranel *et al*., 2005). Furthermore, the fMRI study by Wu *et al.* (2004) revealed activation in this cortical region during attentive processing of the manner component, as opposed to the path component, of motion events. From the perspective of neuropsychology, I am not aware of any studies that have directly tested the well-motivated hypothesis that knowledge of the visual motion patterns encoded by action verbs should be selectively impaired by damage anterior to area MT; however, Tranel *et al.*'s (2003b) lesion study strongly supports this possibility, since it showed that damage underneath MT disrupts non-verbal action concepts.

In this context, it is worth mentioning again that languages vary greatly in how they subdivide the conceptual space of manner-of-motion (see p. 349). In particular, it is intriguing to consider that CZ theory and the SIT principle together lead to the following hypothesis. Perhaps the cross-linguistic diversity in semantic distinctions is reflected, at least in part, in corresponding neuroanatomical diversity in the spatial arrangement of conjunctive neurons (or, more precisely, columns of such neurons) in some CZ within the mosaic of cortical areas extending from MT along the STG and STS – a CZ functionally dedicated to representing the visual motion patterns associated with language-specific verb meanings. According to this hypothesis, the topographical layout of the relevant conjunctive neurons is systematically different for English speakers compared to, say, Spanish speakers. For English speakers there are separate but tightly clustered conjunctive neurons for the closely related visual motion patterns encoded by *creep, glide, slide, slip*, and *slither;* however, for Spanish speakers such conjunctive neurons do not exist because (1) the Spanish manner-verb lexicon does not make any of those subtle semantic distinctions (the whole spectrum is covered by just one verb, *escabullirse*), and (2) there is no independent reason to expect those particular distinctions to be "natural" in the sense of being universally employed in the non-verbal categorization of motion events (see Slobin (2000, 2003) for relevant data and discussion from the perspective of language acquisition). As the spatial resolution of functional neuroimaging techniques continues to improve, it may eventually become feasible to test hypotheses of this nature, thereby shedding further light on the biological bases of the meanings of action verbs. For present purposes, the essential point is this: it may not be a coincidence that prominent theorists in both linguistic typology (e.g., Croft, 2001; Haspelmath, 2003) and cognitive neuroscience (e.g., Simmons and Barsalou, 2003) increasingly use the mapping metaphor in their characterizations of the organization of conceptual knowledge. Perhaps the metaphor is more appropriate than we have hitherto realized (see Kohonen and Hari (1999) for a review of pertinent neurocomputational modeling).

10.3.3 Argument structure constructions

Semantics

The nature of the meanings of argument structure constructions has attracted a great deal of attention in linguistics, but it has not inspired much work in cognitive neuroscience; hence the neuroanatomical substrates of these meanings remain, for the most part, *terra incognita*. Nevertheless, a few neuropsychological studies have yielded results that are consistent with predictions derived from the GRSSH, CZ theory, and the SIT principle.

According to the GRSSH as initially formulated by Pinker (1989) and further elaborated by other researchers (e.g., Mohanan and Wee, 1999), a fundamental division exists between constructional meanings and verb meanings. If this is true, then these two large-scale components of meaning are probably subserved by at least partially separate brain structures, perhaps involving different cortical areas implementing networks of CZs at different levels of abstraction. This in turn predicts that the two components of meaning could be impaired independently of each other by brain damage. I have been conducting a series of studies with aphasic patients to test this prediction, and have obtained results that support it.

The first study focused on the locative alternation (see p. 353) and documented the following double dissociation (Kemmerer, 2000a). Two patients performed well on a verb–picture matching test requiring discrimination between verbs that vary only with respect to subtle visual, affective, and motoric features that are grammatically irrelevant, e.g., *drip–pour–spray, coil–spin–roll*, and *decorate–adorn–embellish*. However, both patients failed a grammaticality judgement test requiring determination of the compatibility between, on the one hand, the meanings of the very same verbs that were used in the matching test and, on the other, the meanings of the constructions comprising the locative alternation – e.g., *drip* but not *drench* can occur in the construction with the (sub)meaning "X enables a mass Y to go to Z via the force of gravity" (cf. *Sam is dripping*/**drenching water on the flowers*), whereas *drench* but not *drip* can occur in the construction with the (sub)meaning "X causes a solid or layer-like medium Z to have a mass Y distributed throughout it" (cf. *Sam is drenching*/**dripping the flowers with water*). Strikingly, the patients treated as ungrammatical many sentences that are quite natural (e.g., *Sam is coiling the ribbon around the pole* and *Sam is decorating the pie with cream*), and treated as grammatical many sentences that are very odd (e.g., **Sam is coiling the pole with the ribbon* and **Sam is decorating cream onto the pie*). Their errors could not be attributed to an impairment of either syntactic processing or metalinguistic judgement ability because both patients passed another test that assessed the integrity of these capacities. The data therefore suggest that although the patients retained an impressive amount of knowledge regarding the semantic nuances of locative verbs, they suffered selective impairments of their appreciation of the more schematic meanings of locative constructions. Importantly, a third patient exhibited the opposite performance profile. She failed a significant number of items in the verb–picture matching test, but had no difficulty with the grammaticality judgement test. For example, even though she could not distinguish *coil* from *spin* and *roll*, she could correctly determine that **Sam is coiling the pole with the ribbon* is awkward and that *Sam is coiling the ribbon around the pole* is fine. In sum, the double dissociation identified by this study provides preliminary evidence that the neural substrates of constructional meanings are separate from those for verb meanings.

Two subsequent studies (Kemmerer and Wright, 2002; Kemmerer, 2003) focused on the body-part possessor alternation and the reversible *un-* prefixation construction (see pp. 353–5), using methods analogous to those employed in the study of the locative alternation. Both studies documented one-way dissociations involving preserved knowledge of verb meanings but impaired knowledge of constructional meanings. First, the study of the body-part possessor alternation found that three aphasic patients could discriminate between verbs that differ in idiosyncratic ways that are irrelevant to the ascension construction (e.g., *scratch–smack–spank* and *break–rip–fracture*), but could no longer make accurate judgements about which of these verbs could occur in the construction (e.g., *She scratched him on the arm* vs. **She broke him on the arm*). The patients' poor performances on the latter test were not due to purely syntactic disorders since they had no difficulty with a different test that evaluated their knowledge of the clausal organization of the ascension construction. Instead, the patients appeared to have deficits involving their knowledge and/or processing of the meaning of the ascension construction. Similarly, in the study of the reversative *un-* prefixation construction, two aphasic patients demonstrated intact knowledge of idiosyncratic aspects of verb meaning that are "invisible" to the construction (e.g., *wrap–buckle–zip* and *squeeze–press–push*), but were impaired at judging whether the very same verbs satisfy the semantic criteria of the construction (e.g., *unwrap* vs. **unsqueeze*). A separate test showed that the patients' errors were not due to an impaired understanding of the basic reversative meaning of *un-* or to problems with various task demands involving morphological analysis, but were instead most likely due to a selective disturbance of the knowledge and/or processing of the meaning of the construction.[6]

Although the three studies just described constitute only the initial cognitive–neuroscientific forays into the complex semantic territory of constructional meanings, the findings support the view that the neural correlates of these meanings are separate from those for verb meanings. This leads to the next question, which concerns the neuroanatomical localization of constructional meanings.

The meanings of argument structure constructions consist of abstract event schemas that often constitute semantic generalizations across various verb classes; hence they occupy a very high level of the action concept hierarchy. Given this background, CZ theory and the SIT principle together predict that the brain regions that operate as CZs for constructional meanings should be anatomically adjacent to those that operate as CZs for verb meanings – that is, they should be near or perhaps still within the fronto-parieto-temporal circuitry underlying the human mirror system. It is difficult to predict exactly what regions these might be, but it is reasonable to suppose that they may include part of the left perisylvian cortex, because then the CZs for constructional meanings would also be close to the networks subserving morphosyntactic structures and processes (these networks are discussed briefly below). The three neuropsychological studies summarized above provide preliminary data that are consistent with this prediction, since the aphasic patients with selective impairments of constructional meanings had the greatest lesion

[6] The three studies just described, as well as the study involving prenominal adjective order reported by Kemmerer (2000b), employed some of the same brain-damaged subjects. It is noteworthy, however, that these subjects exhibited different performance profiles across the studies. For instance, subject 1962RR was impaired across the entire range of constructions, but subject 1978JB was impaired on just the three verb-based constructions, performing normally on the adjective-based construction. The dissociation exhibited by 1978JB raises the possibility that constructional meanings are organized in principled ways in the brain.

overlap in the left inferior premotor/prefrontal region and the left anterior SMG. These neuroanatomical results should be interpreted with caution, however, because they represent data from only a few patients. Hopefully, though, other researchers will soon be inspired to investigate this topic in greater depth by employing not only the lesion method but also hemodynamic methods which have much more precise spatial resolution.

Morphosyntax

The literature on the neural correlates of the morphosyntactic aspects of argument structure constructions is rapidly growing, but is still influenced much more by the Chomskian generative grammar framework than by the new constructionist approach. Here I will only mention a few salient findings. Grammatical categories like noun and verb – which, as noted earlier (see p. 352), fractionate into clusters of subcategories – may be supported by the cortex in and around Broca's area (see Caramazza and Shapiro (2004) for a review). In addition, Broca's area may contribute to the assembly of argument structure constructions during sentence production (Indefrey *et al*., 2001, 2004). With respect to the parsing of argument structure constructions during sentence comprehension, many regions distributed throughout the left perisylvian cortex have been implicated (see Friederici (2004) for a review), but the anterior sector of the superior temporal gyrus appears to play a special role in processing morphosyntactic information (Dronkers *et al*., 2004).

10.4 Discussion

In this concluding section I would like to broaden the discussion of action verbs and argument structure constructions by making a few remarks about the emergence of language during ontegeny and phylogeny. I will highlight the views of Michael Tomasello, since he is one of the leading advocates of the constructionist approach in these areas of inquiry.

10.4.1 Ontogeny

The best-known answer to the question of how children acquire language is that – as first proposed by Chomsky (1959) and later popularized by Pinker (1994), Jackendoff (1994), and others – they are guided in this seemingly monumental task by an evolutionarily specialized, genetically programmed, neurocognitive adaptation called Universal Grammar which includes a kind of blueprint of the basic design characteristics of all natural human languages. This orthodox view has been challenged, however, by a growing body of research motivated by the constructionist framework (see Tomasello (2003a) for the most well-articulated alternative theory). The most important empirical discovery is that virtually all of children's early linguistic competence is item-based in the sense of being organized around particular words and phrases, not around any system-wide innate

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categories. This was demonstrated by Tomasello (1992; see also Hill, 1983) in a detailed diary study of his own daughter's early language development. During exactly the same time period, this child used some verbs in only one type of very simple pivot construction or schema (e.g., *Cut* ___), but used other verbs in more complex frames of different types (e.g., *Draw* ___, *Draw*___ *on* ___, *I draw with* ___, *Draw* ___ *for* ___, ___*draw on* ___). For each individual verb, however, there was great continuity, such that new uses almost always replicated previous uses with only one small change (e.g., the addition of a new participant role). In fact, as Tomasello (2000, p.157) emphasizes, "by far the best predictor of this child's use of a given verb on a given day was *not* her use of other verbs on that same day, but rather her use of that same verb on immediately preceding days; there appeared to be no transfer of structure across verbs." These findings led to the Verb Island Hypothesis, which maintains that children's early linguistic competence consists almost entirely of an inventory of linguistic constructions like those just described – specific verbs with slots for narrowly defined participants such as "drawer" and "thing drawn," as opposed to subject and object (see Arbib and Hill (1988) and Culicover (1999) for similar proposals from rather different perspectives).

Of course, children eventually go beyond these early item-based constructions, and they appear to do so by first recognizing similarities across constructional schemas and then creatively combining these schemas to form novel utterances. For example, among the first three-word utterances creatively produced by Tomasello's daughter was *See Daddy's car*. She had previously said things like *See ball* and *See Mommy*, on the one hand, and things like *Daddy's shirt* and *Daddy's pen*, on the other. So the novel utterance may reflect the combination of a "*See* ___" schema with a "*Daddy's* ___" schema. Note that to accomplish this she had to understand that the complex expression *Daddy's car* was functionally equivalent to the simpler expressions that she had previously included in the slot for the "*See* ___" schema. More generally, the key idea is that through cognitive processes of this nature (which are not restricted to the linguistic domain), children gradually acquire increasingly abstract and adult-like argument structure constructions such as the following (Tomasello, 1999, p.141):

- Imperatives (*Roll it! Smile! Push me!*)
- Simple transitives (*Ernie kissed her; He kicked the ball*)
- Simple intransitives (*She's smiling; It's rolling*)
- Locatives (*I put it on the table; She took her book to school*)
- Resultatives (*He wiped the table clean; She knocked him silly*)
- Ditransitives (*Ernie gave it to her; She threw him a kiss*)
- Passives (*I got hurt; He got kicked by the elephant*)
- Attributives and identificationals (*It's pretty; She's my mommy*)

This overall approach to accounting for early language development has recently been supported by research using both naturalistic and experimental methods to study many different children acquiring many different languages (see Tomasello (2003a) for a review), and has also been successfully extended to the investigation of later language

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development (Diessel, 2004). A corresponding neurobiological theory of language development, with explicit links to the mirror neuron system, can be found in the work of Elizabeth Bates and her colleagues (Dick *et al*., 2004).

10.4.2 Phylogeny

Tomasello (2003a, p.1) begins his book by pointing out that from an ethological perspective one of the most bizarre traits of *Homo sapiens* is that "whereas the individuals of all nonhuman species can communicate effectively with all of their conspecifics, human beings can communicate effectively only with other persons who have grown up in the same linguistic community – typically, in the same geographical region." Then, in direct opposition to the Chomskyan Universal Grammar framework which has dominated linguistics for over 40 years, but in complete agreement with the strongest version of the increasingly influential constructionist approach, he states that "one immediate outcome is that, unlike most other animal species, human beings cannot be born with any specific set of communicative behaviors." The central claim of the position that he subsequently defends is that the evolution of the capacity to communicate symbolically was sufficient for all natural human languages to arise; no independent adaptations for morphosyntax were necessary, the reason being that, as described above, most morphosyntactic constructions are actually symbolic devices that just happen to be more complex and schematic than words, and that develop very gradually on a historical timescale (see also Tomasello, 2003b; cf. Arbib, 2005, and Deacon, 1997, for similar proposals). Symbolic communication may have co-evolved with a number of other uniquely human neurocognitive adaptations, perhaps the most important of which was the ability to interpret and share intentions, since this is what enables human communities to establish social conventions for the referential use of arbitrary signs (Tomasello, 1999, 2005; see Frith and Wolpert, 2003, for pertinent neurobiological research; see also Stanford, this volume). Other relevant adaptations may include intuitive theories about various domains of the world, such as objects, forces, paths, places, manners, states, and substances – domains that are routinely encoded by words as well as constructions in languages worldwide. Pinker (2003) has suggested that all of these distinctively human skills – language, hypersociality, and sophisticated causal reasoning abilities – are adaptations to "the cognitive niche," i.e., a complex set of physical and social conditions that created selection pressures for acquiring and sharing information. I agree with this general hypothesis about the ancestral environment in which human symbolic capacity evolved; however, like Tomasello I doubt if there is currently enough evidence to support Pinker's more specific view – one that is also endorsed by Jackendoff (cf. Pinker and Jackendoff, 2005) – that full-blown human language depends on additional adaptations for morphosyntax. The resolution of this debate will hinge on future research in all of the disciplines that contribute to studying the evolution of language.

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