CHAPTER

21

Real-time Sentence Processing in Aphasia

Lewis P. Shapiro
Beth A. Levine

This work merges linguistic issues that have to do with how verbs are represented with processing issues that have to do with the way in which verbs are used during on-line sentence comprehension in both normal and aphasic adults. The idea here is the following. The mental lexicon contains information about the individual words of a language — at least their phonological form (what they sound like), grammatical category (verb, noun), semantic and conceptual structure (what they refer to in the real world), and crucially, the linguistic environments each lexical item is allowed to enter. For example, consider the verb *regret:* You can say "Joelle regretted the decision" and "Joelle regretted that the decision was made," but you cannot say "Joelle regretted to the woman," this last sentence being ungrammatical in English. These selective sentential environments are represented as part of *regret*'s entry in the lexicon. The mental lexicon is thus one component of the stored linguistic knowledge of a language user.

The normal sentence processing system exploits this knowledge to yield an interpretable sentence. One operation of the system involves simply activating information set against an item's entry in the lexicon. Though there is plenty of information stipulated by linguistic theory that is part of a lexical entry, it is by no means a given that all this information is used by the sentence processing system. Thus, we can ask whether any particular kind of representation measurably affects sentence processing or is, in fact, "psychologically real."

Why would we want to look at the activation of verbs and their role in sentence processing in *aphasia?* Verbs are a problem so far as some Broca's aphasic patients are concerned. In nonfluent speech, verbs are often omitted or simplified (Lapointe, 1985). In naming, action naming is often more impaired than object naming (e.g., Mitchum and Berndt, 1987). In agrammatic comprehension, verbs have been implicated in deficits involving complex sentences like passives and object relative clauses. In regard to this latter problem, Schwartz, Linebarger, Saffron, and Pate (in press) as well as Grodzinsky (in press) have claimed that agrammatic Broca's patients have difficulty using a verb's thematic roles, like agent and patient, for sentence interpretation. More generally, both Swinney, Zurif, and Nicol (in press) and Milberg and Blumstein (1981) have found that lexical access in agrammatic Broca's aphasia no longer operates in a normally fast-acting and automatic fashion. It is the purpose of this study to see if this general problem with verbs and the problem with lexical access can be extended to include the real-time activation of verbs during sentence comprehension.

First, we will describe how verbs are represented in our mental lexicon and then quickly review the results from one of a series of psycholinguistic experiments on normal subjects. We will then describe an experiment using nonfluent agrammatic Broca's aphasic subjects, fluent aphasic subjects, and normal controls that attempts to investigate that part of the verb's lexical entry that affects on-line sentence comprehension.

LINGUISTIC PERSPECTIVE

Verbs can be represented in the lexicon in a number of different ways, and particular linguistic theories can differ as to the structure of these lexical entries. These theories agree for the most part that lexical entries must include both syntactic and semantic information. Syntactic information is captured by the theory of strict categorization (Chomsky, 1981). At least a first-order approximation of semantic information is captured by what is know as predicate-argument structure (Grimshaw, in press). Ultimately, we want to find out which type of representation — strict subcategorization or predicate-argument structure — will have a measurable effect on sentence comprehension.

Strict subcategorization captures the fact that different verbs select for different phrases or clauses — called complements — regardless of their semantic content. A verb is said to subcategorize for a complement if that complement can occur within the entire verb phrase (VP) in which the verb appears. Verbs can subcategorize for different phrases, like a noun phrase (NP) or a prepositional phrase (PP); they can subcategorize for clauses (S′), and they can select for combinations of these. For example, Table 21-1 shows some strict subcategorization entries for different verbs.

In 1, the verb *fix* only allows an NP, as in the sentence "John fixed the bike," where the NP "the bike" occurs within the entire verb phrase "fixed the bike." In 2, the nonalternating dative verb *donate* selects for the

TABLE 21-1. STRICT SUBCATEGORIZATION

Lexical entries		*Sentence examples*
1. *fix*	(_NP)	John ($_{VP}$ fixed [$_{NP}$ the bike])
2. *donate*	(_NP	John ($_{VP}$ donated [$_{NP}$ the clothes])
	NP PP)	John ($_{VP}$ donated [$_{NP}$ the clothes] [$_{PP}$ to the Scouts])
3. *send*	(_NP	John ($_{VP}$ sent [$_{NP}$ the clothes])
	NP PP	John ($_{VP}$ sent [$_{NP}$ the clothes] [$_{PP}$ to the Scouts])
	NP NP)	John ($_{VP}$ sent [$_{NP}$ the Scouts] [$_{NP}$ the clothes])
4. *accept*	(_NP	John ($_{VP}$ accepted [$_{NP}$ the decision])
	S′)	John ($_{VP}$ accepted [$_{S'}$ that the decision was made])

environments NP, as in "John donated the clothes," and also allows an NP followed by a PP, as in "John donated the clothes to the Boy Scouts." In this latter sentence, the NP — "the clothes" — and the PP — "to the Boy Scouts" — fall within the entire verb phrase "donated the clothes to the Boy Scouts." Consider also the alternating dative verb *send* in 3. *Send* allows an NP, an NP PP, as does *donate,* yet in addition allows a double-NP construction.

Another example is the verb *accept,* shown in 4. *Accept* allows an NP, as in "John accepted the decision," and a sentential clause, as in "John accepted that the decision was made." The clause "that the decision was made" falls within the entire verb phrase. The syntactic form of the complements of a verb is learned by the language user and thus forms part of the verb's entry in the mental lexicon.

It is accepted also that verbs are represented with their predicate-argument structure. Each complement of a verb is viewed as an argument of the verb and is assigned a thematic role like agent, goal, or theme, taken from a universal list of such roles. Very generally, these thematic roles characterize the sentence in terms of the participants involved in an action or state described by the verb, that is, in terms of "who did what to whom." Predicate-argument structure can thus be viewed as a first pass at a semantic description of a sentence.

Like much of the work in theoretical linguistics, the present work does not concern itself with the actual content of these thematic roles, but instead variables are substituted for the roles. Table 21-2 contains examples of predicate-argument structure entries.

For example, consider again the transitive verb *fix.* It can be represented by a two-place argument structure with the variables x and y, as shown in number 1: "John fixed the bike." Here two arguments are set in relation to each other by the predicate *fix.* The subject NP — "John" — is linked to the x-argument, and the object NP — "the bike" — is linked to the y-argument. Consider again the verb *donate,* show in number 2; "donate" allows both a two-place argument structure, as in "John donated the clothes," and a three-place structure, as in "John donated the clothes to the Boy Scouts." In this latter sentence, "John" is linked to the x-argument, "the clothes" to the y-argument, and "Boy Scouts" to the z-argument. *Send* also allows either a two- or three-place argument structure, though the arguments can be linked to different phrases in the case of the three-place structure. This is shown in number 3.

Finally, following the theoretical linguistic work of Grimshaw (1979), verbs that allow sentential clauses can also be represented by complex semantic types linked to verbs' arguments. These semantic types are known as propositions (the familiar *that*-clauses), exclamations, and interogatives, and are represented as the variables P, E, and Q, respectively.

TABLE 21-2. PREDICATE-ARGUMENT STRUCTURE

Lexical entries				***Sentence examples***
1. Transitive	*fix*	(_NP)	(x,y)	(John $_x$) fixed (the bike $_y$)
2. Nonalternating datives	*donate*	(_NP	(x,y)	(John $_x$) donated (the clothes $_y$)
		NP PP)	(x,y,z)	(John $_x$) donated (the clothes $_y$) (to the Scouts $_z$)
3. Alternating datives	*send*	(_NP	(x,y)	(John $_x$) sent (the clothes $_y$)
		NP PP	(x,y,z)	(John $_x$) sent (the clothes $_y$) (to the Scouts $_z$)
		NP NP)	//	(John $_x$) sent (the Scouts $_y$) (the clothes $_z$)
4. Two-complements	*accept*	(_NP	(x,y)	(John $_x$) accepted (the decision $_y$)
		S′)	(x,P)	(John $_x$) accepted (that the decision was made $_P$)
5. Four-complements	*discover*	(_NP	(x,y)	(John $_x$) discovered (the keys $_y$)
		S′)	(x,P)	(John $_x$) discovered (that the keys were missing $_P$)
			(x,E)	(John $_x$) discovered (what a jerk he was $_E$)
			(x,Q)	(John $_x$) discovered (whether the keys were missing $_Q$)

Verbs that allow sentential clauses can select for any, or all, of these complex arguments. So, for example, consider again the verb *accept,* which we call a two-complement verb. In number 4, *accept* is shown to allow both a simple two-place argument structure of the form: (x,y), and one of the complex arguments, an (x,P), as in the sentence "John accepted that the decision that was made." "That the decision was made" is considered a proposition argument (represented by the variable P) and is set in relation to the x-argument "John" by the predicate. On the other hand, the verb *discover* allows the simple two-place structure, as well as all *three* complex arguments, as shown in number 5. For example, in the sentence "John discovered whether the keys were missing," "whether the keys were missing" is considered an interrogative argument, represented by the variable Q. Importantly, in all cases containing a complex argument, the argument is linked to a sentential clause in the syntax. That is, there is no way that the theory of strict subcategorization can capture these different semantic types.

In summary, both strict subcategorization and predicate-argument structure form part of a verb's lexical entry, thereby roughly describing both the syntactic and general semantic character of a sentence in which the verb is contained.

PROCESSING PERSPECTIVE

With this linguistic background out of the way, we can now ask the following questions: Is it the case that strict subcategorization, predicate-argument structure, both, or neither affects sentence processing in normal subjects? And is it the case that brain damage selectively impairs the processing of these representations? If so, then we have evidence that bridges the gap between linguistic issues and cognitive and neuropsychological ones.

To seek a relation between verb representation and sentence processing, we have invoked the notion of *verb complexity.* By strict subcategorization complexity, we mean that the more subcategorizations for a verb, the more complex the verb is. By contrast, in terms of predicate-argument structure, the more argument structure possibilities a verb allows, the more complex the verb is. Any two verbs can differ, in principle, in terms of strict subcategorization or argument structure complexity.

For example, compare the verbs in 2 and 3 in Table 21-2. The verb *donate* allows two possible subcategorizations, an NP and an NP PP. The verb *send* allows three possible subcategorizations, an NP, an NP PP, and an NP NP. Thus, from a strict subcategorization standpoint, alternative datives like *send* are more complex than nonalternating datives like *donate,* yet both these verb types are the same so far as argument structure complexity is concerned; both allow a two- (x,y) and three-place (x,y,z) argument structure possibility.

On the flip side, there are verbs that have the same strict subcategorization complexity but differ in terms of argument structure. So, for example, the verbs *accept* and *discover* shown in numbers 4 and 5 in Table 21-2 have the same subcategorization complexity — each allows an NP and an S′. Yet four-complement verbs like *discover* are more complex from an argument structure standpoint than two-complement verbs like *accept.* Complexity allows us to test which representational type — if any — affects sentence processing.

Recently, Shapiro, Grimshaw, and Zurif (1987, 1988) attempted to assess which type of complexity — strict subcategorization or predicate-argument structure — affects sentence processing in normal subjects. We placed verbs of the types like those shown in Table 21-2 into similar, simple NP-V-NP sentences. Example sentences are shown in Table 21-3.

We presented these sentences over headphones to normal listeners along with a complex secondary task designed to measure local sentence processing load. The secondary task was a cross-modal lexical decision (CMLD). Sentences are presented over headphones, and immediately after the verb, a string of letters appears on a screen. The subject, while attempting to understand the sentences, must decide as quickly and as accurately as possible whether the visual probe — the letter string — forms a word in English, and reaction times to this lexical decision are recorded. Critically, when the probe forms an English word, it is not related to the sentence or does not continue the sentence in any meaningful way.

There are several assumptions underlying this task, the details of which are not within the scope of this chapter. These assumptions yield the following: As the verb becomes more complex, the time taken to make the secondary lexical decision in the immediate vicinity of the verb increases. In other words, the task taps local sentence processing overload.

We presented these test sentences, and various foils, over headphones to normal listeners with this secondary lexical decision task. Again, all the sentences were similar in form; only the verb differed as shown in Table 21-3. The results of one of a series of experiments with normal subjects are also shown in Table 21-3. The data reveal that verb representation indeed affects on-line sentence comprehension. Furthermore, it is a verb's predicate-argument structure that is relevant to sentence processing and not strict subcategorization. That is, verbs that were more complex in

TABLE 21-3. EXAMPLE SENTENCES USED IN VERB COMPLEXITY STUDY WITH NORMAL SUBJECTS AND MEAN REACTION TIMES (IN MS) TO THE SECONDARY TASK (FROM SHAPIRO ET AL., 1987)

Verb types	*Sentences*	*Reaction times*
Transitives	The boy fixed # the bike.	626
Nonalternating datives	The boy donated # the clothes.	672
Alternating datives	The boy sent # the bike.	679
Two-complements	The boy accepted # the clothes.	676
Four-complements	The boy discovered # the clothes.	731

# Indicates the presence of a secondary task.

terms of argument structure — that had more argument structure possibilities — yielded longer reaction times to the lexical decision than verbs that were less complex. So, for example, nonalternating (672 ms) and alternating datives (679 ms) yielded statistically similar reaction times to the secondary task, and these two verb types have the same argument structure representations. Yet four-complement verbs (731 ms) yielded significantly longer reaction times than two-complement verbs (676 ms), the former being more complex in terms of argument structure than the latter. Importantly, for argument structure to exert its influence on sentence processing as shown in this experiment, it would seem necessary that *all* argument structure possibilities for a verb be momentarily activated in the vicinity of the verb, even those argument structure possibilities that may not be relevant to the actual sentence being heard.

THE PRESENT STUDY

With this work with normals we now know that the argument structures of verbs seem to measurably affect sentence processing. But what about sentence processing in aphasia? In particular, can the "verb problem" in agrammatic Broca's aphasia be extended to include the real-time processing of verbs and their arguments during sentence comprehension?

Subjects for the aphasia study included seven agrammatic Broca's aphasics, four fluent aphasics, and 10 normal controls (this study should be considered preliminary given the small number of subjects in the fluent group). The Broca's subjects speech was effortful and contained few grammatical function words as compared to nouns and verbs. Yet some verbs were omitted as compared to nominals and were simplified. These Broca's subjects were also agrammatical in comprehension. For example, on independent point-to-point picture matching tasks, and sentence anagram tasks, these patients did not perform at above chance levels on reversible passive and relative clause sentences, yet performed well above chance on reversible actives. The fluent aphasic subjects consisted of three Wernicke's and one conduction aphasic. The fluent group was included for two reasons. First, we wanted to make sure that any interesting patterns that have to do with processing verbs during sentence comprehension would not be a consequence of just any kind of brain damage. And second, there have been claims in the literature — most notably made by both Goodglass and Menn (1985) and Peach, Canter, and Gallaher (in press) — that the same performance limitations characterize both Broca's and some of the fluent aphasias. These claims rest on demonstrations that both groups yield similar performance profiles on comprehension tasks. However, such demonstrations do not rule out the possibility that the processing *antecedents* to these performance limitations may be quite different for each group. Thus, we included a group of fluents to investigate this possibility.

We placed the verb types into simple NP-V-NP-PP sentences as shown in Table 21-4, and presented these over headphones to the subjects, along with the visual lexical decision task. This time, however, in addition to placing the visual probe immediately after the verb, we also placed probes, in a separate set of similar sentences, downstream from the verb, in the immediate vicinity of the preposition (note also that we included probes — as foils — in other parts of the sentences in order to diminish any expectations on the part of the subjects).

Placing the probe downstream from the verb sought to investigate whether the verb complexity effect found in the vicinity of the verb would be absorbed, or disappear, as the sentence unfolded over time. To make sure that the subjects were attending to the sentences for meaning, we randomly stopped the tape after a sentence on 20 percent of the trials and asked subjects to indicate the meaning of the sentence they just heard. We emphasize here that all the subjects could do this task as evidenced by near-perfect performance on this comprehension check, as well as below 15 percent errors on the secondary lexical decision task.

The results of this study are shown on the graphs in Figure 21-1. Two separate sets of analyses were performed, one on the "simple" verbs (i.e., transitives, nonalternating, and alternating datives) and one on the "complex" verbs (i.e., two- and four-complement verbs). We performed two separate sets of analyses instead of one overall ANOVA because the complex verbs were placed in sentences that were structurally distinct from those sentences in which the simple verbs were placed, thus a comparison across all five verb types could not be made under a single analysis. For both the simple and complex verbs, mixed design ANOVAs were performed, with the group as the between-subjects variable (normal, agrammatic Broca, fluent) and verb type and probe position (verb, preposition) as the within-subjects variables. Both analyses found statistically significant interactions between group and verb type, $p < .05$. Repeated measures ANOVAs, with both verb type and probe position as within-subjects variables, were then conducted for each subject group.

First, the normal data both replicate and extend that of Shapiro and colleagues (1987). The analyses revealed a statistically significant interaction between verb type and probe position, $p < .05$, for both the simple verbs and the complex complement verbs. Tests for simple effects of verb type at each probe position found that those verb types that were more complex in terms of argument structure (e.g., four-complement verbs — 1084 ms) yielded statistically significantly longer RTs on the lexical decision task when the probes were placed in the immediate vicinity of the verb than verbs that were less complex (e.g., two-complement verbs —

TABLE 21-4. EXAMPLE SENTENCES FROM APHASIA STUDY (SHAPIRO AND LEVINE, 1988)

Verb type	*Sentences*
Transitives	The man fixed # the old car with # a stick.
Nonalternating datives	The man donated # the old car to # the Scouts.
Alternating datives	The man sent # the old car # to the woman.
Two-complements	The man accepted # that the coins in # the vault were missing.
Four-complements	The man remembered # that the coins in # the vault were missing.

# Indicates presentation of a secondary task.

1012 ms), $p < .05$. Thus, all possible argument structure arrangements for a verb were momentarily activated. Strict subcategorization did not yield such patterns. But when the probes were placed well after the verb, in the vicinity of the preposition, these complexities were no longer observed. That is, no statistically significant differences were found among any of the verb types (e.g., two-complement verbs — 1052 ms, four-complement verbs — 1030 ms). The temporal unfolding of the sentence seems to have absorbed the cost associated with verb complexity. This may mean that only one of the multiple argument structure possibilities for any verb remains active when the sentence processing system is tapped well beyond the appearance of the verb.

The RT patterns for the agrammatic Broca's subjects were the same as those for the normal subjects, although the relative reaction times were greater. A repeated measures ANOVA revealed a statistically significant verb type × probe position interaction, $p < .05$. Verbs that were more complex in terms of argument structure (e.g., four-complement verbs — 1222 ms) yielded statistically significantly longer RTs to the lexical decisions than verbs that were less complex (e.g., two-complement verbs — 1120 ms), $p < .05$, when the sentence was tapped in the immediate vicinity of the verb. Thus, all possible argument structures for a verb were momentarily activated. Again, however, these statistically significant effects disappeared when the sentences were tapped well after the verb, at the preposition (e.g., two-complement verbs — 1198 ms, four-complement verbs — 1193 ms). So the problems that agrammatic Broca's patients have with the thematic rules of verbs during sentence comprehension (show by both Grodzinski and Schwartz and colleagues), and the general lexical access deficit (as claimed by Swinney et al. and Milberg and Blumstein, 1981) do not seem to extend to the real-time processing of verbs

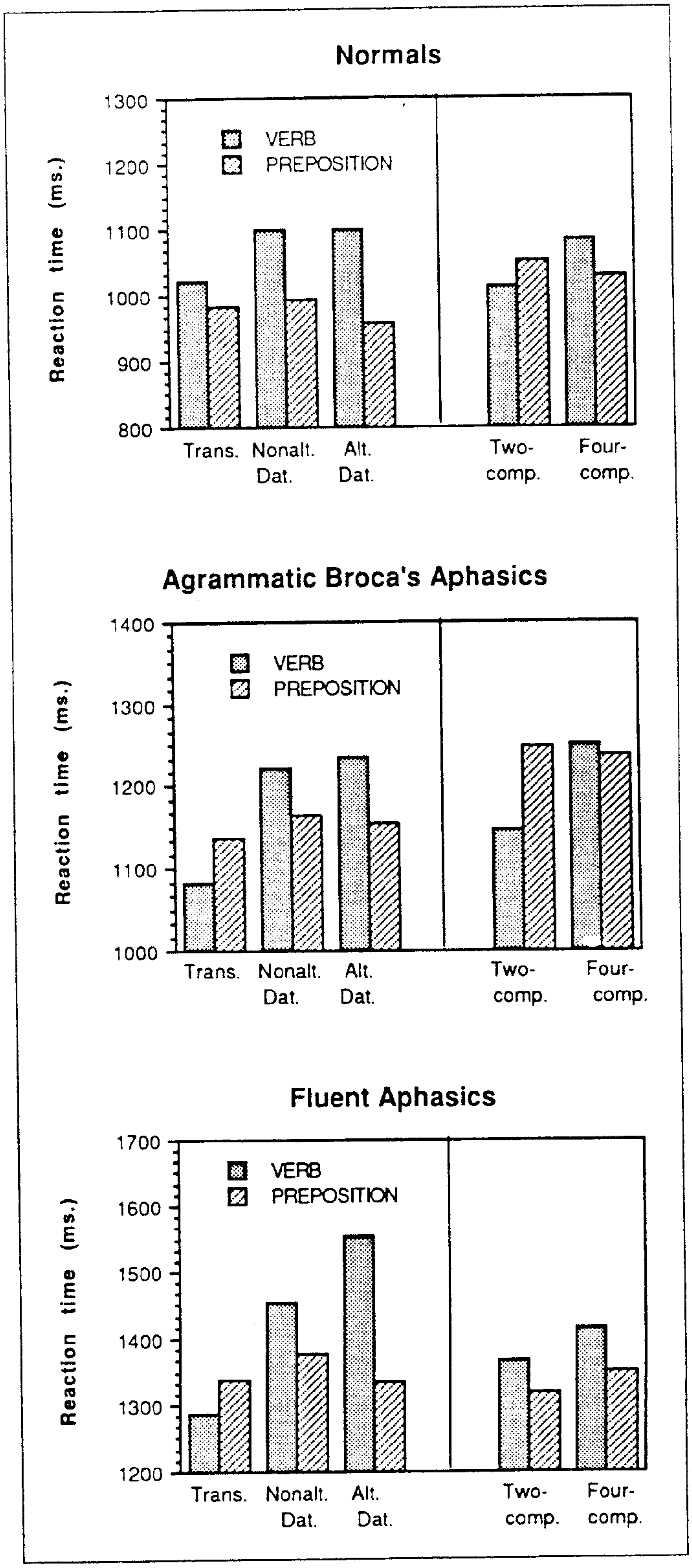

Figure 21-1. Reaction times to secondary task for three subject groups.

during sentence comprehension. In fact, the structural information about verbs that is represented in the mental lexicon and the processing device that acts on this information seem perfectly intact in these patients.

Finally, the fluent group did reveal different patterns as compared to both normal and Broca's subjects. Though the repeated measures ANOVA for the simple verbs found a statistically significant interaction between verb type and probe position, $p < .01$, a test for simple effects of verb type at probe position found that verbs that were more complex in terms of *strict subcategorization* (e.g., alternating datives — 1556 ms) yielded statistically significantly longer RTs to the secondary task than verbs that were less complex (e.g., nonalternating datives — 1456 ms), $p < .05$, when the probes were presented in the vicinity of the verb. Again, the statistically significant differences among the verb types disappeared when the probes were presented downstream in the vicinity of the preposition. Importantly, however, those verb types differing in *argument structure* did not yield statistically significantly different results when the probes were placed in the vicinity of the verb, unlike both the normals and the agrammatic Broca's subjects.

Thus, these fluent aphasic subjects do not seem to be sensitive to the argument structure information of verbs. This is an interesting result if one considers that argument structure is a first-order approximation of the semantic information carried in a sentence. These fluent aphasic patients seem to have a deficit that involves activating the lexical information about verbs that has more to do with "semantics." We must now investigate if such a deficit found during on-line sentence processing will also extend to the ultimate sentence comprehension problems found with these patients on off-line tasks and outside the laboratory and clinic. We are presently investigating this.

In summary, we found the following: (1) The argument structure information represented with verbs in the lexicon affects the processing of sentences in normal subjects. (2) All argument structure possibilities are momentarily activated in the vicinity of the verb during sentence comprehension. Yet as the sentence continues to unfold over time, this exhaustive activation disappears. This might mean that though all argument structure possibilities are activated at the verb, only one remains active as the sentence continues to unfold over time. (3) For agrammatic Broca's patients, the device that activates the verb and all of its argument structure possibilities operates normally. Thus, the problems these subjects show with verbs in both production and comprehension cannot be explained by reference to the real-time processing of information represented with verbs in the lexicon. (4) Fluent aphasic patients appear not to be sensitive to the argument structure information presented with verbs and therefore may have a semantic-like sentence processing deficit.

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DISCUSSION

Q = question; A = answer; C = comments.

Q. I'm interested in the third graph; what were the fluent aphasics sensitive to?

A. Strict subcategorization. We were surprised by this. But let's look at the first side of the coin. You have to ask the question: Why is argument structure affecting sentence processing in normal subjects? There is evidence from linguistic theory — having to do with word formation rules — that lexical entries are organized by the argument structure of verbs, and not strict subcategorization. Therefore, it makes a lot of sense that the processing system would operate on the organizing principle of the lexicon-argument structure. But the Wernicke's data do not fit such a theory. What we'd love to be able to say is that these patients are just not sensitive to argument structure and isn't that interesting because argument structure is more tied to "semantics." As you pointed out, there's another side to the coin; these patients seem to be sensitive to strict subcategorization, and that's a mystery. Though these are preliminary results, using our particular theoretical perspective, these data to date are difficult to interpret.

Q. Could you talk a little bit about how you analyzed the data statistically to get to the graphs?

A. We first performed an overall ANOVA with the three subject groups, the verb types, and the probe positions as the independent variables, and with reaction times to correct lexical decisions as the dependent variable. We found interactions between subject group and verb type. We then performed individual ANOVAs for each subject group and found significant interactions between verb type and probe position. Finally, we tested for simple effects of verb type at each probe position and found, for the normals and agrammatic Broca's patients, statistically significant RT differences among verb types differing in argument structure, like the two- and four-complement verbs, but no RT differences between verb types differing in strict subcategorization.

Q. Could you speak to the reaction time differences between the normal and the Broca's subjects? For example, I'm interested in the two- versus four-complement verbs. For the Broca's subjects, the difference approaches 100 ms, yet for the normals, the difference is around 70 ms.

A. We are not really interested in the absolute reaction times for the different subject groups but instead are interested in the reaction time patterns. So, the only thing I have to say about the differences you have pointed out is that the Broca's subjects are slower on the lexical decision tasks than the normals, yet still exhaustively activate the relevant information represented with the verb.

C. With regard to the Wernicke's data that you find surprising, might I suggest that if you do not take a competence-based linguistic theory approach, but instead take a performance-based approach in which grammatical frames behave according to psychological laws of frequency, recency, size of unit, and so on, then I think your mystery becomes less mysterious. The difference between the transitives and datives could reflect two simple facts. One is that transitives and datives are generally more frequent phrase structure types than the longer range complement structures. The second point is the size of the unit you are manipulating, how far downstream you have to project, how much material you have to activate and keep in mind. To project or plan a four-complement structure is very different than the kind of rather local quick projection you'd have to make with a transitive or dative verb. So, on performance grounds, you might expect to get the dissociation that you got on what the Wernicke's were sensitive and not sensitive to.

A. Yes, except that all the verbs were in the same sentence frames, NP-V-NP-PP.

C. But if you look across spoken discourse at the frequency of phrase structure types, not necessarily specific verbs, you find that certain kinds of phrase structure types may be constructed more often in real speech. There is evidence from Bock and others that suggest that phrase structure frames obey psychological laws; they can be primed, they show recency effects, they show frequency effects, and so on. And you are tapping right at a verb that in one case may be projecting a frequent local structure and in another condition you're tapping at a verb that is projecting or setting up expectancies for a less frequent and larger, perhaps psychologically harder to manipulate structure. There may be a performance account that could complement the linguistic account you use for the other data.

A. Yes, but all the verb types allow, among other possibilities, what you might consider to be the more frequent phrase structure, the direct object NP. On your account, a subject may be projecting, at the point of the verb, any verb, the same frequent local structure, yet we still get differential results for the different verb types. I agree that activating a four-complement structure is very different from activating a transitive or dative and has to do with how much material you have to activate. In any event, a performance model of the sort you are implying has the same problem as the exhaustive access model I am proposing. It does not explain why the Wernicke's patients, and not the agrammatic Broca's patients, are sensitive to strict subcategorization and thus perform differently than normal controls.

Q. You've built a hierarchy of verb complexity. Would you care to speculate about how verb complexity might be clinically applied?

A. Many researchers and clinicians speak to sentence complexity, yet never explicitly define what they mean. With the kind of work I have been talking about, we now have an idea of how verbs and their structural properties enter into the notion of sentence complexity. We've recently used these kinds of verb distinctions — those that have to do with argument structure complexity — in the c-ViC program, a computer-based visual communication program run on the MaC that many of you may be familiar with. Basically, we've run two aphasic patients on an experiment using c-ViC, and so far it looks like the linguistic distinctions that we find are relevant to on-line sentence processing in both normal and Broca's subjects seem also to be relevant in this artificial visual language task, which is, in fact, a rehabilitation tool. There is much more that can be said about this particular experiment, the results, and their interpretation. The bottom line might be that when working with aphasic patients, you might want to consider the kinds of sentences you are producing and eliciting and specifically consider the verbs and their potential argument structures. Some verbs are less complex than others, yet the sentence frames in which they are contained may be the same. Whether or not these data have practical clinical significance beyond using c-ViC or outside the experimental laboratory remains to be seen.