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Grammatically relevant and grammatically irrelevant features of verb meaning can be independently impaired

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Abstract

According to the 'grammatically relevant semantic subsystem' hypothesis proposed by Pinker (1989), the meanings of verbs contain two different types of information: (1) a restricted set of semantic features that are visible to grammar and that influence the syntactic argument structure possibilities of verbs; and (2) an open-ended set of idiosyncratic perceptual and conceptual features that are not visible to grammar and that enable verbs to encode all kinds of subtle distinctions involving manner of motion, change of state, and so forth. If these two components of verb meaning reside at different levels of mental representation, as the hypothesis maintains, then it is possible that they could be independently disrupted by brain damage. This paper reports a series of experiments that confirmed this prediction.

Three brain-damaged subjects exhibited different performance profiles on two tests that evaluated their knowledge of grammatically relevant and grammatically irrelevant components of verb meaning. 1978JB and 1962RR performed well, but 2011SS performed poorly, on a word-picture matching test that required them to discriminate between verb triplets that differed only with respect to subtle, grammatically irrelevant perceptual and conceptual features—e.g., spill–pour–sprinkle. In contrast, 1978JB and 1962RR performed poorly, but 2011SS performed well, on a second test that required them to judge the grammaticality of sentences containing the very same verbs—e.g., Sam spilled beer on his pants vs. *Sam spilled his pants with beer. Linguistic analyses have shown that the grammaticality of these sentences depends on the compatibility between certain semantic features of the verbs and the inherent semantic content of the grammatical constructions. Finally, all of the subjects performed well on a third test that required them to judge the grammaticality of sentences that have purely syntactic violations. Taken together, these results suggest that 1978JB and 1962RR have a disorder that selectively involves the level of grammatically relevant semantic structure, whereas 2011SS has a disorder that selectively involves grammatically irrelevant aspects of verb meaning. This study therefore supports the hypothesis that grammatically relevant and grammatically irrelevant components of verb meaning are segregated in the mind/brain.

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Introduction

During the past two decades, a large amount of research in linguistic theory has been devoted to understanding why verbs that refer to conceptually similar events sometimes have very different syntactic properties. Consider, for example, the three action verbs break, cut and hit. All of these verbs prototypically designate events in which a volitional agent acts forcefully on an object in a specific manner, and most people have no difficulty generating mental images or scripts of how these actions are usually performed. With regard to syntactic behaviour, however, the three verbs have very different properties. In particular, each verb has a different set of restrictions on which syntactic argument structure alternations it allows. As shown in table 1, break and cut allow the 'middle' alternation but hit does not; break allows the 'inchoative' alternation but cut and hit do not; and break does not allow the 'part-possessor ascension' alternation but cut and hit do allow it.

Although these syntactic differences appear to be arbitrary, careful analysis reveals that they can be explained in terms of rather subtle semantic differences. There is increasing evidence that many grammatical constructions are directly associated with certain very schematic meanings that reflect basic patterns of human experience, and in order for a verb to occur in a particular construction, its meaning must be compatible with that of the construction (e.g., Wierzbicka 1988; Pinker 1989; Langacker 1991; Levin 1993; Goldberg 1995; Michaelis and Lambrecht 1996; Shibatani and Thompson 1996; Jackendoff 1997a; Kay 1997; Van Valin and LaPolla 1997; Verspoor et al. 1997; Tomasello 1998; Kay and Fillmore 1999, in prep). A crucial point, however, is that the aspects of meaning that are relevant to the interaction between verbs and constructions are quite narrow. What matters are certain features that are always associated with the kind of event denoted by a verb; features that are merely characteristic cannot have an influence on the syntactic properties of the verb. For example, the 'middle' construction specifies that an object has the generic property of being able to undergo a change of state with relative ease, and for this reason only verbs that encode an 'effect' can occur in the construction (see Levin 1993 and references cited there). Both break and cut encode

Table 1. The syntactic properties of verbs depend on specific semantic properties of the verbs and the constructions

Verb	Transitive	Middle (+effect)
break (effect)	I broke the glass	This glass breaks easily
cut (motion, contact, effect)	I cut the bread	This bread cuts easily
hit (motion, contact)	I hit the wall	*This wall hits easily
Verb	**Transitive**	**Inchoative (+effect, –contact, –motion)**
break (effect)	I broke the plate	The plate broke
cut (motion, contact, effect)	I cut the rope	*The rope cut
hit (motion, contact)	I hit the car	*The car hit
Verb	**Transitive**	**Part-possessor ascension (+contact)**
break (effect)	I broke Brian's arm	*I broke Brian on the arm
cut (motion, contact, effect)	I cut Brian's arm	I cut Brian on the arm
hit (motion, contact)	I hit Brian's arm	I hit Brian on the arm

an effect, so they are acceptable; however, hit is different. While it may be true that hitting events often have significant consequences for the object that is contacted, they don't always have such consequences (e.g., if I hit a steel slab with my fist, I am more likely to damage my fist than the slab). Thus, the 'effect' feature is not a necessary semantic component of hit, and this prohibits it from occurring in the 'middle' construction. The 'inchoative' construction (also known as the 'anticausative' or 'unaccusative' construction) is distinct from the 'middle' construction in so far as it specifies an actual change of state in an object; in addition, it stipulates that the only permissible verbs are those that encode an effect but do not entail either motion or contact (Pinker 1989; Levin 1993; Levin & Rappaport Hovrav 1995). Break is possible because it is a pure change-of-state verb, but cut and hit are both excluded—cut entails motion, and hit does not encode an effect. Finally, the 'part-possessor ascension' construction signifies that one object comes into contact with a particular part of another object (see Levin 1993 and references cited there). Break cannot occur in this construction because it does not necessarily require contact; on the other hand, both cut and hit do specify direct contact, so they can freely appear in the construction.

This overall approach to investigating the syntax–semantics interface of verbs has led to what Pinker (1989) calls the 'grammatically relevant semantic subsytem' hypothesis. This view holds that there is a small set of semantic features that are visible to grammar and that not only influence the syntactic possibilities of verbs, but also tend to be encoded by closed-class morphemes such as auxiliaries, determiners, adpositions, and nominal and verbal inflections. Grammatically relevant semantic features include motion, contact, effect, animate/inanimate, count/mass, bounded/unbounded, 0/1/2/3-dimensionality, and so forth. Other perceptual and conceptual features are not visible to grammar and therefore do not contribute to the syntactic properties of verbs. Such features include the following: temporal setting (e.g., morning vs. evening), spatial setting (e.g., indoors vs. outside), degree of event realization (e.g., almost, just barely), particular manner of motion (e.g., smearing vs. dabbing), particular shape of entities (e.g., conical, with a protrusion), colour of entities (e.g., red, blue), and so forth (see Talmy 1983, 1985, 1988, 1991, in press, for extensive discussion). In addition to the primary factor of (un)importance to grammar, two other factors are closely tied to the distinction between grammatically relevant and grammatically irrelevant aspects of meaning. First, many semantic features that fall within the grammatically relevant subsystem recur across genetically and geographically unrelated languages with fairly high reliability, whereas grammatically irrelevant perceptual and conceptual features are much more idiosyncratic and crossculturally variable. Second, grammatically relevant semantic features appear to be less salient to consciousness than grammatically irrelevant perceptual and conceptual features, as shown by the fact that arduous linguistic analysis is often required to uncover the semantic motivations behind the seemingly odd syntactic behaviour of verbs.

Although the precise nature of grammatically relevant semantics is not completely clear (Frawley 1992; Slobin 1997; Mohanan and Wee 1999), the general idea that an autonomous subsystem of this kind does exist has played a major role in the field of language acquisition research (e.g., Bickerton 1981; Slobin 1985; Pinker 1984, 1989). The notion has not, however, been explored from the perspective of aphasiology. The purpose of this paper is to report a set of experiments which tested certain predictions that follow from the hypothesis that grammatically relevant and grammatically irrelevant components of verb meaning are segregated in the mind. If the hypothesis is correct, it is likely that the two components of meaning are mediated by at least partially

distinct brain mechanisms. Therefore, it may be possible for the two components to be selectively impaired independently of each other by brain damage. Here I describe exactly this kind of double dissociation and argue that it provides empirical support for the validity of the hypothesis. First, however, I will describe the 'locative' alternation, which is the particular type of syntactic argument structure alternation that is the focus of the experiments.

The locative alternation

The locative alternation embraces two subalternations, one for 'putting' events and another for 'removing' events:

- 'putting' events

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

- 'removing' events

Sam cleared the dishes from the table	Sam cleared the table of dishes
Sam stole $100 from the wallet	*Sam stole the wallet of $100
*Sam robbed $100 from the man	Sam robbed the man of $100

As with the verbs in table 1, the verbs in these sentences are very choosy about the syntactic argument structures they can take. It is not possible to explain this choosiness in purely syntactic terms, however, because all of the verbs obviously allow both a direct object NP and an oblique PP. Instead, the best way to account for the phenomena is to pursue a semantic analysis. Several specific proposals have been made (e.g., Pinker 1989; Gropen et al. 1991a, b; Levin and Rappaport Hovrav 1991; Levin 1993; Rosen 1996; Brinkmann 1997).[1] I will adopt the analysis offered by Pinker (1989) and Gropen et al. (1991a, b), as it is the most well developed.[2]

For 'putting' verbs, each of the two grammatical constructions that make up the locative alternation has a very schematic construction-specific meaning. Variables for entities are mapped onto thematic roles, and these are in turn mapped onto NPs in a syntactic template, as illustrated in figure 1A. The meaning of the first construction is 'X causes Y to go to Z in some manner', and this construction is called 'theme-object' because the Y entity plays the role of theme (i.e., moving entity) and is linked to the direct object NP in the syntactic template—e.g., Sam sprinkled salt on the popcorn. In

[1] This is only a small sample of major references for the locative alternation. Levin (1993) cites 69 references prior to the publication of her own book.

[2] Both Rosen (1996) and Brinkmann (1997) criticize the Pinker/Gropen analysis and outline alternative theories. However, the Pinker/Gropen analysis remains the most thorough one available because it is explicitly designed to accommodate a very wide range of English data—142 'putting' verbs ('removing' verbs are characterized in terms of a similar theory by Levin and RappaportHovrav 1991 and Levin 1993). For instance, this analysis is able to explain why smear jam onto the bread is okay but *decorate cream onto the pie is bad. It is not clear how the theories developed by Rosen (1996) and Brinkmann (1997) can handle these facts. It is important to note, though, that the differences between the analyses proposed by Pinker/Gropen, Rosen and Brinkmann are pitched at a fairly low level of description; at a more general level, all of the approaches share the assumption that the proper explanation of the phenomena involves a restricted set of grammatically relevant semantic features. The debate is over the exact content of those features.

contrast, the meaning of the second construction is 'X causes Z to change state by adding Y'; this is called the 'goal-object' construction because the Z entity plays the role of goal and is linked to the direct object NP in the syntactic template—e.g., Sam sprinkled the popcorn with salt. From a functional point of view, the two constructions can be regarded as encoding different subjective construals of what is objectively the same type of event. Human cognition is quite flexible, and we are able to take multiple perspectives on particular events by allocating our attention to the entities in various ways. For example, if I see Sam sprinkling salt on his popcorn, I can conceptualize the salt as the main affected entity, as it changes location from being in a container to being on the popcorn, or I can conceptualize the popcorn as the main affected entity, as it changes state from being uncovered to being partially covered. The theme-object 'putting' construction encodes the first kind of construal, and the goal-object 'putting' construction encodes the second kind.

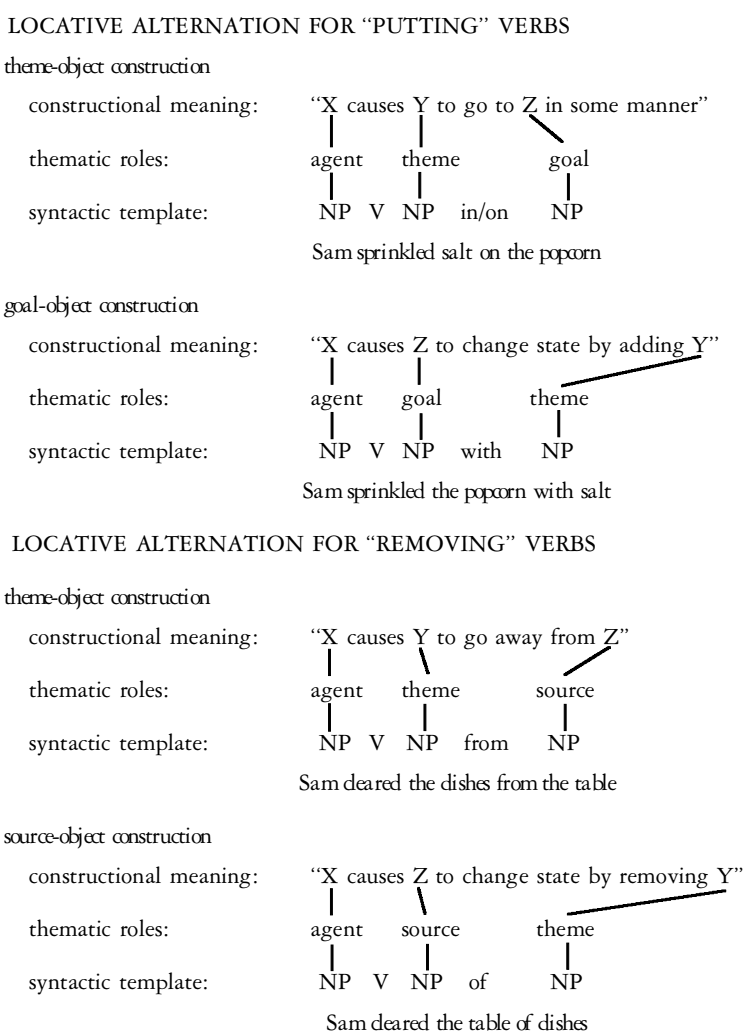

Figure 1. Locative alternations for 'putting' and 'removing' verbs.

As shown in figure 1B, the two constructions that make up the locative alternation for 'removing' verbs also have very schematic construction-specific meanings that encode different subjective construals of the same objective type of event. The first 'removing' construction is similar to the first 'putting' construction in so far as the theme is treated as the main affected entity and is mapped to the direct object NP in the syntactic template; the main difference between the two constructions is that the former is about causing a theme to go to a goal, whereas the latter is about causing a theme to go away from a source—e.g., Sam cleared the dishes from the table. Likewise, the second 'removing' construction is similar to the second 'putting' construction in so far as the source is treated as the main affected entity and is linked to the direct object NP; the main difference is that the former construction is about the goal changing state as a result of adding the theme to it, whereas the latter is about the source changing state as a result of taking the theme away from it—e.g., Sam cleared the table of dishes.

With regard to the interaction between individual verbs and the four locative constructions, the general principle is that a verb can only occur in a construction if its meaning is compatible with that of the construction. Sprinkle can take both of the 'putting' constructions because it encodes a specific manner of motion (an aggregate of tiny particulate objects moves downward in a loose pattern via the force of gravity) as well as a specific effect on the goal (its upper surface becomes covered with the objects in a fairly even spatial distribution). On the other hand, pour can only take the theme-object 'putting' construction because although it encodes a specific manner of motion (a liquid moves downward in a cohesive steam via the force of gravity), it does not say anything about the effect on the goal (e.g., one can pour water into a glass, but if the glass has a gaping hole in the bottom, the water will go right through and leave the glass more or less unchanged). Conversely, fill can only take the goal-object 'putting' construction because it encodes an effect on the goal (the entity becomes filled) but is mute about the manner in which this effect is brought about (e.g., one can fill a glass by pouring water into it, by dunking it in a tub of water, or even by letting it sit out in the rain). Similar constraints apply to which verbs can occur in which of the two 'removing' constructions. Clear allows both constructions because it specifies not only that the theme goes away from the source, but also that the surface or interior of the source is left in a void state. Steal, on the other hand, can only appear in the theme-object 'removing' construction because although it indicates that someone takes something that does not belong to them, it does not entail that the source is adversely affected (e.g., if one stole a penny from a Swiss bank, one could hardly expect to be hunted down by the police). Rob has exactly the opposite syntactic behaviour as it refers to 'removing' events in which the source is adversely affected by the theft of something with high value. In simpler terms, stealing is done to possessions, whereas robbing is done to people—hence the Beatles lyric 'She could steal but she could not rob' (from 'She Came in Through the Bathroom Window'), which implies that the woman was motivated to obtain objects but not to inflict harm (Pinker 1989; Goldberg 1995).

This overall approach to characterizing the locative alternation seems to be on the right track, but it has a serious problem. As stated earlier, the functional basis for the existence of the locative alternation is that different constructions encode different subjective construals of the same objective kind of the event. But human cognition is so flexible that most events can be conceptualized in many ways, so how does one know if a particular verb specifies a manner of motion and/or a change of state? For example, one can put water on flowers by spraying the water, dripping the water, or dumping the water so the flowers are completely drenched. No matter which method is used, our

mental flexibility enables us to focus on either the water or the flowers as the most 'affected' entity. However, different verbs have their own unique semantic perspectives:

spray:	Sam sprayed water on the flowers	Sam sprayed the flowers with water
drip:	Sam dripped water on the flowers	*Sam dripped the flowers with water
drench:	*Sam drenched water on the flowers	Sam drenched the flowers with water

Pinker (1989) argues that the solution to this problem is to decompose the broadly defined constructional meanings described earlier into several more narrowly defined sub-meanings. This makes the criteria for compatibility between verbs and constructions more stringent. One of the narrowly defined versions of the theme-object 'putting' construction means '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 narrowly defined versions of the goal-object 'putting' construction means 'X causes a solid or layer-like medium Z to have a mass Y distributed throughout it', and this licenses expressions like drench/soak/saturate/infuse the flowers with water and excludes expressions like *drip the flowers with water.[3]

It is crucial to note that according to this analysis, only some features of a verb's meaning are relevant to the verb's syntactic behaviour—namely, those that make the verb compatible with one of the narrowly defined sub-meanings of a particular construction. All of the other idiosyncratic perceptual and conceptual features of a verb's meaning are completely invisible to grammar—e.g., all of the features that distinguish between the verbs drip, dribble, pour, and spill, or between the verbs drench, soak, saturate, and infuse. The two components of verb meaning—grammatically relevant vs. grammatically irrelevant—are assumed to be segregated in the mind.

Figure 2 presents a rough model of the major levels of representation involved in mapping from perceived events—in this case, a 'dripping' event and a 'drenching' event—to appropriate locative constructions. The first level is called 'grammatically irrelevant meaning' and it includes all of the perceptual and conceptual features that comprise one's understanding of the given event. For the dripping event, this level captures the specific rate, shape and visuospatial trajectory of the water as it falls onto the flowers; and for the drenching event, it captures the specific appearance of the final state of the flowers as being totally wet. These features make up part of the meaning of the verbs drip and drench. In addition, at this level of representation both events can be construed in multiple ways by viewing either the water or the flowers as the main affected entity. The next two levels of representation are for 'grammatically relevant meaning'. The first of these is for the semantic features of drip and drench that determine which syntactic argument structures they can take. These representations indicate that only one type of event construal is possible for each verb—theme-focus for drip, and goal-focus for drench. Other information is filtered out—e.g., drip indicates that the liquid moves in a certain manner, but the details of manner-of-motion are not spelled out here; instead this information resides at the level of grammatically irrelevant meaning.[4] The next level of representation is for construction-specific meanings. This level contains not only the

[3] Altogether, Pinker (1989) lists 19 sub-meanings of the two 'putting' constructions, each of which accommodates between 1 and 20 verbs. Levin (1993) provides a sightly larger inventory.

[4] Pinker (1989) provides more rigorous decompositions of the semantic structure of locative verbs. His analyses are formulated in terms of an elaborate inventory of semantic elements and operations.

broadly defined meanings of the 'theme-object' and 'goal-object' constructions, but also the more narrowly defined versions of them. The arrows in figure 2 show that the semantic structure of drip is compatible with one of the sub-meanings of the 'theme-object' construction but is not compatible with any of the sub-meanings of the 'goal-object' construction; exactly the opposite is the case for drench. Finally, the last level of representation is for the syntactic templates of the two locative constructions.

The central idea of this approach to characterizing the locative alternation is that grammatically relevant and grammatically irrelevant aspects of meaning reside at different levels of representation. If this is true, then it may be the case that the two components of meaning are mediated by partially independent neural networks. This in turn predicts that brain damage could impair one component while leaving the other intact. The purpose of the experiments described here was to explore this possibility.

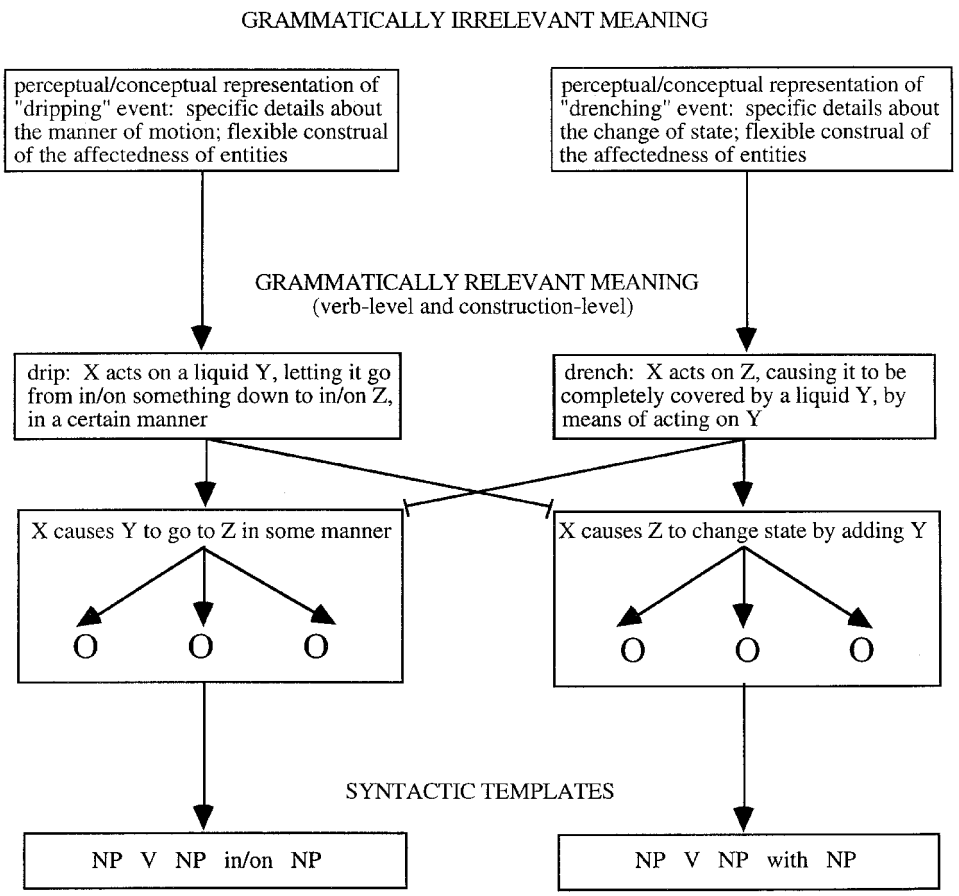

Figure 2. Four levels of representation in the mapping from perceived 'dripping' and 'drenching' events to appropriate locative constructions: (1) grammatically irrelevant meaning, (2-3) grammatically relevant meaning for both verbs and constructions, and (4) syntactic templates. Pointed lines indicate excitatory projections, whil blunt ones indicate inhibitory projections. Circles in the box for the second level of grammatically relevant meaning indicate constructional submeanings.

Experiment 1

Method

Subjects: Three brain damaged subjects are reported in this study. They were selected from the Patient Registry of the University of Iowa's Division of Cognitive Neuroscience, and gave informed consent in accordance with the Human Subjects Committee of the University of Iowa. The information provided here about the particular lesion sites of the subjects comes from magnetic resonance (MR) 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 was used to reconstruct each subject's lesion in three dimensions using Brainvox (Damasio and Frank 1992; Damasio 1995).

1978JB is a 53-year-old right-handed female with 12 years of education. In 1994 she suffered a left-hemisphere CVA that affected the inferior premotor/prefrontal cortex, the anterior supramarginal gyrus, the insula, and part of the lenticular nucleus. In the acute phase of her illness, she satisfied clinical criteria for global aphasia. This resolved into a severe Broca's aphasia, and at the time of the experiments reported in this paper, she continued to exhibit symptoms consistent with this classification, according to the Multilingual Aphasia Exam and the Boston Diagnostic Aphasia Exam.

1962RR is a 64-year-old right-handed male with 16 years of education. In 1991 he suffered a left-hemisphere CVA that damaged the inferior premotor/prefrontal cortex, the supramarginal and angular gyri, and the posterior two-thirds of the superior temporal gyrus. Initially he displayed global aphasia, but this gradually resolved into a predominantly anomic aphasia, as assessed by a variety of methods.

2011SS is a 32-year-old right-handed female with 12 years of education. In 1995 she suffered a left-hemisphere CVA that affected a small portion of the inferior premotor cortex within the sylvian fissure, the middle insula, and a small portion of the posterior superior temporal gyrus within the sylvian fissure. Acutely, she exhibited an atypical aphasia with dysfluent and paraphasic but well articulated and prosodic speech. Comprehension was significantly impaired, as were repetition, naming, writing, and associative fluency. She had an excellent recovery, however, and at the time of the experiments described here, she performed at the low end of the normal range on several standardized tests of speech and language.

All three subjects have undergone extensive neuropsychological investigation according to the standard protocols of the Benton Neuropsychology Laboratory (Tranel 1996). None of them manifested difficulty attending to or perceiving visual stimuli, nor did they have aphasia severe enough to prevent understanding of instructions or production of coherent responses.

The three brain-damaged subjects were compared with 10 normal control subjects. All of the control subjects were right-handed; four were male and six female; age ranged from 25 to 58 years (mean = 41.8, s.d. = 9.8); and education ranged from 12 to 16 years (mean = 15.2; s.d. = 1.7).

Materials: A test was administered that evaluated the subjects' knowledge of grammatically irrelevant perceptual and conceptual features of verb meaning. The test employed a verb–picture matching paradigm and included 34 items. The stimuli were presented on 8-by-11-inch plain white pages in a binder notebook. In the middle of each page was a 3.5-by-5-inch colour photograph of an agent performing a particular type of action (the same agent appeared in all of the pictures). 19 of the

photographs showed 'putting' events, and 15 showed 'removing' events. Above each photograph were three verbs aligned horizontally across the page and printed in boldface upper-case 18-point font. The subjects' task was to indicate which verb best described the action depicted in the photograph. The target verb occurred in first position in 11 items, in second position in 11 items, and in third position in 12 items. All of the items are listed in Appendix A.

Special care was taken to make the distractor verbs as similar as possible to the target verbs with respect to a variety of features such as the agent's intention, the spatio-temporal details of manner of motion, the change of state or location of the object acted upon, and so forth. This was done so that the subjects would be forced to access very subtle and idiosyncratic properties of the meaning of each verb. In addition, an effort was made to keep the three verbs for each item as similar as possible in terms of syntactic argument structure possibilities. For 18 items, all three verbs are restricted to the same locative construction. For 12 items, the three verbs are alike in so far as there is one locative construction in which they can all occur; however, at least one of the verbs can also occur in the alternative construction. For the remaining four items, the three verbs do not have in common a particular locative construction. Because the main focus of the test was on the perceptual/conceptual and syntactic properties of the verbs, it was not possible to control in a rigorous way for other lexical factors such as frequency, age of acquisition, etc.

Procedure: The subjects were tested individually in a quiet examination room in the Department of Neurology at the University of Iowa. 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 for this item 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 presented to the subjects in written format and were also read aloud by the experimenter. Subjects' responses were recorded in writing.

Results and discussion

All of the control subjects performed quite well on the test (mean = 95.8% correct, s.d. = 2.7%, range = 91–100%). Because their scores were very high with a small standard deviation, and also because their average education level was higher than that of two of the three brain-damaged subjects, a fairly conservative criterion was set for classifying a brain-damaged subject's performance as being defective. Specifically, the subject's percent correct had to fall four or more standard deviations below the mean for the normal control subjects, which corresponds to a score of 85% or lower.

1978JB had little difficulty with the test, selecting the correct verb for 31 of the 34 items (91%, $z = -1.7$). Similarly, 1962RR performed within the designated normal range, making just four errors (88%, $z = -2.8$). In contrast, 2011SS only got 27 of the 34 items right (79%, $z = -6.2$), which is below the cut-off for defective performance. The items that she failed are shown in table 2. These items were distributed throughout the test, so her incorrect verb choices were probably not due to increasing fatigue over the course of the experiment. It is intriguing, however, that the majority of her errors were for 'removing' verbs. She missed a third of these verbs (10/15 correct, 67%), but only missed two of the 'putting' verbs (17/19 correct, 89%). This difference could reflect more trouble appreciating the meanings of the

Table 2. Items failed by 2011SS in Experiment 1.

Photograph	Target	Distractor	Distractor
Man coiling ribbon around pole	coil	spin	roll
Man stuffing clothes into bag	stuff	pile	stack
Man stealing dollar from wallet	steal	smuggle	abduct
Man snatching a woman's purse	snatch	reach	grasp
Man brushing crumbs off a table	brush	skin	wipe
Man depriving woman of a drink	deprive	divest	conceal
Man emptying clothes from basket	empty	drop	lower

Italic typeface indicates the verb that the subject incorrectly selected as the best match for the action shown in the photograph.

former than the latter type of verb, but further research would be necessary to confirm this hypothesis.[5]

These results suggest that the ability to retrieve subtle, idiosyncratic perceptual and conceptual features of the meanings of locative verbs is preserved in 1978JB and 1962RR but moderately impaired in 2011SS.[6] According to the theory presented earlier, these features make up the component of verb meaning that is independent of grammar, shown in the top level of figure 2. At this level of representation, the meanings of verbs are distinguished along a wide range of intentional, spatial, temporal and causal dimensions that are irrelevant to the syntactic argument structure possibilities of the verbs. Although 2011SS's impairment may selectively involve just the grammatically irrelevant aspects of verb meaning, it may instead be more extensive, affecting grammatically relevant aspects of verb meaning as well. One of the aims of Experiment 2 was to explore this issue.

Experiment 2

Methods

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

[5] As noted earlier, the target verbs for the verb–picture matching test were not controlled for frequency, so it is worthwhile to determine whether frequency was a factor that influenced 2011SS's performance. The frequencies for all of the target verbs were identified (Francis and Kucera 1982), and a one-tailed unpaired t-test indicated that the target verbs for the items that 2011SS failed did not have a significantly lower frequency than the target verbs for the items that she passed ($p = .14$). Thus frequency did not appear to affect her performance.

[6] Sarah Breedin pointed out that 2011SS's poor performance on this test might be due to a visual impairment that disrupts her ability to process photographs depicting actions. To evaluate this alternative explanation, 2011SS was given another verb–picture matching test approximately six months after she took the first one. This test employed the same photographs and had the same target verbs, but the distractor verbs were completely unrelated to the target verbs—e.g., the distractors for *coil* were *juggle* and *melt*, and those for *brush* were *rinse* and *install*. The subject performed very well on this test (97%) correct), suggesting that her visuoperceptual abilities are sufficient to carry out word–picture matching tasks and that her deficit probably affects her knowledge of the very subtle features of verb meaning that distinguish, say, *coil* from *roll*, and *brush* from *wipe*.

Materials: The subjects were given a test that was designed to assess their knowledge of the grammatically relevant semantic features of the same 34 verbs that were used in Experiment 1. A grammaticality judgement paradigm was employed that included 68 sentences (two sentences for each verb). The method of stimulus presentation was parallel to Experiment 1. Each test item consisted of a page in a binder notebook. A photograph depicting an action appeared in the middle of the page (the photographs were the same as in Experiment 1). Above the photograph was written a single sentence describing the action. The subjects' task was to indicate whether the sentence was grammatical. Although the photographs were not an essential prerequisite for making grammaticality judgements, they were included for two reasons: first, to make the test format as similar as possible to the format of the verb–picture matching test in Experiment 1; and second, to facilitate comprehension of ungrammatical sentences that might not otherwise make sense—e.g., Sam is lifting the table of the lamp.

All of the sentences had the form of one of the four locative constructions reviewed earlier; they are listed in Appendix B. Based on the 19 'putting' verbs and corresponding photographs from Experiment 1, 19 pairs of sentences were formulated such that the members of each pair differed only in whether the theme-object 'putting' construction or the goal-object 'putting' construction was used. For seven of the verbs, only the theme-object construction is grammatical; for six, only the goal-object construction is grammatical; and for the remaining six, both constructions are grammatical. In a similar fashion, based on the 15 'removing' verbs and corresponding photographs from Experiment 1, 15 sentence pairs were formulated that differed only in whether the theme-object 'removing' construction or the source-object 'removing' construction was used. For ten of the verbs, only the theme-object construction is grammatical; for two, only the goal-object construction is grammatical; and for the remaining three, both constructions are grammatical. The number of grammatical and ungrammatical sentences of each of the four construction types was not completely balanced because pilot data revealed that it was not possible to get an equal number of verbs of each class that satisfied the joint criteria of (1) having easily depictable meanings, (2) differing in only subtle ways from other verbs, which is a requirement of Experiment 1, and (3) occurring in sentences that elicit reliable grammaticality judgements from normal control subjects. When designing grammaticality judgement tests, it is often desirable to embed the sentences that are of primary theoretical interest within a much larger set of structurally unrelated 'filler' sentences of various kinds (Cowart 1997). This was not done here because it would have necessitated a substantial increase in the length of the test, and this in turn would have had the negative effect of increasing the probability of fatigue for brain-damaged subjects.

Procedure: For all subjects, this test was administered after the verb–picture matching test in Experiment 1, the reason being that the sentences in this test contain the target verbs for the items in the matching test. As in Experiment 1, the subjects were examined individually in a quiet room, and they were given the same items in the same order. The order was random, except that no more than two sentences of the same type of construction could occur in sequence. For each item in the test, the sentence was presented to the subjects in written format and was also read aloud by the experimenter. The subjects' responses were recorded in writing. The precise instructions for the test were as follows: 'For this test, I'm going to show you the same pictures that were in the previous test. This time each picture is associated with a complete sentence. All of the sentences clearly relate to the pictures. However, the sentences differ in whether they are

constructed in a natural way. That is, some of the sentences fit the way we normally put words together in English, and others don't. Your task is to label each sentence as either "good" or "bad".' A single practice item was provided so that the subjects could become familiar with the nature of the task. Just as in Experiment 1, the photograph for this item showed a man seasoning a pizza with hot pepper. Instead of having just one sentence above the picture—as in the actual test items—two sentences were present: Sam is seasoning his pizza with hot pepper, and Sam is seasoning hot pepper on his pizza. The experimenter pointed out that the first sentence sounds natural and hence should be called 'good', whereas the second one sounds strange and hence should be called 'bad'.

A forced-choice categorical 'good' vs. 'bad' response system was used in order to simplify comparisons between the responses of individual brain-damaged subjects and those of a group of normal control subjects. It would be preferable to have subjects make ratings on a continuous scale because this would better reflect the inherent gradability of grammaticality judgements (Cowart 1997). For the purposes of the present study, however, this approach has an important weakness. Specifically, because the focus of the study is on the performance of individual brain-damaged subjects, it was necessary to be able to score each subject's response for each test item as either correct or incorrect. If, say, a 7-point scale was used that ranged from 'very bad' to 'very good', how should a brain-damaged subject's rating of 5 for a particular item be scored relative to an average rating for the same item of 6.2 for normal control subjects? Given this limitation of a continuous rating scale, it seemed more appropriate to adopt a binary categorical response system.

Results and discussion

As in Experiment 1, the control subjects achieved very high scores on the test (mean = 97.7% correct, s.d. = 2.5%, range = 93–100%). For this reason, the cut-off for classifying a brain-damaged subject's performance as defective was set once again at four standard deviations below the mean for controls. This corresponds to a score of 87%.

Looking first at 2011SS, although she performed poorly on the verb–picture matching test in Experiment 1, she achieved a high score on the grammaticality judgement test in this experiment (94%, z = −1.5). She only gave incorrect responses for four sentences. Three of them were 'putting' sentences—*Sam is bandaging a cloth around his finger, *Sam is coiling the pole with the ribbon, and *Sam is filling Coke into the glass—and the fourth was a 'removing' sentence—*Sam is rubbing the doorknob of fingerprints. All of her errors consisted of treating ungrammatical sentences as if they were grammatical. It is interesting to directly compare her performance on the judgement test with her performance on the matching test in Experiment 1. Of the 68 sentences in the judgement test, for 14 of them she did not get the corresponding target verb right in the matching test (recall that she made errors for seven verbs in the matching test, and each of these verbs occurs twice in the judgement test, totalling 14 sentences). This suggests that her knowledge of the perceptual and conceptual features of the meanings of the verbs may be impaired. And yet for those 14 sentences, she was able to accurately judge the grammaticality of 13 of them (the exception was the sentence with coil presented earlier). This constitutes evidence that her knowledge of the grammatically relevant semantic features of the same verbs is intact. Overall, then, the results indicate that 2011SS may have a disorder that selectively affects the grammatically irrelevant component of verb meaning while preserving the grammatically relevant component.

Turning now to 1978JB, she performed quite well on the verb–picture matching test in Experiment 1, but had considerable difficulty with the grammaticality judgement test in Experiment 2, giving accurate responses for only 54 of the 68 sentences (79%, $z = -7.5$) and thus falling into the defective range. The particular sentences that she failed are shown in table 3. These items were distributed fairly evenly throughout the test, so her errors are unlikely to be due to growing fatigue over the course of the experiment or to 'intuition burn-out' from being exposed to the same types of constructions multiple times. The fact that all of her errors involved rating ungrammatical sentences as sounding grammatical may lead one to suppose that she simply had a response bias for treating most sentences as acceptable. However, of the 25 ungrammatical sentences in the test, she did make accurate judgements for 14, which is over half (56%).[7] One possibility is that she is able to process grammatical locative sentences but is stymied by ungrammatical ones and thus ends up performing at chance on them.[8] Another possibility is that in carrying out the judgement test, she sometimes relied too much on the pictures, so that when there was an ungrammatical sentence together with a picture showing a coherent action, she often thought that because the action made sense, the sentence was probably acceptable too.[9] In order to test this hypothesis, 1978JB was given the very same grammaticality judgement test a second time, approximately four months after the first testing session, only this time the pictures were covered up so that the stimuli consisted only of sentences. Once again she performed very poorly (51/68, 75%, $z = -9.1$), and all 17 of her errors involved treating ungrammatical sentences as being grammatical (see table 4). Indeed, of the 25 ungrammatical sentences in the test, she correctly judged only 8 of them (32%) as being ungrammatical, which is a smaller proportion than in the first testing session. These results indicate that her tendency to make false positive errors is not due to over-reliance on the pictures but may in fact reflect some kind of response bias for rating bad locative sentences as being okay.

It is important to note that for 11 of the 14 sentences that 1978JB missed in the first testing session, she performed well in selecting the corresponding target verb in Experiment 1. The three exceptions are the sentences with dog, wipe and rub—she

Table 3. Items failed by 1978JB in Experiment 2 (session 1 – with pictures)

'Putting' sentences	'Removing' sentences
*Sam is spilling his pants with beer	*Sam is wiping the stove of grease
*Sam is sticking the wall with a message	*Sam is brushing the table of crumbs
*Sam is coiling the pole with a ribbon	*Sam is rubbing the doorknob of fingerprints
*Sam is dripping the paper with water	*Sam is robbing $7 from the woman
*Sam is immersing the water with the plate	
*Sam is filling Coke into the glass	
*Sam is clogging the rag into the sink	
*Sam is decorating cream onto the pie	
*Sam is bandaging a cloth around his finger	
*Sam is smothering a pillow over the woman	

[7] In addition, it is worth noting that ongoing research with other brain-damaged subjects has shown that when they make errors on the grammaticality judgement test, the errors tend to be false positives, i.e., rating ungrammatical sentences as being grammatical.

[8] Thanks to Roelien Bastiaanse for this observation.

[9] Thanks to Sarah Breedin for this observation.

Table 4. Items failed by 1978JB in Experiment 2 (session 2 – without pictures)

'Putting' sentences	'Removing' sentences
*Sam is coiling the pole with a ribbon	*Sam is wiping the stove of grease
*Sam is dripping the paper with water	*Sam is brushing the table of crumbs
*Sam is immersing the water with the plate	*Sam is rubbing the doorknob of fingerprints
*Sam is dropping the wastebasket with the tissue	*Sam is separating the whites of the darks
*Sam is filling Coke into the glass	*Sam is removing the shelf of a book
*Sam is clogging the rag into the sink	*Sam is snatching the woman of her purse
*Sam is decorating cream onto the pie	*Sam is robbing $7 from the woman
*Sam is bandaging a cloth around his finger	*Sam is depriving the drink from the woman
*Sam is covering a towel over the chair	

failed the items with these verbs in Experiment 1. This suggests that for the remaining 11 sentences that she misjudged, she probably has intact knowledge of the grammatically irrelevant perceptual and conceptual features of the verb meanings. Hence her judgement errors are most likely due to a disorder at some other level of representation and/or processing. It may be that the disorder involves grammatically relevant semantic structure. If that were the case, the disorder could affect the level of verb semantics, the level of constructional semantics, or both (see figure 2). Similarly, for 14 of the 17 sentences that she failed in the second testing session, she got the right verb in Experiment 1 (again the exceptions were *dog*, *wipe* and *rub*), which provides further support for the view that her impairment primarily involves grammatically relevant semantics. Crucially, however, it is theoretically possible that the disorder does not involve grammatically relevant semantic structure at all but rather some aspect of purely syntactic processing, or even the metalinguistic ability to make grammaticality judgements. The purpose of Experiment 3 was to address these alternative possibilities.

Finally, 1962RR had a performance profile similar to 1978JB's. Although he achieved a high score on the verb–picture matching test in Experiment 1, his score on the grammaticality judgement test in Experiment 2 was quite low (42/68, 62%, $z = -14.3$). As with 1978JB, his errors were distributed throughout the test. Unlike 1978JB, however, he made several different types of errors (see table 5). Of his 26 errors, only 11 involved treating ungrammatical sentences as being grammatical; the remaining 15 errors were of the opposite type, namely treating grammatical sentences as being ungrammatical. In addition, there were a number of cases in which he missed both sentences containing the same verb. For *immerse*, *decorate*, *fill*, *snatch*, and *rob*, one sentence is grammatical and the other is ungrammatical, and 1962RR made incorrect judgements for both of them; also, *empty* is an 'alternating' verb, which means that the theme-object and the source-object sentences are equally good, but 1962RR misjudged both of them as being bad. Remarkably, for 23 of the 26 sentences that he failed in this experiment, he selected the correct verb in the verb-picture matching test, suggesting intact knowledge of the grammatically irrelevant features of the meanings of those verbs. Thus, like 1978JB, his poor performance in the judgement test may reflect a disturbance of the grammatically relevant semantic features of the verbs. To confirm this, however, it is necessary to rule out alternative explanations, such as that the disorder involves purely syntactic processing or perhaps metalinguistic judgement ability. These issues are addressed in Experiment 3.

Table 5. Items failed by 1962RR in Experiment 2

'Putting' sentences	'Removing' sentences
*Sam is immersing the water with the plate	*Sam is snatching the woman of her purse
*Sam is decorating cream onto the pie	*Sam is robbing $7 from the woman
*Sam is filling Coke into the glass	*Sam is separating the whites of the darks
*Sam is coiling the pole with a ribbon	*Sam is stealing the wallet of a dollar
*Sam is pouring the glass with water	
*Sam is dropping the wastebasket with the tissue	
*Sam is clogging a rag into the sink	
Sam is immersing the plate in the water	Sam is snatching the purse from the woman
Sam is decorating the pie with cream	Sam is robbing the woman of $7
Sam is filling the glass with Coke	Sam is emptying the clothes from the basket
Sam is spraying cleanser on the window	Sam is emptying the basket of clothes
Sam is dripping water on the paper	Sam is lifting the lamp off the table
Sam is smearing jam onto the bread	Sam is draining the cooler of water
Sam is wiping grease off the stove	
Sam is wrapping the bowl with the towel	
Sam is loading the trunk with boxes	

Experiment 3

Methods

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

Materials: As noted earlier, 1978JB's and 1962RR's poor performances on the grammaticality judgement test in Experiment 2 may not have arisen from an impairment of grammatically relevant semantics, but rather from an impairment of syntactic processing or of the ability to make metalinguistic grammaticality judgements. To address this issue, another test was administered to all of the subjects. As with the test in Experiment 2, this test employed a grammaticality judgement paradigm, but instead of focusing on the semantically constrained argument structure possibilities of verb, it focused on the purely syntactic subcategorization features of verbs. Based on 15 verbs, 15 pairs of sentences were formulated such that the members of each pair had different syntactic structures—specifically, one sentence was transitive and the other intransitive. All of the sentences are listed in Appendix C. For each of the first five sentence pairs, one sentence is grammatical but the other in ungrammatical because a direct object NP is present even though it is not licensed by the verb. For each of the next five sentence pairs, one sentence is grammatical but the other is ungrammatical because a direct object NP is required by the verb but is not present. Finally, for each of the last five sentence pairs, the two sentences differ with respect to whether a direct object NP is present, but both are grammatical because the verb is optionally transitive. Thus, whereas the grammaticality judgement test in Experiment 2 emphasized the arrangement of arguments according to their thematic roles (e.g., can the direct object NP play the role of theme?), this test emphasizes the presence or absence of arguments regardless of their thematic roles. Unlike the test in Experiment 2, pictures were not included with the sentences in this test. However, the same kind of categorical 'good' vs. 'bad' rating was used.

Procedure. For all subjects, this test was administered after the tests in Experiments 1 and 2. As in the previous experiments, the subjects were examined individually in a quiet room, they were given the same items in the same order, and their responses were recorded in writing. For each item in the test, the sentence was presented to the subjects in written format and was also read aloud by the experimenter. The order of items alternated in an intransitive–transitive–intransitive–etc. pattern, but within this pattern the sequence of grammatical vs. ungrammatical sentences was random. Subjects were told that the regular alternating pattern of construction types was not relevant to the task and that they should just concentrate on determining whether each sentence 'fit the way we normally put words together in English'. To clarify the task, subjects were given two examples of 'good' sentences—Sam likes chocolate and Sam danced—and two examples of 'bad' sentences—*Sam likes and *Sam danced the woman. The following points were made about these sentences: 'Sam danced is "good" even though nothing more is said about how, where, or why he danced. In a conversation, this information might be included. But the sentence is still alright by itself—it is structurally, or grammatically, okay, unlike Sam likes, which is "bad". For Sam danced the woman, it is possible to make sense of it—for example, it could mean that Sam danced with the woman. However, the sentence is still "bad" because it doesn't fit the way we normally put words together—it violates the grammatical rules of English.'

Results and discussion

The control subjects performed very well on the test (mean = 97.8% correct, s.d. = 3.3, range = 93–100%). All three brain-damaged subjects also achieved high scores. 2011SS gave accurate responses for all 30 sentences, 1978JB only missed one item (97% correct), and 1962RR only missed two items (93% correct).

2011SS's good performance is not surprising as it is consistent with her demonstration of normal grammaticality judgement abilities in Experiment 2. 1978JB's and 1962RR's good performances are much more interesting from a theoretical point of view. First, these results provide evidence that the subjects' capacity to process the syntactic structure of simple (i.e., monoclausal) sentences is intact; and second, the results indicate that the subjects' capacity to make metalinguistic grammaticality judgements is intact. Overall, then, the experiment suggests that these subjects' low scores on the judgement test in Experiment 2 cannot be attributed to a disorder of either of these capacities. Instead, the evidence from Experiments 1 and 2 points to a selective impairment at the level of grammatically relevant semantics.

General discussion

The purpose of the experiments described here was to test the hypothesis that grammatically relevant and grammatically irrelevant features of verb meaning reside at different levels of representation in the mind. This hypothesis predicts that the two components of verb meaning are mediated by at least partially distinct brain mechanisms and hence could be disrupted independently of each other by brain damage. The results of the experiments confirm this prediction as a strong double dissociation was exhibited by the brain-damaged subjects.

1978JB and 1962RR performed well on the verb–picture matching test in Experiment 1 that focused on the idiosyncratic, grammatically irrelevant features of the meanings of locative verbs. This test requires discrimination between verb triplets that

vary only with respect to subtle perceptual and conceptual features—e.g., coil–spin–roll, decorate–adorn–embellish, and drip–pour–spray. Hence their good performances reveal an impressive amount of verb knowledge. On the other hand, both subjects performed significantly below normal on the grammaticality judgement test in Experiment 2 that focused on the systematic, grammatically relevant semantic features of the very same verbs, i.e., the features that determine which constructions the verbs can occur in. For example, the two subjects treated as grammatical a large number of sentences that normal control subjects have no difficulty recognizing as being very odd—e.g., *Sam is coiling the pole with the ribbon, *Sam is decorating cream onto the pie, and *Sam is dripping the paper with water. The errors cannot be attributed, however, to an impairment of either syntactic processing or metalinguistic judgement ability because neither subject had trouble with the control test in Experiment 3 that evaluated the integrity of these capacities. The available evidence therefore suggests that the subjects' deficits are restricted to the level of grammatically relevant semantic structure. In the processing model shown in figure 2, this level lies intermediate between the top level of grammatically irrelevant meaning and the bottom level of syntactic templates. In addition, it consists of two sub-levels—one for verb meaning and another for constructional meaning. In principle, the subjects' disorders could affect any or all of the mapping stages or representational sub-levels that are associated with grammatically relevant semantics. The experimental design did not allow these more specific aspects of processing to be isolated from one another, so the exact nature of the subjects' difficulties with processing grammatically relevant meaning cannot be ascertained. However, for purposes of evaluating the 'grammatically relevant semantic subsystem' hypothesis, it is sufficient to be able to say that the subjects displayed a clear dissociation between, on the one hand, impaired processing of some aspect of grammatically relevant meaning and, on the other hand, preserved processing of grammatically irrelevant meaning.

2011SS had a very different performance profile. In contrast to 1978JB and 1962RR, she failed a significant number of items in the verb–picture matching test in Experiment 1. This may reflect an impaired ability to appreciate the kinds of grammatically irrelevant perceptual and conceptual features that distinguish between the meanings of locative verbs, features like the particular manner in which one entity is put into or onto another (e.g., coil vs. spin vs. roll), or the particular way in which one entity is removed from another (e.g., brush vs. skim vs. wipe). On the other hand, she performed extremely well on the grammaticality judgement tests in Experiments 2 and 3. These findings indicate that she not only has normal syntactic processing and metalinguistic judgement abilities, but also has intact knowledge of the grammatically relevant semantic features of verbs and constructions. For instance, although her understanding of the idiosyncratic perceptual/conceptual aspects of the meanings of coil and brush appears to be disrupted, she has nevertheless retained the grammatically relevant semantic knowledge which is necessary to determine that the sentences Sam coiled the ribbon around the pole and Sam brushed the crumbs off the table are acceptable, but the sentences *Sam coiled the pole with the ribbon and *Sam brushed the table of crumbs are unacceptable. This knowledge includes the rather abstract information that coil can mean 'X causes Y to go to Z' but not 'X causes Z to change state by adding Y', and the information that brush can mean 'X causes Y to go away from Z' but not 'X causes Z to change state by removing Y'. Thus, 2011SS's impairment seems to selectively involve the level of grammatically irrelevant features of verb meaning; the level of grammatically relevant meaning is preserved.

The contrasting performance profiles of 1978JB, 1962RR, and 2011SS constitute a double dissociation between grammatically relevant and grammatically irrelevant

aspects of meaning. The results are therefore consistent with the view that these two aspects of meaning are segregated in the mind, which is to say, mediated by partially independent brain mechanisms. This outcome has significant implications for both linguistic theory and aphasiology.

For linguistics, this study is important because it provides a completely new form of evidence for Pinker's (1989) 'grammatically relevant semantic subsystem' hypothesis. A few previous studies have supported this hypothesis by using experimental psychological methods (Gropen et al. 1989, 1991a,b; Bley-Vroman and Yoshinaga 1992); however, the lion's share of evidence to date has come solely from careful linguistic analyses of verbs and closed-class morphemes (e.g., Talmy 1983, 1985, 1988, 1991, 2000; Pinker 1989; Frawley 1992; Levin and Rappaport Hovrav 1991, 1995; Levin 1993; Van Valin and LaPolla 1997; Rappaport Hovrav and Levin 1998). For this reason, the double dissociation reported here provides a valuable source of convergent evidence from a very different perspective. Still, there are several questions about the precise nature of grammatically relevant semantics that remain open. For instance, as noted earlier (see footnote 2), it is not entirely clear if the characterization of the locative alternation developed by Pinker (1989), Gropen et al. (1991a,b) and Levin and Rappaport (1991) is correct. Other analyses have been offered (e.g., Rosen 1996; Brinkmann 1997), and further research is necessary to determine which approach is theoretically and empirically most coherent. Nevertheless, one point that does not appear to be in dispute is that the final analysis will depend crucially on some kind of restricted set of grammatically relevant semantic features. Another issue is whether grammatically relevant semantic features are innately prespecified in the mind/brain in order to facilitate language acquisition, or if instead they become progressively modularized over the course of language development (Slobin 1997). The present study does not bear directly on this issue and is consistent with both possibilities. Once again, as the formula goes, 'more research is needed'.

Turning to aphasiology, this study is important because it adds a completely new dimension to recent thinking about the internal organization of verb meanings. Over the past few years, an increasing amount of work has been done on the ways in which knowledge of verb meaning can be impaired by brain damage. For example, dissociations have been identified between concrete and abstract verbs (Breedin et al. 1994; Berndt et al. 1997), between semantically complex and semantically simple verbs (Breedin et al. 1998, 1999; Kemmerer and Tranel, in press), and between reverse-role verbs (e.g., buy vs. sell) and other classes of verbs such as opposite-role (e.g., break vs. fix) and manner of motion (e.g., walk vs. run) (Byng 1988; Breedin and Martin 1996; Marshall et al. 1996). These results suggest that verb meanings may be organized in the brain along conceptual dimensions in a principled way. Furthermore, dissociations have been found between tasks requiring the referential use of verbs (e.g., to name pictures of actions) and the analytic use of verbs (e.g., to answer questions about relationships between the meanings of different verbs) (Kemmerer et al., in press). Yet another important finding is that dissociations occur between, on the one hand, knowledge of the semantic properties of verbs, such as motion features and participant roles, and on the other hand, knowledge of the syntactic properties of verbs, such as their subcategorization frames (Breedin and Martin 1996). These dissociations provide strong support for the representational modularity of semantic and syntactic information (Jackendoff 1997b). At the same time, however, there is evidence in the neuropsychological literature for a close interactive relationship between the semantic and syntactic properties of verbs. For instance, verb retrieval in both isolated contexts and sentence contexts is influenced by syntactic factors such as transitivity and the number of sub-

categorization frames that a verb allows (Jonkers and Bastiaanse 1996, 1997, 1998; Caplan and Hanna 1998; Thompson et al. 1998; Kemmerer and Tranel, in press). These findings are not incompatible with representational modularity, and they fit nicely with recent 'lexicalist' movements in grammatical theory which argue that the syntactic properties of verbs are largely a projection of their semantic properties.

The vast majority of studies, however, have focused on what has been referred to in this paper as the grammatically irrelevant aspects of verb meaning. The present study is therefore valuable in so far as it provides neuropsychological support for the view that verb meanings have two distinct components: (1) a restricted set of semantic features that are visible to grammar and that determine the syntactic argument structure possibilities of verbs; and (2) an open-ended set of idiosyncratic perceptual and conceptual features that are not visible to grammar and that enable verbs to encode all kinds of subtle distinctions involving manner of motion, change of state, and so forth.

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Appendix A

Stimuli for the verb–picture matching test in Experiment 1. Class A = all three verbs are restricted to the same locative construction. Class B = all three verbs have one locative construction in common, but at least one of the verbs also allows the alternative construction. Class C = the three verbs do not share a single locative construction. The order of items here is systematic because it corresponds to the organization of grammatical constructions shown in Appendix B. The order of items in the actual test was random.

Number	Photograph	Target	Distractor	Distractor	Class
1	Man pouring water in glass	pour	spill	spray	B
2	Man spilling beer on pants	spill	pour	sprinkle	B
3	Man dropping tissue in wastebasket	drop	lower	dangle	A
4	Man sticking post-it on wall	stick	mount	perch	A
5	Man coiling ribbon around pole	coil	spin	roll	A
6	Man dripping water on newspaper	drip	pour	spray	B
7	Man immersing plate in dishwater	immerse	lodge	install	A
8	Man filling glass with Coke	fill	squirt	splash	B
9	Man clogging rag into sink	clog	dam	choke	A
10	Man decorating pie with cream	decorate	adorn	embellish	A
11	Man bandaging finger with cloth	bandage	bind	lash	A
12	Man covering chair with towel	cover	wrap	coat	B
13	Man smothering woman with pillow	smother	strangle	choke	A
14	Man spraying window with cleanser	spray	pour	spill	B
15	Man loading boxes in trunk of car	load	install	stack	B
16	Man smearing jam onto bread	smear	dab	squirt	B
17	Man stuffing clothes into bag	stuff	pile	stack	B
18	Man sprinkling salt on popcorn	sprinkle	spill	spray	B
19	Man wrapping towel around bowl	wrap	coil	twist	B
20	Man stealing dollar from wallet	steal	smuggle	abduct	A
21	Man taking a magazine from a table	take	withdraw	extract	A
22	Man grabbing a woman's orange	grab	clutch	yank	A
23	Man snatching a woman's purse	snatch	reach	grasp	C
24	Man lifting a lamp off a table	lift	hoist	extract	A
25	Man removing a book from a shelf	remove	extract	separate	A
26	Man separating clothes (white/dark)	separate	disconnect	detach	A
27	Man wiping grease off a stove	wipe	scrub	scour	A
28	Man brushing crumbs off a table	brush	skim	wipe	A
29	Man rubbing fingerprints off door	rub	scrape	scour	A
30	Man robbing $7 from woman	rob	snatch	con	C
31	Man depriving woman of a drink	deprive	divest	conceal	C
32	Man clearing papers off table	clear	wipe	skim	B
33	Man emptying clothes from basket	empty	drop	lower	B
34	Man draining water from cooler	drain	drip	dribble	C

Appendix B

Sentences used in the grammaticality judgement test in Experiment 2, organized according to type of construction. The order of sentences in the test was random.

'Putting' sentences

1. Theme-object only

Sam is pouring water in the glass	*Sam is pouring the glass with water
Sam is spilling beer on his pants	*Sam is spilling his pants with beer
Sam is dropping the tissue in the wastebasket	*Sam is dropping the wastebasket with the tissue
Sam is sticking the message on the wall	*Sam is sticking the wall with the message
Sam is coiling the ribbon around the pole	*Sam is coiling the pole with the ribbon
Sam is dripping water on the paper	*Sam is dripping the paper with water
Sam is immersing the plate in the water	*Sam is immersing the water with the plate

2. Goal-object only

*Sam is filling Coke into the glass	Sam is filling the glass with Coke
*Sam is clogging a rag into the sink	Sam is clogging the sink with a rag
*Sam is decorating cream onto the pie	Sam is decorating the pie with cream
*Sam is bandaging a cloth around his finger	Sam is bandaging his finger with a cloth
*Sam is covering a towel over the chair	Sam is covering the chair with a towel
*Sam is smothering a pillow over the woman	Sam is smothering the woman with a pillow

3. Alternating

Sam is spraying cleanser on the window	Sam is spraying the window with cleanser
Sam is loading boxes into the trunk	Sam is loading the trunk with boxes
Sam is smearing jam onto the bread	Sam is smearing the bread with jam
Sam is stuffing clothes onto the bag	Sam is stuffing the bag with clothes
Sam is sprinkling salt on the popcorn	Sam is sprinkling the popcorn with salt
Sam is wrapping a towel around the bowl	Sam is wrapping the bowl with the towel

'Removing' sentences

1. Theme-object only

Sam is stealing a dollar from the wallet	*Sam is stealing the wallet of a dollar
Sam is taking a magazine from the table	*Sam is taking the table of a magazine
Sam is grabbing the orange from the woman	*Sam is grabbing the woman of the orange
Sam is snatching the purse from the woman	*Sam is snatching the woman of her purse
Sam is lifting the lamp off the table	*Sam is lifting the table of the lamp
Sam is removing a book from the shelf	*Sam is removing the shelf of a book
Sam is separating the darks from the whites	*Sam is separating the whites of the darks
Sam is wiping grease off the stove	*Sam is wiping the stove of grease
Sam is brushing crumbs off the table	*Sam is brushing the table of crumbs
Sam is rubbing fingerprints off the doorknob	*Sam is rubbing the doorknob of fingerprints

2. Source-object only

*Sam is robbing $7 from the woman	Sam is robbing the woman of $7
*Sam is depriving the drink from the woman	Sam is depriving the woman of a drink

3. Alternating

Sam is clearing the papers from the table	Sam is clearing the table of papers
Sam is emptying the clothes from the basket	Sam is emptying the basket of clothes
Sam is draining water from the cooler	Sam is draining the cooler of water

Appendix C

Sentences used in the grammaticality judgement test in Experiment 3, organized according to type of construction. The order of sentences in the test followed an intransitive–transitive–intransitive–etc. pattern with grammatical and ungrammatical sentences distributed randomly.

Intransitive only

*Sam laughed the joke	Sam laughed
*Sam slept the chair	Sam slept
*Sam arrived the house	Sam arrived
*Sam sneezed the tissue	Sam sneezed
*Sam fell the stairs	Sam fell

Transitive only

Sam devoured the apple	*Sam devoured
Sam opened the door	*Sam opened
Sam found a wallet	*Sam found
Sam crushed the can	*Sam crushed
Sam tickled the child	*Sam tickled

Optional transitivity

Sam ate the hotdog	Sam ate
Sam watched the game	Sam watched
Sam applauded the singer	Sam applauded
Sam drove the car	Sam drove
Sam painted the wall	Sam painted