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Selective impairment of knowledge underlying *un-* prefixation: further evidence for the autonomy of grammatical semantics

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Abstract

This paper focuses on grammatical semantics, which is a level of linguistic representation that lies at the interface between syntactic categories and conceptual categories. We report a series of neuropsychological experiments that investigated the semantic constraints on the English verbal *un-* prefixation construction. In order for a verb to occur in this construction, it must designate an event which involves the creation of a constricted, reversible spatial configuration—e.g. *wrap–unwrap*, *buckle–unbuckle*, and *clog–unclog*, but not *float–*unfloat*, *boil–*unboil*, or *fluff–*unfluff*. Other features of verb meaning are completely invisible to the construction—e.g. the idiosyncratic features that distinguish between *wrap*, *buckle*, and *clog*. Of six brain-damaged patients who were studied, two exhibited the following dissociation. On the one hand, they performed well on a verb–picture matching test that required them to discriminate between subtle features of verb meaning that are not relevant to *un-* prefixation. On the other hand, they failed a grammaticality judgment test that required them to determine whether the very same verbs satisfy the narrow semantic criteria for the construction. A final control test demonstrated that their errors on the judgment test were not due to problems with certain task demands, but were instead most likely due to an impairment that selectively affected their knowledge or processing of grammatical semantics.

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1. Introduction

> Another English cryptotype is that of the transitive verbs of a covering, enclosing, or surface-attaching meaning, the reactance of which is that *un-* may be prefixed to denote the opposite. Hence we say *uncover*, *uncoil*, *undress*, *unfasten*, *unfold*, *unlock*, *unroll*, *untangle*, *untie*, *unwind*, but not *unbreak*, *undry*, *unhang*, *unheat*, *unlift*, *unmelt*, *unopen*, *unpress*, *unspill*. With the exception of a few words mostly semiarchaic, e.g. *unsay*, *unthink*, *unmake*, the use of *un-* as a reversative prefix in true verbs coincides with the centripetal enclosing and attaching meaning. We have no single word in the language which can give us a proper clue to this meaning or into which we can compress this meaning; hence the meaning is subtle, intangible, as is typical of cryptotypic meanings. Benjamin Lee Whorf (1936/1956)

A striking feature of human languages is that words belonging to the same grammatical category often display morphosyntactic differences that do not appear to correspond in any straightforward way to semantic differences. In English, for instance, there is considerable variation across verbs with respect to the argument structure frames they allow, yet it is not immediately obvious how this variation might be related to the meanings of the verbs. To take a simple example, the sentences below indicate that the verbs *sprinkle*, *pour,* and *fill* have different argument structure possibilities; however, these verbs appear to be semantically similar since they all specify that an agent causes something to move from one location to another.

Sam sprinkled salt on the popcorn.	Sam sprinkled the popcorn with salt.
Sam poured water on the plant.	*Sam poured the plant with water.
*Sam filled beer into the glass.	Sam filled the glass with beer.

Puzzles of this kind lie at the heart of an assumption that has been prevalent throughout the history of generative linguistics and is still quite widespread, namely the assumption that grammar and meaning are largely independent of one another. During the past few decades, however, this assumption has been challenged by a growing body of research which suggests that grammar and meaning may be much more closely related than previously thought. This research has been conducted by linguists working in several theoretical frameworks, including Construction Grammar (Bencini & Goldberg, 2000; Croft, 2001; Davis & Koenig, 2000; Fillmore & Kay, in press; Fillmore, Kay, & O'Connor, 1988; Goldberg, 1995, 1996; Kay, 1997; Kay & Fillmore, 1999; Michaelis & Lambrecht, 1996), Cognitive Grammar (Langacker, 1987, 1991; Vespoor, Lee, & Sweetser, 1997), and Role and Reference Grammar (Van Valin & LaPolla, 1997), as well as by linguists who are not affiliated with these particular theories (Fisher, Gleitman, & Gleitman, 1991; Grimshaw, 1993; Hale & Keyser, 1993; Jackendoff, 1997; Levin, 1993; Levin & Rappaport Hovav, 1995; Mohanan & Wee, 1999; Pinker, 1989, 1994; Rappaport Hovav & Levin, 1998; Wierzbicka, 1988; Zwicky, 1994). What all of these investigations have in common is some version of the idea that argument structure frames

Table 1
Constructions analyzed by Goldberg (1995)

Name of construction	Meaning of construction	Form of construction
Ditransitive	X causes Y to receive Z	Subject Verb $Object_1$ $Object_2$ *Pat faxed Bill the letter*
Caused Motion	X causes Y to move Z	Subject Verb Object Oblique *Lou sneezed the napkin off the table*
Resultative	X causes Y to become Z	Subject Verb Object Complement *She wiped the table clean*
Intransitive Motion	X moves Y	Subject Verb Oblique *The fly buzzed into the room*
Conative	X directs action at Y	Subject Verb $Oblique_{at}$ *Ethel shot at Fred*

or other kinds of morphosyntactic constructions are directly associated with very schematic meanings that reflect basic aspects of human experience.

For example, according to a constructional approach, in order for a word to occur in a particular construction, its meaning must be compatible with that of the construction. Under this type of approach, the explanation for the different patterns of grammaticality in the sentences presented above is roughly as follows. The construction in the first column has the syntactic structure 'NP V NP *in/on* NP' and the schematic meaning 'X causes Y to go to Z in some manner,' whereas the construction in the second column has the syntactic structure 'NP V NP *with* NP' and the schematic meaning 'X causes Z to change state in some way by adding Y' (Pinker, 1989). *Sprinkle* can occur in both constructions because it encodes not only a particular manner of motion (an aggregate of tiny objects moves downward in a loose pattern), but also a particular change of state (something gets covered with tiny objects in a fairly even spatial distribution). On the other hand, *pour* can only take the first construction because although it encodes a particular manner of motion (a liquid moves downward in a cohesive stream), it does not necessarily imply a change of state (e.g. if I pour some water into a glass that has a gaping hole in the bottom, the water will go right through without affecting it in any significant way). Conversely, *fill* can only take the second construction because it encodes a change of state (a container becomes full), but is mute about the specific manner in which this happens (there are clearly myriad ways of filling containers).

Although this new style of semantically oriented grammatical analysis has only just begun, a variety of constructions in English and in other languages have already been studied from this perspective. The most extensive work has been done by Levin (1993), who classified over 3000 English verbs into 50 separate semantic classes and approximately 200 semantic subclasses according to commonalties in syntactic behavior and semantic meaning. Other investigations have tended to focus on in-depth analyses of just one or perhaps a handful of specific constructions. For instance, Kay and Fillmore (1999) concentrated on the so-called *What's X doing Y?* construction (e.g. *What's this junk mail doing in my box?*), and Goldberg (1995) discussed semantic accounts of the five constructions shown in Table 1.

One of the more interesting consequences of this general approach is that it leads to a

distinction between two components of verb meaning, as discussed in recent work in lexical semantics (Grimshaw, 1993; Hale & Keyser, 1993; Rappaport Hovav & Levin, 1998). For example, Rappaport Hovav and Levin (1998) distinguish between 'structural' and 'idiosyncratic' verb meaning. They define structural meaning as meaning which is relevant to determining the semantic classes of verbs that are grammatically relevant, and idiosyncratic meaning as meaning which distinguishes individual verbs from other members of the class. In other words, some semantic features of verbs are relevant to their morphosyntactic possibilities, since these features are what determine whether the meaning of a particular verb is compatible with the meaning of a particular class or construction. Other semantic features, however, are irrelevant to grammar and instead represent idiosyncratic information about such things as the agent's intention, the shape and composition of the entities acted upon, their rate and path of motion, the internal changes of state they undergo, and so forth. For example, the verbs *pour*, *drip*, *dribble*, and *spill* all specify that 'X causes Y to go to Z in some manner,' and for this reason they can all occur in the first locative construction shown above (cf. *Sam poured/dripped/dribbled/spilled water on the plant*). The multifarious semantic details that distinguish the meanings of these verbs are not, however, relevant to their ability to occur in this construction. Similarly, the verbs *drench*, *soak*, *saturate*, and *infuse* all specify that 'X causes Z to change state in some way by adding Y,' and this is what licenses the occurrence of these verbs in the second locative construction shown above (cf. *Sam drenched/soaked/saturated/infused the plant with water*). Again, the semantic features that make each of these verbs unique do not influence their argument structure possibilities. It is as if the grammar has a special filter that only allows certain critical features of lexical meaning to pass through; these features are 'visible' whereas the remaining features are 'invisible' (Mohanan & Wee, 1999).

Although research along these lines has been developing rapidly in linguistic theory, it has not inspired much work in the field of cognitive neuroscience; hence the neural basis of grammatical semantics remains, for the most part, *terra incognita*. Nevertheless, a few neuropsychological studies have been done that are consistent with the distinction between grammatically relevant and grammatically irrelevant aspects of meaning. Marshall et al. (1996) described a brain-damaged patient who could not distinguish between verbs that are closely related with respect to grammatically irrelevant features of meaning (e.g. *follow* versus *chase*), but could still indicate how participant roles like actor and undergoer are mapped onto syntactic positions like subject and object, even for reverse-role verbs which designate the same event but assign different roles to the participants (e.g. *chase* versus *flee*). Breedin and Saffran (1999) describe a patient with a similar pattern of performance.

Two other studies have documented the opposite kind of dissociation in brain-damaged patients—intact knowledge of grammatically irrelevant meaning, but impaired knowledge of grammatically relevant meaning. Kemmerer (2000b) reported six patients who passed a word–picture matching test that evaluated their understanding of the basic property concepts encoded by adjectives (e.g. *big*, *brown*, etc.), but failed a grammaticality judgment test that evaluated their appreciation of the semantic constraints that govern how the same adjectives are ordered before a noun (e.g. *big brown dog* versus **brown big dog*). Their poor performance on the second test could not be attributed to a purely syntactic

disorder since all of them passed a third test that focused on noun–phrase structure. In another study with a similar design, Kemmerer (in press) described three patients who could discriminate between verbs whose meanings differ in grammatically irrelevant ways (e.g. *scratch–smack–spank*), but could no longer make accurate judgments about the semantically constrained argument structure possibilities of the same verbs (e.g. *She scratched him on the hand* versus **She broke him on the hand*). Again, the patients' poor performance on the second test was not due to a purely syntactic disorder since they had no difficulty with a third test that focused on the syntactic organization of the pertinent constructions.

Finally, one study has documented a double dissociation between grammatically relevant and grammatically irrelevant aspects of meaning, focusing on the two locative constructions described above. Using the same general methodology as in the previous two studies, Kemmerer (2000a) showed that one patient was impaired at discriminating between grammatically irrelevant features of verb meaning (e.g. *pour–drip–spill*), but normal at judging which argument structure frames the verbs allow (e.g. *Sam poured water on the plant* versus **Sam poured the plant with water*), whereas two other patients displayed exactly the opposite performance profile. Moreover, as before, the deficit for the latter two patients did not affect purely syntactic knowledge since they performed well on an independent test that involved simple clausal syntax.

Taken together, these studies lend support to the view that grammatically relevant and irrelevant components of meaning are mediated by partially distinct neural mechanisms that can be independently disrupted by brain damage. It is important to note, however, that the studies have several limitations. For instance, the patients who performed poorly on tests that address grammatical semantics could have disturbances that affect either or both of two different levels of representation: (1) the features of word meaning that are relevant to the constructions; and (2) the constructional meanings themselves. Alternatively, the patients could have disturbances that spare these representations and instead affect the processing pathways that feed into or out of them. Despite this indeterminacy regarding the exact functional locus of impairment, the data still suggest that *some* aspect of grammatical semantics is selectively impaired in these patients. Another limitation of the previous studies is that the anatomical data are not entirely consistent. Although virtually all of the patients with disorders involving grammatical semantics have lesions within the left perisylvian cortex, the specific sites are distributed across the frontal, temporal, and parietal sectors of this large region; nevertheless, the majority of cases have damage that includes the inferior premotor/prefrontal region extending back to the anterior supramarginal gyrus.

The purpose of this paper is to report a new study that provides additional neuropsychological evidence for the autonomy of grammatical semantics. This study focuses on the process governing verbal *un-* prefixation. In the epigraph above, Whorf points out that some verbs can take the reversative *un-* prefix (e.g. *unlock*, *unfold*, *untie*, *unwind*), whereas others cannot (e.g. **unpress*, **undry*, **unhang*, **unspill*). As with the various constructions described above, whether or not a verb allows *un-* depends on whether it satisfies certain narrow semantic criteria. In the next section we elaborate on a novel theory of these criteria, and in the subsequent sections we report a series of experiments that we conducted with a group of six brain-damaged patients. These experiments

investigated the integrity of the patients' knowledge of aspects of verb meaning that differ with respect to whether they are relevant to *un-* prefixation. One patient was normal on all of the tests that we administered. Three other patients exhibited a general conceptual disorder, failing a test of semantic features that are irrelevant to *un-* prefixation as well as a test of features that are relevant. Finally, the last two patients exhibited the following dissociation: good performance on the test of grammatically irrelevant semantic features, but poor performance on the test of grammatically relevant ones. Moreover, their poor performance on the latter test could not be due to difficulties with certain task demands, since they passed a third test that assessed these factors. We interpret the results as suggesting that these two patients have a disorder that selectively affects their knowledge or processing of the narrow semantic constraints that determine which verbs can occur in the *un-* prefixation construction.

2. Semantic constraints on verbal *un-* prefixation

During language development, children go through a period when they sometimes produce overgeneralization errors that involve applying a construction to a verb that appears to fall outside the semantic scope of the construction (Pinker, 1989). This happens for verbal *un-* prefixation, as shown by several amusing examples from Bowerman (1982):[2]

Mother grabbing child in game: *I have to capture you.*
Child: *Uncapture me*!
Child coming to mother with clip earring dangling from ear; wants it off:
How do you unsqueeze it?
Child taking stocking down from fireplace: *I'm gonna unhang it.*
Child telling ghost story: *He tippitoed to the graveyard and unburied her*

One reason why these uses of *un-* are amusing is that we instantly recognize them as errors; however, recognizing that they are errors is not the same thing as understanding why they are errors, and most of us would be hard pressed to account for the ungrammaticality of such expressions in a convincing way. What is it that children learn about *un-* prefixation that enables them to eventually restrict their use of this construction to only a subset of verbs? Ever since Whorf's (1936/1956) seminal observations, linguists have known that semantics is a critical part of the story, yet the right analysis has been elusive.

A number of proposals have in common the idea that *un-* is confined to verbs that designate some kind of potentially reversible change of state (Andrews, 1986; Clark, Carpenter, & Deutsch, 1995; Dowty, 1979; Funk, 1988).[3] It is true that many of the

[2] See Wright (1998) for more discussion of children's uses of verbal *un-*.

[3] In this paper, we focus only on the morphological process involving verbal *un-* prefixation, leaving aside the process involving adjectival *un-* prefixation. Although a number of adjectives in English also allow *un-* prefixation (e.g. *unhappy*, *undesirable*), it is unclear whether or not verbal *un-* and adjectival *un-* really represent the same prefix. A number of researchers argue that verbal *un-* and adjectival *un-* have different historical origins and that these differences account for different semantic labels (Dowty, 1979; Marchand, 1969; Thomas, 1983).

verbs that take the prefix seem to fit this description (e.g. *fold–unfold*, *crease–uncrease*, *crumple–uncrumple*). However, this approach is problematic because it predicts both false positives and false negatives. On the one hand, verbs that are generally classified as change-of-state (Levin, 1993) do not allow *un-* prefixation, even though they encode potentially reversible events (e.g. *boil–*unboil*, *soften–*unsoften*, *corrode–*uncorrode*, *purify–*unpurify*). On the other hand, verbs that are typically not classified as involving a change-of-state nevertheless freely admit *un-* (e.g. *button–unbutton*, *dress–undress*, *screw–unscrew*, *wrap–unwrap*).[4]

A few other proposals share the notion that the verbs to which *un-* applies constitute several semantically distinct subclasses. Li (1992) posits two subclasses—'rotating' or 'turning' verbs, and 'binding' or 'locking' verbs. Taking the splitting strategy much further, Sawada (1995) posits six subclasses—'binding' verbs, 'closing' verbs, 'wrapping' verbs, 'dressing' verbs, 'packing' verbs, and 'weaving' verbs. Although these analyses have many virtues, they also have some serious weaknesses. Li's analysis is limited because certain verbs which allow *un-* prefixation do not seem to fit into either subclass (e.g. *scramble–unscramble*, *dress–undress*); thus, it fails to fully encompass the range of *un-* verbs. In addition, it leaves open the question of why *un-* does not apply to some verbs that fall within the given subclasses (cf. the two verbs that constitute the name of the first subclass—*rotate–*unrotate* and *turn–*unturn*). Sawada's analysis accounts for more examples of prefixed verbs than Li's analysis; however, no clear attempt is made to identify possible semantic links between the many different subclasses of verbs. Instead it is assumed that the subclasses are semantically distinct.

A new analysis was recently developed by Wright (1999). Most of the verbs that allow *un-* fall into two broad verb classes, described by Levin (1993) as 'combining and attaching' verbs (especially the subclass of 'tape' verbs, many of which are derived from nouns that specify the instrument used to attach one thing to another) and 'putting' verbs (especially the subclasses of 'fill' verbs, 'butter' verbs, 'pocket' verbs, 'coil' verbs, and 'spray/load' verbs). Although these verbs appear to be rather diverse in terms of semantic classification, they actually have in common some interesting syntactic and semantic features. First of all, they tend to specify three different syntactic positions for participant roles—a subject position for an agent, an object position for a theme (roughly, an entity that is moved by the agent), and an oblique position for a source or goal, as in the sentence *Bill*$_{\text{agent}}$ *loaded the boxes*$_{\text{theme}}$ *into the car*$_{\text{goal}}$.[5] Moreover, all of the verbs seem to designate events in which an agent causes something to enter a new spatial configuration (usually relative to a third entity, but sometimes relative to itself). In general, a change of spatial configuration refers to some kind of alteration of the location, structure, or shape of an

[4] These types of verbs are not generally classified as involving a change of state. Although a verb such as *button* does imply that the object in the event undergoes a change (e.g. in the sentence *Sally buttoned her shirt* the verb *button* implies that the shirt enters a particular configuration), it does not imply any change in the internal composition of the object.

[5] There are, however, surface structure variations on this basic linking pattern, including the optionality of the oblique position for many verbs (e.g. *Pat chained the dog (to the fence)*). Also, some verbs lack the oblique position entirely (e.g. *Pat zipped her jacket*); however, this makes sense because many of these verbs specify how one part of an object is moved relative to another part of the same object, so a distinct third entity need not be specified.

entity. The *un-* prefix then specifies the reversal of this configuration. This analysis correctly predicts that certain verbs that do not belong in either the 'combining and attaching' class or the 'putting' class can, nevertheless, take *un-* prefixation since they satisfy this general semantic criterion for the construction (e.g. *fold–unfold*, *mold–unmold*, *scramble–unscramble*, *dress–undress*).

In addition, another semantic restriction on *un-* prefixation, first noticed by Whorf (1936/1956) and later elaborated by Clark et al. (1995), Cruse (1979), and Wright (1999), is that the new spatial configuration is in some sense more constrained or constricted than the original one, so higher energy is required to maintain it; hence the prefix designates the restoration of a condition closer to natural disorder, or in other words, a condition of greater entropy. This helps to explain why the *un-* forms of verbs require less agentivity than the base forms. For instance, the scenario described by the sentence *The lecturer's pants became unzipped during the course of his speech* is perfectly plausible, not to mention quite humorous, but the scenario described by the sentence *The lecturer's pants became zipped during the course of his speech* is highly unlikely, and not nearly as funny. The constraint also accounts for why the sentence *Sam uncrossed his arms* is fine, but the sentence **Sam uncrossed the street* is not. Crossing one's arms implies the creation of a particular kind of constricted spatial configuration, whereas crossing a street clearly does not.

Other factors also play a role in determining which verbs can productively undergo *un-* prefixation. First, the prefix cannot readily apply to a verb if the resulting derived form has a meaning which is already encoded by an existing verb root. This is one manifestation of Clark's (1987) 'principle of contrast,' which militates against synonymy. For example, one reason for the ungrammaticality of **uncapture* is the existence of verbs like *release* and *let go*, which already express the intended meaning. Similarly, **unlift* may be blocked by *lower*, and **unclose*by *open*. Another manifestation of the same general principle is that a verb cannot take *un-* if the lexicon already contains a different derived reversative form of the same verb. Thus, **uncompose* is blocked by *decompose*, **uncode* by *decode*, **uninfect* by *disinfect*, and **unmount* by *dismount*.[6]

Bringing all of these considerations together, we offer the following informal description of the *un-* prefixation process.[7] At the level of derivational morphology, the construction consists simply of a symbol for 'prefix' attached to a symbol for 'verb,' with the composite unit annotated by a feature indicating verb status—$[[\text{prefix}]\text{-}[\text{V}]]_{\text{V}}$. The prefix is connected to the phonological representation of *un-*, but the verb stem is not connected to any particular phonological representation since there do not seem to be any phonological constraints on which verbs can appear in the construction. At the level of grammatical semantics, the verb stem is associated with a schematic meaning something like 'X causes Y to enter a constricted, potentially reversible spatial configuration relative to Z.' No verb

[6] It should be noted, however, that other negative prefixes in English, such as *de-* and *dis-*, do not have identical distribution to *un-*. These prefixes generally entail important semantic and morphological differences (Andrews, 1986; Colen, 1980–1981).

[7] We acknowledge the various theoretical approaches to describing morphological affixation processes. However, for the purposes of this paper, we adopt an approach along the lines of Construction Grammar because it appears to accommodate the data particularly well.

actually has a meaning this general, which is why the meaning is a purely constructional one. Yet, many verbs have specific meanings that are compatible with this semantic template, and these are the ones that are allowed to occur in the construction. Note that from the point of view of the construction, only the relevant semantic features of verbs are visible, so verbs that satisfy the semantic criteria but, nevertheless, differ in idiosyncratic ways (e.g. *zip*, *button*, *snap*) are essentially treated as identical. The prefix has semantic scope over the verb stem in the construction, so the final composite meaning of the construction expresses the reversal of the event designated by the verb stem—'X causes Y to come out of a constricted spatial configuration relative to Z.' Since the other factors that bear on *un-* prefixation apply more generally throughout the linguistic system, they do not need to be built into our description of the construction.

Although this new theory of *un-* prefixation undoubtedly has weaknesses, we believe that it is explanatorily more coherent and comprehensive than other theories that have been offered. For the purposes of this paper, however, what really matters is not so much the precise details of the semantic restrictions on this process, but rather the fact that there *are* such restrictions. The aim of the experiments that we conducted was to test certain neuropsychological predictions that follow from the overall conception of the interface between lexicon and grammar, predictions that depend critically on the general distinction between grammatically relevant and irrelevant features of meaning, but not necessarily on the minutiae of these features. In short, if this general distinction is valid, then it may be the case that the two components of meaning are mediated by partially segregated neural systems. This in turn predicts that brain damage could, at least in principle, selectively impair one component while leaving the other intact. As we will show, our experiments focusing on *un-* prefixation yielded results that support this prediction.

3. Experiment 1

3.1. Methods

3.1.1. Subjects

Six brain-damaged patients were selected from the Patient Registry of the University of Iowa's Division of Cognitive Neuroscience. All subjects gave informed consent in accordance with the Human Subjects Committee of the University of Iowa. The information provided below about the patients' lesion sites comes from magnetic resonance imaging data obtained in a 1.5 Tesla scanner with an Spg sequence of thin (1.5 mm) and contiguous T_1 weighted coronal cuts. The neuroimaging data were used to reconstruct each subject's lesion in three dimensions using Brainvox (Damasio, 1995; Damasio & Frank, 1992). The information about the patients' language status comes from tests that are part of the battery of standard protocols of the Benton Neuropsychology Laboratory (Tranel, 1996; Tranel, Damasio, & Damasio, 1997). All of the patients had undergone extensive neuropsychological investigation according to these protocols prior to the experiments reported here, and none of them had aphasia severe enough to prevent the comprehension of instructions or the production of scorable responses, nor did they manifest any difficulty attending to or perceiving visual stimuli.

1. 1978JB is a 54-year-old right-handed woman with 12 years of education. A left-hemisphere CVA in 1995 caused a lesion involving the inferior premotor/prefrontal cortex extending deep into the basal ganglia, the inferior half of the pre- and postcentral gyri, the most anterior sector of the supramarginal gyrus, and the insula. She was initially a global aphasic; however, this resolved into a persisting severe Broca's aphasia.
2. 1760KS is a 47-year-old right-handed man with 12 years of education. He suffered a left-hemisphere CVA in 1991 that damaged a large portion of the inferior premotor/prefrontal cortex and underlying white matter, the inferior half of the pre- and postcentral gyri, the supramarginal and angular gyri, the insula, and the posterior sector of the superior temporal cortex, extending into the sylvian fissure. The lesion caused a severe Broca's aphasia which has remained stable.
3. 1076GS is a 76-year-old right-handed man with 16 years of education. In 1986 he suffered a left-hemisphere CVA that damaged the entire middle and superior temporal gyri, as well as the insula and portions of the supramarginal and angular gyri. He satisfies the criteria for a moderate Wernicke's aphasia.
4. 1962RR is a 70-year-old right-handed man with 18 years of education. He experienced a left-hemisphere CVA in 1991 which damaged a small portion of the inferior premotor/prefrontal cortex, the inferior third of the pre- and postcental gyri, the entire supramarginal and angular gyri, and the posterior two-thirds of the superior temporal gyrus, extending into the sylvian fissure. His lesion is similar to that of 1760KS, except the parietal and temporal components of his lesion are larger, whereas the frontal component of 1760KS's is larger. Initially, he displayed global aphasia, but this gradually resolved into a predominantly anomic aphasia with some residual agrammatism. In August 1999, he had another CVA which disturbed sensation and mobility in his right hand and leg; however, no changes were observed in an MRI.
5. 1726RO is a 65-year-old right-handed man with 12 years of education. He had a CVA in 1991 that affected the posterior inferior frontal cortex and extended deep into the basal ganglia; the lesion also tapered back to the anterior part of the supramarginal gyrus. At the time of testing, he manifested a moderate Broca's aphasia.
6. 1130JP is a 54-year-old right-handed woman with 11 years of education. In 1987 she suffered a left-hemisphere CVA that damaged the left superior parietal cortex. At the time of testing, she had mild word-finding difficulties, but otherwise her linguistic capacity was unimpaired.

These six brain-damaged patients were compared with five normal right-handed control subjects, three male and two female. Age ranged from 49 to 80 years (mean = 58.2, s.d. = 12.6), and education ranged from 12 to 16 years (mean = 14.4, s.d. = 2.2).

3.1.2. Materials

The subjects were given a test that evaluated their knowledge of idiosyncratic features of verb meaning that are *not* relevant to whether *un-* prefixation is possible. The test employed a verb–picture matching paradigm and contained 40 items. It was designed in the same way as the verb–picture matching tests that were used in the previous studies of the locative alternation (Kemmerer, 2000a) and possessor ascension (Kemmerer,

submitted). The stimuli were presented on 8.5-by-11-inch plain white pages in a three-ring binder notebook. In the middle of each page was a 3.5-by-5-inch color photograph of an agent performing a particular type of action. Above each photograph were three verbs aligned horizontally across the page and printed in boldface upper-case 18-point font. The subject's task was to indicate which verb best describes the action depicted in the photograph. The target verb occurred in first position in 13 items, in second position in 13 items, and in third position in 14 items. The sequence of target verb positions was random, subject to the proviso that the same target position could not occur more than three consecutive times. All of the items are listed in Appendix A.

For each item the two distractor verbs were very similar to the target verb with respect to a variety of semantic features such as the agent's intention, the spatiotemporal details of manner of motion, the change of state or location of the object acted upon, and so forth. The purpose of making the verb triplets so similar in meaning was to increase the difficulty of the test and force the subjects to access and compare very subtle, idiosyncratic properties of the meaning of each verb. In some cases, one or even both of the distractor verbs could, in a more general context, be considered a possible description of the action shown in the photograph; however, in the context of the test, the target verb always provided a more precise description and, hence, was more appropriate than the distractors. For example, in one item the photograph showed a woman braiding a girl's hair, and the three verbs at the top of the page were *braid*, *twist*, and *tie*. Here *braid* was clearly the target, and the other two verbs were distractors that have very closely related meanings.

In addition, the three verbs for each test item were always the same with respect to *un-* prefixation—either all three verbs allow *un-*, or all three do not. For instance, *braid*, *twist*, and *tie* all allow the prefix because they all specify the creation of a constricted, reversible spatial configuration. In contrast, a different test item had three verbs—*bake*, *simmer*, and *boil*—that do not allow the prefix since they do not satisfy the narrow semantic criteria of the construction. What this implies is that the test evaluates the ability to discriminate between features of verb meaning that are grammatically irrelevant, or at least irrelevant to the construction of interest, namely *un-* prefixation. Making sure that the verbs for each item were equivalent in terms of *un-* prefixation did have a cost, however. Specifically, it was necessary to use some of the same verbs for several different items—a few verbs served as a target in one item and as a distractor in other items, while a few other verbs served only as distractors in a number of items (see Appendix A for details). The multiple instances of particular verbs were deliberately scattered through the test so that subjects would not encounter them in quick succession.

Information about the frequencies of all the verbs was obtained from the CELEX database which counts the number of times a word occurs in a corpus of approximately 17.4 million words (Baayen, Piepenbrock, & Gulikens, 1995). A comparison of the frequencies of the target verbs with the frequencies of the distractor verbs did not reveal a significant difference (target verbs: mean = 107.2, s.d. = 225.6; distractor verbs: mean = 84.7, s.d. = 160.2; one-tailed *t*-test: $p = 0.25$).

Finally, it is important to note that some of the verbs designate actions involving certain kinds of objects, and the roots of these verbs are in fact homophonous with the roots of the nouns for those objects (e.g. *chain*, *clamp*, *leash*, etc.). We included them because they are excellent cases of verbs that allow *un-* prefixation (in particular, they belong to the 'tape'

Table 2
Results for the brain-damaged subjects in Experiment 1

Subject	% correct	*z*-score
1978JB	82.5	− 4
1760KS	80	− 5
1076GS	75	− 7
1962RR	90	− 1
1726RO	92.5	0
1130JP	95	1

subclass of 'combining and attaching' verbs; see Experiment 2 for further details). However, a drawback of using them in the verb–picture matching test was that, for the items in which they occur, subjects might be able to get the right answer by essentially treating the task as noun–object matching instead of verb–action matching. Although we could not prevent subjects from using this kind of strategy, we attempted to discourage it by presenting all of the verbs in the test in the progressive participial form (i.e. with the *-ing* suffix), thereby emphasizing that the words were being used as verbs that designate actions.

3.1.3. Procedure

The subjects were tested individually in a quiet examination room. All subjects were given the same items in the same order. One practice item was given so as to familiarize the subjects with the nature of the task. The photograph showed a man seasoning a pizza with hot pepper, and the three verbs were *season*, *garnish*, and *decorate*. For all of the items in the test, the verbs were not only presented in written format, but were also read aloud by the experimenter. Subjects' responses were recorded in writing.

3.2. Results and discussion

As expected, the control subjects performed quite well, but still below ceiling, missing on average three items (mean = 92.5% correct, s.d. = 2.5%). Because their scores were relatively high with a small standard deviation, we used a rather conservative method for analyzing the data for the brain-damaged patients. Specifically, a patient's score was classified as defective if it was four or more standard deviations below the mean for normal controls, which is equivalent to 82.5% correct or lower.

The results are shown in Table 2. Three of the patients (1978JB, 1760KS, and 1076GS) had significant trouble with the test and obtained scores that fell within the defective range. However, the other three patients (1962RR, 1726RO, and 1130JP) had scores similar to those of the normal controls. The errors made by the first three patients are shown in Table 3. There was a moderate degree of overlap in which items the patients missed, which suggests that a few of the items may have been slightly more difficult than the others and, hence, more likely to be failed. However, even if this were the case, the factor of item difficulty could only account for a fraction of the data, since there was also a considerable amount of diversity across the error patterns.

Table 3
Items failed by: (A), 1978JB; (B), 1760KS; and (C), 1076GS in Experiment 1.(The first column provides a brief description of the action shown in the photograph; the second column indicates the target verb; the third column indicates the distractor verb that the subject incorrectly selected as the best match for the action shown in the photograph; and the fourth column indicates the other distractor verb)

Action in photograph	Target verb	Error	Distractor
A. 1978JB			
man heating pot of soup	heating	frying	baking
woman leashing dog	leashing	chaining	shackling
man coiling ribbon around pole	coiling	twisting	lacing
man simmering pot of soup	simmering	frying	roasting
woman dangling bag	dangling	dragging	swinging
man securing chain-lock on door	chaining	bolting	latching
woman craning her neck	craning	arching	hunching
B. 1760KS			
woman leashing dog	leashing	chaining	shackling
woman cuddling cat	cuddling	stroking	petting
man coiling ribbon around pole	coiling	lacing	twisting
woman putting cork in wine bottle	corking	capping	clamping
man putting binder clip on papers	clipping	hooking	stapling
man securing chain-lock on door	chaining	latching	bolting
woman craning her neck	craning	arching	hunching
man putting metal hook through ring	hooking	chaining	bolting
C. 1076GS			
girl lacing shoe	lacing	threading	tying
man heating pot of soup	heating	frying	baking
man floating stick in pool of water	floating	washing	sailing
man securing bolt-lock on door	bolting	latching	hooking
man coiling ribbon around pole	coiling	twisting	lacing
man putting binder clip on some papers	clipping	stapling	hooking
two train cars being coupled together	coupling	locking	crossing
woman twisting a strip of styrofoam	twisting	folding	bending
man securing chain-lock on door	chaining	bolting	latching
man putting metal hook through ring	hooking	chaining	bolting

The main finding of this experiment was that three of the patients (1978JB, 1760KS, and 1076GS) appear to have an impaired ability to discriminate between subtle, idiosyncratic features of verb meaning that are irrelevant to the verbs' grammatical properties, or at least to whether they allow *un-* prefixation. In contrast, the other three patients (1962RR, 1726RO, and 1130JP) have preserved this ability. The purpose of the next experiment was to evaluate the integrity of the patients' knowledge of the narrow semantic constraints of the *un-* prefixation construction. Although the patients who failed the first test may have disorders that are restricted to grammatically irrelevant features of verb meaning, it may be that their disorders encompass grammatical semantics as well. As for the patients who passed the first test, while they may also have preserved knowledge of grammatical semantics, it could be that they have a selective impairment of this component of meaning. The aim of the second experiment was to address these issues.

4. Experiment 2

4.1. Methods

4.1.1. Subjects

The same brain-damaged patients and normal control subjects that participated in Experiment 1 also participated in this study.

4.1.2. Materials

The subjects were given a grammaticality judgment test that was designed to assess their knowledge of the semantic content of the *un-* prefixation construction, and also their knowledge of whether the meaning of a given verb is compatible with that of the construction. The test included 40 sentences containing the verbs that served as 'target verbs' in Experiment 1. Most of these sentences actually described the actions that were shown in the photographs in Experiment 1. All of the sentences had the following general structure, where 'V' stands for a verb and 'NP' stands for an object noun–phrase: *She Ved the NP, and then she unVed it*. For example, one of the sentences was *She twisted the wire, and then she untwisted it*. In half of the sentences, the *un-* form of the verb was grammatical, and in the other half it was ungrammatical; in addition, in every sentence the *un-* form of the verb was underlined. The sentences are listed in Appendix B. The order of sentences was random, except that no more than four sentences of the same type could occur in sequence. The subject's task was to indicate whether the *un-* form of the verb was 'good' or 'bad.' Although this binary rating system does not reflect the inherently gradient nature of grammaticality judgments, it has the advantage of enabling the subject's responses to be scored as correct or incorrect in a straightforward way.

Several factors were taken into consideration in selecting the verbs. First, all of the verbs had to designate types of actions that could easily be portrayed in static photographs, since in Experiment 1 the grammatically irrelevant features of the verb meanings needed to be investigated through the verb–picture matching paradigm. In addition, for the ungrammatical *un-* forms of verbs, care was taken to ensure that their ungrammaticality was due to a violation of the narrow semantic constraints on the *un-* prefixation construction, and not to some other consideration, such as designating an event that is not really reversible, or being blocked by a pre-existing verb with the same basic meaning. This is because we wanted to be confident that if a subject consistently rated the ungrammatical *un-* forms of verbs as bad, this was a reflection of the subject's sensitivity to the semantic restrictions on the construction. Finally, all of the verbs had to be acceptable with just an object noun-phrase and not an additional prepositional phrase. The reason for this is that we wanted to keep the sentences as short and simple as possible to reduce syntactic processing demands.

For the grammatical *un-* forms of verbs, it was important to maximize the likelihood that the subjects would evaluate them by first recognizing the prefix and stem as distinct morphemes and then determining whether the meaning of the verb satisfies the semantic constraints of the construction (to the extent that their knowledge of these constraints was still intact). The alternative processing strategy would be to treat the words as entire units without internal morphological structure. Several arguments support the view that

the *un*-forms of verbs are typically processed in a decompositional manner. First, the weight of evidence from studies of the on-line processing of morphologically complex words indicates that words that are generated through a highly regular, transparent affixation process tend to be decomposed during word recognition, whereas words that have more irregular, opaque internal structures tend to be stored as precompiled units in long-term lexical memory (Caplan, 1992; Marslen-Wilson et al., 1994; Marslen-Wilson & Tyler, 1998; Pinker, 1999). Since *un-* prefixation is fully regular and quite transparent, it is likely that people usually decompose *un-* prefixed verbs on-line. Another argument comes from recent work by Hay (2000, submitted). She found that the relation between the frequency of a derived word and the frequency of its base has a significant effect on morphological decomposition. In particular, her research suggests that derived words that are less frequent than their bases are significantly more decompositional. Applying this to *un-* prefixation, if the *un-* forms of verbs are typically less frequent than the corresponding base verbs, there is a greater probability of on-line decomposition. In designing our experiment, we deliberately included as many low-frequency *un-* forms of verbs as possible. We searched for all of our *un-* forms in CELEX (Baayen et al., 1995) and found that only four of them were listed and all had very low frequencies—*unhook*, *unleash*, *uncork*, and *uncouple* (mean = 26.8, s.d. = 26.4).[8] In contrast, all of the base verbs were listed and had much higher frequencies (mean = 202.9, s.d. = 312.3). If, for the sake of statistical comparison, we make the idealized assumption that the 16 unlisted *un-* forms have 0 frequency, then the difference between the derived and base verbs is very significant (one-tailed *t*-test: $p < 0.004$). In the context of Hay's research, these findings provide further evidence that the derived verbs in our experiment are likely to be decomposed during on-line processing.

To ensure that our own judgments about the grammaticality or ungrammaticality of the various *un-* forms of verbs were representative of the general population, we collected ratings from a group of 20 normal subjects with the following demographic features: age ranged from 18 to 84 years (mean = 40.6, s.d. = 17.0); education ranged from 12 to 20 years (mean = 16.5, s.d. = 2.8); 11 subjects were male and nine female; and 19 subjects were right-handed and one left-handed. These subjects were given a list of 60 sentences containing *un-* forms of verbs; 40 of the sentences were the ones that we ultimately included in the final test (i.e. the test that the brain-damaged patients received), and the other 20 were sentences that we eliminated from the final test. Because our goal was to pool the judgments of a large group of subjects so as to measure the different degrees of grammaticality of the *un-* forms of verbs, we asked the subjects to rate the *un-* forms on a five-point scale, with 1 being 'very bad,' 5 being 'very good,' and the intermediate numbers representing correspondingly intermediate degrees of grammaticality. The results for the 40 sentences that were retained are shown in Table 4. As predicted, the 20 'good' *un-* forms of verbs were given high ratings (mean = 4.7, s.d. = 0.6), and the 20 'bad' forms were given low ratings (mean = 1.2, s.d. = 0.4). The other 20 sentences were omitted from the final test because, first, only 40 sentences were needed, and second, the

[8] We also searched for the *un-* forms in two other word frequency databases and again found that only a few were listed and had very low frequencies (six in Carroll et al., 1971, and five in Francis & Kucera, 1983).

Table 4
Ratings for the good and bad *un-* forms of verbs that were used in the grammaticality judgment test in Experiment 2. Ratings were made on a 5-point scale with 1 being 'bad,' 5 being 'good,' and the intermediate numbers representing intermediate degrees of grammaticality

Good *un-* forms of verbs			Bad *un*-forms of verbs		
Verb	Rating mean	Rating s.d.	Verb	Rating mean	Rating s.d.
unhook	5.0	0.0	unpush	1.0	0
uncross	4.9	0.2	untouch	1.0	0
unlace	4.9	0.2	unhug	1.0	0
unlatch	4.9	0.2	unpinch	1.0	0
unclog	4.9	0.3	unfloat	1.1	0.2
unleash	4.8	0.4	uncuddle	1.1	0.2
unbolt	4.8	0.4	unsimmer	1.1	0.2
untwist	4.7	0.6	unboil	1.1	0.3
uncoil	4.7	0.6	unturn	1.1	0.3
uncork	4.7	0.6	unpress	1.1	0.3
unbraid	4.7	0.6	undangle	1.2	0.5
unclip	4.7	0.6	unrotate	1.3	0.5
unclench	4.7	1.0	unheat	1.3	0.6
uncouple	4.6	1.1	unpowder	1.5	0.7
uncurl	4.5	0.7	unsubmerge	1.5	0.9
unchain	4.5	1.0	unsqueeze	1.5	0.8
unshackle	4.4	0.9	unfluff	1.5	0.8
uncock	4.4	0.8	uncrane	1.6	1.0
unpin	4.1	1.3	unchill	1.9	1.1
unpucker	3.8	1.4	undecorate	2.1	0.9
Mean	*4.6*	*0.6*	*Mean*	*1.3*	*0.5*

average ratings for some of the *un-* forms of verbs in those sentences were closer to the middle of the scale, which indicates that their grammaticality status was less clear.

4.1.3. Procedure

For all of the subjects, this test was administered immediately after the verb–picture matching test in Experiment 1. The instructions for the test were formulated very carefully so as to specifically address the issue of differences in familiarity between the good and bad *un-* forms of verbs. As mentioned above, if a subject produced consistently accurate grammaticality judgments, it was important to be fairly certain that this behavior reflected intact knowledge of the semantic constraints on the construction, and not other factors. Yet, one of the ways in which the good and bad *un-* forms of verbs were distinct from each other was that the good forms were all familiar existing words, whereas the bad ones were all unfamiliar nonexisting words. So, in principle, a subject could perform well by focusing just on familiarity. To discourage subjects from adopting such an approach, the instructions explicitly pointed out that, in general, just because a word is unfamiliar does not imply that it is ungrammatical, since new words can be created that sound fine—e.g. *mega-lizard*. The instructions also stated directly that the subjects should ignore familiarity and concentrate instead on whether the words sound natural or unnatural.

The precise instructions were as follows: 'I'm going to show you some sentences. Each

Table 5
Results for the brain-damaged subjects in Experiment 2

Subject	% correct	*z*-score
1978JB	85	− 5.6
1760KS	82.5	− 6.9
1076GS	60	− 19.4
1962RR	75	− 11.1
1726RO	62.5	− 18.1
1130JP	92.5	− 1.4

sentence describes an action, and then the opposite action. The opposite action is expressed by a verb with *un-* attached to it. Here are some examples:

George wrapped the present, and then he unwrapped it.
The soldiers surrounded the city, and then they unsurrounded it.

In these sentences, *unwrapped* sounds okay, but *unsurrounded* sounds odd or awkward. You might think that *unsurrounded* is bad because it's unfamiliar (you've probably never said it or heard it before). But this can't be right, because the word *mega-lizard* is also unfamiliar, and it sounds fine. So, as we go through the sentences, please ignore familiarity. Just focus on whether the words sound natural or not—that is, ask yourself if they are well-formed, grammatical words of English. For each sentence, just say 'good' or 'bad'.'[9]

All of the subjects were given the same items in the same order. For each item, the sentence was presented to the subject in written format and was also read aloud by the experimenter. The subject' responses were recorded in writing.

4.2. Results and discussion

The normal control subjects performed quite well on the test (mean = 95% correct, s.d. = 1.8). As in Experiment 1, because the scores for these subjects were so high and had a relatively small standard deviation, we established the cutoff for defective performance by brain-damaged patients as being four or more standard deviations below the mean for normal controls. This corresponds to 87.8% correct or lower.

Using this approach, five patients obtained scores that were classified as defective, and one patient performed within normal limits. Table 5 shows the percent correct and *z*-scores for all six patients, and Table 6 shows the specific errors made by the five patients who

[9] Another way of circumventing the problem of familiarity would be to administer a grammaticality judgment test with good and bad *un-* forms of made-up verbs. For instance, Whorf (1936/1956) remarked that 'if *flimmick* means, let us say, 'tie a tin can to,' then it falls into the cryptotype and I can say, e.g. 'he *unflimmicked* the dog.' However, if it means 'to take apart,' there will be no tendency for anyone to make a form *unflimmick* meaning 'put together,' e.g. 'he *unflimmicked* the set of radio parts.' Such a form will appear strange and unacceptable.' We considered designing an experiment of this nature, but decided not to pursue it at this time because of the many difficulties involved in developing reliable, standardized methods for teaching new verbs to brain-damaged patients and assessing their comprehension and judgment of these verbs.

Table 6
Items failed by 1978JB, 1760KS, 1076GS, 1962RR, and 1726RO in Experiment 2. The verbs were presented to the patients in the context of the sentences shown in Appendix B. Xs indicate items that were rated incorrectly—specifically, good verbs that were rated as 'bad,' and bad verbs that were rated as 'good'

Good *un-* forms of verbs						Bad *un-* forms of verbs					
	1978JB	1760KS	1076GS	1962RR	1726RO		1978JB	1760KS	1076GS	1962RR	1726RO
unhook						unpush					
uncross						untouch			x		
unlace			x			unhug					x
unlatch			x			unpinch					x
unclog		x				unfloat			x		x
unleash						uncuddle					x
unbolt						unsimmer					x
untwist				x		unboil					x
uncoil				x		unturn			x	x	x
uncork		x				unpress			x		
unbraid			x			undangle	x			x	
unclip		x		x		unrotate	x		x		
unclench						unheat					x
uncouple			x			unpowder				x	x
uncurl		x	x			unsubmerge	x				x
unchain			x			unsqueeze	x		x	x	x
unshackle			x	x		unfluff				x	x
uncock			x			uncrane	x	x		x	x
unpin			x			unchill					x
unpucker		x	x			undecorate	x	x			x

were impaired. Although more patients failed the grammaticality judgment test in this experiment than the verb–picture matching test in Experiment 1, it is unlikely that this difference reflects greater difficulty of the judgment test. If the judgment test was unusually difficult, one would expect this to show up in the results for the normal control subjects, but in fact they performed slightly *better* on the judgment test (95%) than on the matching test (92.5%). In addition, it is important to emphasize that not all of the brain-damaged patients failed the judgment test. One of them (1130JP) obtained a high score (92.5%, $z = -1.4$), which suggests that the processing requirements of this test are not significantly more challenging than those of the matching test.

There were interesting similarities as well as differences across the various error patterns shown in Table 6. For instance, there was a preponderance of errors for *un-* forms of verbs that were a bit closer to the middle than to the extremes of the 5-point rating scale used by the group of 20 normal subjects (see Table 4). This makes sense because although the grammaticality status of all of the forms was unambiguous, the status of the ones toward the middle of the scale was less obvious. In addition, there was a greater overall proportion of false positive errors (i.e. treating ungrammatical forms as good) than false negative errors (i.e. treating grammatical forms as bad). However, at the level of error patterns for individual patients, there was a considerable amount of variation along this dimension. These differences across the error patterns could reflect underlying differences in the nature of the patients' impairments, or they could reflect more superficial differences in the kinds of strategies that the patients employed during the test.

From a theoretical point of view, the most interesting performance profiles were those of 1962RR and 1726RO. These two patients had normal scores on the verb–picture matching test in Experiment 1, but they failed the grammaticality judgment test in the present experiment. A close examination of 1962RR's performance profile revealed that he gave incorrect ratings for ten *un-* forms of verbs in the judgment test, but he selected the correct picture for nine of the same verbs in the matching test. Similarly, 1726RO made 15 errors in the judgment test, but he got all but one of those verbs right in the matching test. These results suggest that the patients may have a dissociation between, on the one hand, intact knowledge of features of verb meaning that are irrelevant to the *un-* prefixation construction, and on the other hand, impaired knowledge of the narrow semantic criteria that determine which verbs can occur in the construction. It is important to note, however, that the available data are not sufficient to ascertain the precise characteristics of the patients' disorder involving grammatical semantics. The impairment could affect the schematic meaning of the construction and/or the particular semantic features of verbs that make them compatible with that meaning. Alternatively, the impairment could spare those representations and instead affect any of the processing pathways that flow into and out of them. However, even though these questions remain open, it still appears that at a more general level of analysis, the data support the view that the patients have a selective disturbance involving *some* aspect of grammatical semantics.

Turning now to 1978JB, 1760KS, and 1076GS, they failed both the verb–picture matching test in Experiment 1 and the grammaticality judgment test in this experiment. These findings suggest that the patients have conceptual disorders that affect not just grammatically irrelevant features of linguistic meaning, but also grammatically relevant features. 1076GS appears to have a more severe disorder than either 1978JB or 1760KS,

based on the fact that he committed a greater number of errors in both tests. As with 1962RR and 1726RO, it is impossible to determine with certainty the details concerning the patients' impairments. Even so, it is interesting to consider the degree to which the specific verbs that the patients missed in the matching test correspond with the ones that they missed in the judgment test. In some cases, a verb was missed in one test, but not the other, suggesting the possibility that there may be an underlying dissociation between knowledge of grammatically relevant versus irrelevant meaning. This is, however, very speculative, and further research would be necessary to explore these issues.

In summary, this experiment showed that five of the six brain-damaged patients were impaired at making grammaticality judgments about which verbs can occur in the *un-* prefixation construction. For the two patients who performed well in Experiment 1 (1962RR and 1726RO), these results constitute evidence for a disorder that selectively affects grammatical semantics. In contrast, for the three patients who performed poorly in Experiment 1 (1978JB, 1760KS, and 1076GS), the results point to broader conceptual problems.

Before any firm conclusions can be made about this experiment, however, it is necessary to rule out several alternative explanations for the patients' poor performances. The patients could have trouble with morphological decomposition of the derived *un-* forms of verbs, or impaired knowledge of the basic reversative meaning of the *un-* prefix. Another possibility is that the patients could have syntactic deficits that prevented them from fully understanding the sentences that were used as stimuli. The purpose of Experiment 3 was to address these issues.

5. Experiment 3

5.1. Methods

5.1.1. Subjects

The same brain-damaged patients and normal control subjects that participated in Experiments 1 and 2 also participated in this study.

5.1.2. Materials

The subjects were given a test that required them to comprehend ten sentences that were structurally very similar to the ones that were used in the judgment test, and that contained both bare and *un-* prefixed forms of verbs. The complete list of sentences is shown in Appendix C. Six of the sentences had the following structure: *V the NP, and then unV it*. For example, the first sentence in the test was *Fold the paper, and then unfold it*. The other four sentences had direct object NPs as well as oblique PPs. For example, one of the sentences was *Tie the string to the cup, and then untie it*. Unlike the sentences in the judgment test, all of these sentences lacked subject NPs; however, the subject NPs in the judgment test were always simple pronouns (in fact, the same pronoun, *she*, was used consistently), so this was a fairly trivial difference. Comprehension was measured by asking the subjects to act out the meaning of each sentence using physical objects that were provided. In every case, we chose objects that could be used for many different kinds

of actions; this was done to offset the possibility that a subject could perform correctly without understanding the sentences but simply by recognizing the most natural ways to manipulate the objects. All of the verbs were ones that were not used in the matching and judgment tests, but would nonetheless be appropriate controls for assessing knowledge of morphological structure, as well as knowledge of the basic reversative meaning of the *un-* prefix. Frequency information was obtained from CELEX (Baayen et al., 1995) for all of the derived *un-* forms of verbs and for all of the corresponding base forms. In every case, the frequency of the derived form was lower than that of the base form, and there was a statistically significant difference between the two groups of forms (*un-* prefixed verbs: mean = 39.8; s.d. = 49.9; base verbs: mean = 655.4, s.d. = 977; one-tailed *t*-test: $p < 0.05$). As we pointed out in Experiment 2, research conducted by Hay (2000, submitted) suggests that when this kind of frequency difference exists between derived and base forms, it is likely that the derived forms are decomposed on-line.

5.1.3. Procedure

For all of the subjects, this test was administered after the judgment test. The precise instructions were as follows: 'Now I'm going to show you some more sentences. All of them are like the ones in the last test—the first part of each sentence describes an action, and the second part describes the opposite action. This time, however, all of the sentences sound fine—they are perfectly grammatical. Your task is to act out the meaning of each sentence with real objects.' The sentences were shown to the subjects in written format and were also read aloud by the experimenter. One practice item was included to familiarize the subjects with the nature of the task. The sentence for that item was *Crumple the paper, and then uncrumple it*.

5.2. Results and discussion

All of the control subjects performed flawlessly on the test. The brain-damaged patients also performed extremely well (mean = 98%, s.d. = 4.5). Only one patient (1076GS) achieved a score lower than 100%, and he only made a single error. In particular, for the sentence *Wind the string around your finger, and then unwind it*, instead of carrying out the specified action, he wadded up the string into a little ball and held it in his fist, then he opened up his fist and straightened out the string. Thus, his error suggests an impaired understanding of the meaning of *wind*. Overall, then, the results from this experiment indicate that the poor performances of five of the brain-damaged patients on the grammaticality judgment test in Experiment 2 cannot be attributed to problems with: (1) morphological decomposition of derived *un-*forms of verbs; (2) knowledge of the basic reversative meaning of *un-*; or (3) syntactic processing. Instead, the results from the judgment test point to a disorder affecting the patients' knowledge of the semantic constraints that dictate which verbs can occur in the *un-* prefixation construction.

6. General discussion

The goal of the experiments reported in this paper was to contribute to the small but growing body of neuropsychological research exploring the putative distinction between

grammatically relevant and grammatically irrelevant aspects of meaning. If these two types of meaning are in fact distinct, as recent research in linguistic theory suggests, then they may be implemented in partially segregated neural systems. This in turn predicts that the two components of meaning could in principle be impaired independently of each other by brain damage. The results of our experiments support this prediction, since a one-way dissociation was found for two of the six patients who were investigated.

1962RR and 1726RO performed well on the verb–picture matching test in Experiment 1 which required them to discriminate between subtle, idiosyncratic features of verb meaning that are irrelevant to whether the verbs can occur in the construction that we focused on, namely *un-* prefixation. For example, the patients had no difficulty comparing and contrasting the meanings of closely related verbs such as *twist–bend–fold*, *push–prod–poke*, and *boil–simmer–bake*. These findings indicate that the patients have well-preserved knowledge of very specific aspects of verb meaning, such as details concerning the agent's intention, the shape and trajectory of motion, the particular changes of state or location that objects undergo, and so forth.

Further evidence for the patients' relatively good knowledge of grammatically irrelevant aspects of verb meaning comes from other studies. 1962RR performed well on two verb–picture matching tests that were designed like the one in this study (Kemmerer, 2000); 1726RO only took one of these tests, but he also performed well on it (Kemmerer, in press). In addition, both patients were given a battery of six tests that require processing verbs in different ways (Kemmerer, Tranel, & Barrash, 2001). 1962RR passed three of these tests, and 1726RO passed two. Crucially, one of the tests that both patients passed (1962RR, 99%; 1726RO, 97%) is a 69-item verb–picture matching test in which, for each item, the subject is shown a single verb and two photographs of actions, and must select which picture best illustrates the meaning of the verb. The fact that both patients performed extremely well on this test strongly supports the view that their knowledge of grammatically irrelevant aspects of verb meaning is intact. The patients' low scores on some of the other tests in the battery were most likely due to impairments of specific computational operations that are unique to those tests, and not to disrupted knowledge of the concepts encoded by verbs (see Kemmerer et al., 2001, for detailed arguments to this effect).

On the other hand, 1962RR and 1726RO failed the grammaticality judgment test in Experiment 2 which required them to determine whether the same verbs that were used in Experiment 1 satisfy the narrow semantic criteria for *un-* prefixation. For instance, although in Experiment 1 1962RR correctly selected the verb *twist*(as opposed to either of the distractors, *bend* and *fold*) to describe a picture of a woman twisting a long thin sponge, in Experiment 2 he incorrectly rated the verb*untwist* as being ungrammatical. Similarly, in Experiment 1 1726RO correctly selected the verb *boil* (as opposed to either of the distractors, *simmer* and *bake*) to describe a picture of a pot of boiling water, but in Experiment 2 he incorrectly rated the verb **unboil* as being grammatical. It is important to reiterate that the patients' poor performances on the judgment test cannot be explained in terms of greater difficulty of this test compared to the matching test, since the results from the normal control subjects suggest that the two tests do not differ significantly in difficulty; indeed, the control data indicate that, if anything, the judgment test is slightly *easier*. In addition, the patients' poor performances cannot be attributed to problems with

certain task demands—specifically, decomposing the morphological structure of the *un-* forms of verbs, appreciating the basic reversative meaning of *un-,* and processing the syntactic structure of the sentences—because both patients performed well on the act-out test in Experiment 3 that evaluated the integrity of these capacities.

We propose that 1962RR and 1726RO may have a disorder that selectively affects the level of grammatical semantics. In particular, they may have impaired sensitivity to the constraints governing the *un-* prefixation construction. Unfortunately, the limits of the experimental design prevent us from determining whether the impairment involves the critical semantic information itself, or instead the processes that manipulate this information. However, the impossibility of characterizing the impairment in precise terms does not detract from the significance of the main finding, which is that the impairment does appear to selectively affect *some* aspect of the narrow semantic restrictions on *un-* prefixation. This in turn supports the hypothesis that the level of grammatical semantics may be functionally and neurally independent of other kinds of linguistic meaning, at least to some extent. The hypothesis would obviously be strengthened if some of the patients had exhibited the opposite type of dissociation—i.e. poor performance on the matching test in Experiment 1 and good performance on the judgment test in Experiment 2—but this pattern was not found. Identifying such a dissociation is a goal of future research. However, we are encouraged by the fact that a genuine double dissociation between grammatically relevant and irrelevant features of meaning *was* found in a different study that focused on the locative alternation (Kemmerer, 2000a).

With respect to anatomical considerations, the results of this study are as follows. Five of the six patients obtained defective scores on the judgment test, but there is only one lesion site that all of them have in common—the anterior portion of the left supramarginal gyrus. Apart from this, the strongest lesion overlaps are as follows: four patients have lesions in the left inferior premotor/prefrontal region (1978JB, 1760KS, 1962RR, and 1726RO), and three have lesions in the posterior superior temporal gyrus (1760KS, 1076GS, and 1962RR). Thus, the data from this study suggest that the left anterior supramarginal gyrus may play an important role in grammatical semantics, and that Broca's and Wernicke's areas may also be involved to some degree. The findings concerning brain areas associated with grammatically irrelevant features of verb meaning are inconsistent. Three patients (1978JB, 1760KS, and 1076JB) failed the matching test, and the only lesion site they have in common damage in the left supramarginal gyrus; however, a different patient who performed well on the matching test (1962RR) also has damage in this area. Clearly, more research is needed to understand how grammatically relevant and irrelevant components of meaning are implemented in the brain.

Returning to the behavioral results, it is worth emphasizing their implications for current issues in neurolinguistics. Within the past few years, an increasing number of studies have investigated the neural substrates of grammatical categories by focusing on the distinction between the two major parts of speech—nouns and verbs. Neuropsychological studies with brain-damaged subjects have reported double dissociations between these two large-scale categories, and functional neuroimaging studies with healthy subjects have reported differential patterns of activation (e.g. Pulvermuller, 1999; Silveri

& Di Betta, 1997).[10] At the same time, a great deal of attention has been devoted to investigating the neural organization of the conceptual system. For instance, neuropsychological studies with brain-damaged subjects as well as functional neuroimaging studies with healthy subjects have converged on the view that a variety of conceptual distinctions, such as living versus nonliving entities, are in fact captured in the brain, although the details have not been determined yet (see Martin, Ungerleider, & Haxby, 2000, and Shelton & Caramazza, 2001, for recent reviews).

So far, however, these two lines of research have progressed independently of each other, and very few studies have directly addressed the interface between grammatical and conceptual categories from the perspective of cognitive neuroscience (Kemmerer, 2000a,b, submitted). Our study takes a step in this direction by drawing on new developments in linguistic theory which suggest that very rich connections between syntax and semantics do exist, but not so much at the level of large-scale part-of-speech categories; instead the connections reside primarily at the level of particular constructions and the subclasses of words that can occur in them. As we pointed out in the Introduction, the major claim of this approach is that grammatical constructions directly encode rather schematic semantic structures, and in order for a word to occur in a given construction, its meaning must be compatible with that of the construction. This leads to the distinction that was the main focus of this paper, namely the distinction between grammatically relevant and irrelevant components of meaning. Although the construction-based framework has been increasingly influential among researchers who work on language acquisition (Tomasello, 2000a,b), it has not yet been adopted by many people in the neurolinguistic community. We hope that this paper will inspire more research in this area in the future.

Whorf (1936/1956) was the first linguist to explore the mysteries of *un-* prefixation, so we began our paper with a quotation from him. It seems fitting that we leave the final word to Paula Gunn Allen (1997), a contemporary poet who offers a very different, but equally brilliant perspective on this fascinating topic.

> Zen Americana
> Un is okay.
> Un pretentious. Un decided. Un known.
> Un ego is where I want to be. How do you open
> the door to Un? What does the un place look like,
> look alikes?
>
> Un beginning; can I un wake myself, un sleep
> motionless in a bright green chair?
> Maybe un lamps light the room (the un place).
> When I get there, maybe it will be dark, un lit
> where it has no occasion to be any way.

[10] A debate is developing, however, over whether the observed differences between nouns and verbs actually reflect the grammatical part-of-speech distinction, or if instead they are due to semantic factors, since the experiments usually use nouns that designate concrete entities and verbs that designate physical actions (e.g. Bird, Howard, & Franklin, 2000; Koenig et al., 2001; Shapiro, Shelton, & Caramazza, 2000).

(Un celebrated.)
(Un repentant.)
(Un regenerate.)
(Un believed.)

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Appendix A

Stimuli for the verb–picture matching test in Experiment 1. The first column provides a brief description of the action shown in the photograph; the second column indicates the target verb; and the third and fourth columns indicate the two distractor verbs. The order of items here is not the order in which they occurred in the test; instead it corresponds to the order of items in Table 4.

Action in photograph	Target	Distractor	Distractor
1. Man putting metal hook through ring	hooking	chaining	bolting
2. Girl crossing her arms	crossing	bending	twisting
3. Girl lacing shoe	lacing	threading	tying
4. Man latching door	latching	clamping	tying
5. Man clogging sink with rag	clogging	capping	clamping
6. Woman leashing dog	leashing	chaining	shackling
7. Man bolting door	bolting	latching	hooking
8. Woman twisting a strip of styrofoam	twisting	folding	bending
9. Man coiling ribbon around pole	coiling	twisting	lacing
10. Woman putting cork in wine bottle	corking	capping	clamping
11. Woman braiding girl's hair	braiding	twisting	tying
12. Man putting binder clip on papers	clipping	stapling	hooking
13. Woman clenching her fist	clenching	curling	clamping
14. Man coupling train cars	coupling	locking	crossing
15. Man curling his finger	curling	bending	winding
16. Man securing chain-lock on door	chaining	latching	bolting
17. Girl putting handcuffs on woman	shackling	hooking	chaining
18. Man cocking gun	cocking	clenching	loading
19. Woman pinning girl's hair	pinning	braiding	tying
20. Woman puckering her lips	puckering	curling	clenching
21. Girl pushing file cabinet	pushing	prodding	poking

(*continued*)

Action in photograph	Target	Distractor	Distractor
22. Man touching statue with finger	touching	grabbing	pinching
23. Baseball players hugging after a win	hugging	patting	nuzzling
24. Man pinching his own arm	pinching	pricking	poking
25. Man floating stick in pool of water	floating	washing	sailing
26. Woman cuddling cat	cuddling	stroking	petting
27. Man simmering pot of soup	simmering	frying	roasting
28. Man boiling pot of water	boiling	simmering	baking
29. Man turning page of book	turning	rotating	pressing
30. Man pressing doorbell	pressing	jabbing	poking
31. Woman dangling bag	dangling	dragging	swinging
32. Globe showing earth rotating on axis	rotating	twisting	twirling
33. Man heating pot of soup	heating	frying	baking
34. Woman powdering her face	powdering	pushing	squeezing
35. Girl submerging ball in pool	submerging	sinking	floating
36. Woman squeezing pear	squeezing	pressing	pushing
37. Woman fluffing pillow	fluffing	flipping	flattening
38. Woman craning her neck	craning	arching	hunching
39. Woman putting wine bottle in fridge	chilling	freezing	warming
40. Man decorating pie with cream	decorating	adorning	embellishing

Appendix B

Stimuli for the grammaticality judgment test in Experiment 2. The order of items here is not the order in which they occurred in the test; instead it corresponds to the order of items in Table 4.

Grammatical un- forms of verbs

1. She hooked the gate, and then she unhooked it.
2. She crossed her arms, and then she uncrossed them.
3. She laced the shoe, and then she unlaced it.
4. She latched the jewelry box, and then she unlatched it.
5. She clogged the sink, and then she unclogged it.
6. She leashed the dog, and then she unleashed it.
7. She bolted the door, and then she unbolted it.
8. She twisted the wire, and then she untwisted it.
9. She coiled the rope, and then she uncoiled it.
10. She corked the wine bottle, and then she uncorked it.
11. She braided her hair, and then she unbraided it.
12. She clipped the papers together, and then she unclipped them.

(*continued*)
13. She clenched her fist, and then she unclenched it.
14. She coupled the train cars, and then she uncoupled them.
15. She curled her finger, and then she uncurled it.
16. She chained the door, and then she unchained it.
17. She shackled the prisoner, and then she unshackled him.
18. She cocked the gun, and then she uncocked it.
19. She pinned her hair, and then she unpinned it.
20. She puckered her lips, and then she unpuckered them.

Ungrammatical un- forms of verbs
21. *She pushed the elevator button, and then she unpushed it.
22. *She touched the statue, and then she untouched it.
23. *She hugged the man, and then she unhugged him.
24. *She pinched the man, and then she unpinched him.
25. *She floated the ball, and then she unfloated it.
26. *She cuddled the cat, and then she uncuddled it.
27. *She simmered the stew, and then she unsimmered it.
28. *She boiled the water, and then she unboiled it.
29. *She turned the page, and then she unturned it.
30. *She pressed the buzzer, and then she unpressed it.
31. *She dangled her purse, and then she undangled it.
32. *She rotated the plate, and then she unrotated it.
33. *She heated the soup, and then she unheated it.
34. *She powdered her nose, and then she unpowdered it.
35. *She submerged the ball, and then she unsubmerged it.
36. *She squeezed the pear, and then she unsqueezed it.
37. *She fluffed the pillow, and then she unfluffed it.
38. *She craned her neck, and then she uncraned it.
39. *She chilled the wine, and then she unchilled it.
40. *She decorated the pie, and then she undecorated it.

Appendix C

Stimuli for Experiment 3. The order of sentences here is the order in which they were presented to the subjects.

1. Fold the paper, and then unfold it.
2. Zip the bag, and then unzip it.
3. Button the shirt, and then unbutton it.
4. Fasten the strap, and then unfasten it.
5. Tangle the string, and then untangle it.
6. Wind the string around your finger, and then unwind it.
7. Tie the string to the cup, and then untie it.

(*continued*)
8. Cover the pencil with the paper, and then uncover it.
9. Wrap the cup with the paper, and then unwrap it.
10. Buckle the belt, and then unbuckle it.

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