with the verb and the number of different argument structure frames associated with the verb) on such lexical decisions.' In this interference task, lexical decisions were made to a word presented immediately after hearing the verb in the sentence; these words were unrelated to anything in the sentence. The amount of time to make such a lexical decision was deemed to reflect the processing load presented by the verb in the sentence, under standard dual-task methodology assumptions. In his experiment, Shapiro employed five different verb. types (transitive, datives, alternating datives, two-complement and four-complement verbs) matching, in some cases, the number of subcategorization frames and varying the number of argument structures, and, in other cases, matching the number of argument structures but varying the number of subcategorization frames.

The results of these studies demonstrated no consistent effect of the number of subcategorizational frames carried by the verb on interference reaction times, but they did show a consistent effect of argument structure complexity on reaction times; transitives-those verbs with the fewest argument structures-showed significantly less interference than datives and alternating datives, and two-complement verbs-again, with fewer argument structures-showed significantly less interference than four-complement verbs. These seminal studies led Shapiro and colleagues to postulate that argument structures are stored and accessed directly with the verb, and, conversely, that subcategorizational relations are not directly accessed with verb representations.'

These studies led to a short but lively debate in the literature concerning sensitivity of methodologies (and other methodological issues) following studies by Schmauder (1991) and Schmauder et al. (1991) which found no obvious evidence of an argument structure complexity metric using several different experimental paradigms. It is not entirely apparent why these two groups of researchers found conflicting results (although many hypotheses have been set forth). However, the basic effect has been effectively replicated a number of times now, and it appears to certainly exist in some form.

' Argument structure frames consist of variables that have been abstracted over thematic roles. For example, the thematic roles of (Agent, Theme, Goal) are represented as the argument structure: (x,y,z). Under this approach, argument structures for the same set of thematic roles all have the same argument structure. Thus, datives and ditransitives under this account are both represented as (x,y,z), which are translated as (agent, theme, goal), but a structure which would be translated as (agent, theme, locative), for example, as in the case of *put,* is represented as (x,y,z), and is considered to be a different argument structure.

j In a second experiment, Shapiro and colleagues looked at whether it was the maximum number of arguments within all argument structure possibilities that was driving their effort of argument structure complexity, and found no evidence to support such an hypothesis.

In what follows, we present evidence suggesting that a type of verb complexity somewhat different from that originally posited by Shapiro et al. (1987) actually underlies what Shapiro found. We suggest that while Shapiro was fundamentally correct concerning the *general* type of information stored and accessed with verbs in discourse, his results are better accounted for in terms of the number of argument (participant) roles associated with the central sense of the verb than in terms of the number of argument structures associated with a verb. We posit that in this different interpretation may lie the basis for understanding some of the lack of ease in replicability of the effect.

Our hypothesis, then, is that the thematic roles related to the central sense of a verb are stored and accessed with that verb in ongoing comprehension. We will call these "participant roles" following Goldberg (1992, 1995). For example, a verb such as *give* is a three-participant role verb involving the *giver, givee,* and *thing given.* The verb *kick,* on the other hand, is understood as a two-participant role verb, involving the *kicker* and *kickee* (as in *The boy kicked the ball).* Note that although *kicking* may involve a recipient *(to Bob),* it is not crucial to the central sense of the verb. We are hypothesizing that the complexity metric actually reflected in the Shapiro et al. (1987) results is not the maximum number of internal arguments structures for a verb (variables which are calculated over thematic roles) but, instead, the number of actual participant (thematic) roles that are associated with the central sense of the verb.

REEXAMINATION OF EXISTING DATA:

In order to establish the empirical plausibility of our proposal, we first wish to briefly consider (and informally reanalyze) the original categorization of verbs into subcategorization frames and argument structure types made by Shapiro et al. (1987). At the time the work was done, the state of the field was such that it seemed fairly self-evident that certain verbs were transitive, dative, etc. However, as more consideration has been given to such categorizations in recent years, at least two issues are worth some further consideration. (We present these with all due respect for the work that was done at the time, pioneering work, of necessity, will be changed and shaped as theory progresses-what was important about the pioneering work was its original approach and insight, which remains unchallenged). First, not all subcategorization frames and argument structures were included in the totals Shapiro et al. (1987, 1989) used for each verb. This is relevant because the conclusions Shapiro and colleagues reach are intended to reflect the total argument structure potential of each verb. Thus, details such as the

problem of differing dialects and ideolects among listeners may be a legitimate cause for concern. For example, Shapiro classified *return* as a nonalternating dative, although the *Oxford Advanced Learner's Dictionary* (Hornby, 1989, p. 1082) classifies it as an alternating dative as well (e.g., *She returned him a book).* As another example, *donate* is included in the class of nonalternating datives, although the alternating dative form, as in the sentence *I donated the library some books,* is perfectly fine for many speakers.

Second, not all the senses of a verb were taken into account in these original categorizations. For example, the verb fir, which was categorized as a transitive verb, also has a ditransitive structure when it means "to make," as in *Fix me a sandtivich.* Another example is the verb *secure,* which can mean "succeed in getting." In this sense, it is not only used transitively, it can also be used as an alternating dative, as in *I secured her the tickets* and *I secured the tickets for her.* In the original studies, this verb was classified as transitive (which, of course, is certainly likely to be its most common usage). Overall, however, since there are only five or six verbs employed in each class, the possibility that even one verb did not belong in a particular class might have a relatively large impact on the variability of results. Additionally, ideolect differences existing in different testing locals might enter strongly into an interaction with these concerns.

Given these issues with verb classification, we decided to reexamine the Shapiro et al. experiments to determine if there was any hint in these data that it might be the number of roles, per se, that underlay their findings. To this end we first collected data from 40 subjects on the number of participant roles associated with verbs, including those in the Shapiro et al. studies. (Methods involved in this off-line test are discussed in detail in the following section.) Our goal here was to find two subsets of verbs from the Shapiro et al. studies that could be clearly classified as having different numbers of participant roles from among those verbs examined by Shapiro and his colleagues. Of the 23 verbs that Shapiro et al. used, five of them were considered by these 40 subjects to be verbs that entailed three participants. We then matched these verbs for length and frequency with other verbs that the subjects rated as entailing only two-participant roles.. (When exact matches could not be chosen, length and frequency were chosen so as to work against the participant role complexity hypothesis. Thus verbs with fewer participant roles were longer and less frequent than those with more participant roles.) The resulting matched verbs are shown in Table I. These 10 verbs were the only relatively close matches possible from the original 23 verbs. As can be seen, despite being shorter in length and higher in frequency (which should predict less interference on an interference task), the three-participant role verbs produced an average of 27-ms more interference than the two-participant role verbs. While highly speculative (and essentially impossible to test substantively for significance), the trend seen in these data suggested to us that the participant role complexity hypothesis might be worth further investigation, and indeed might underlie, at least partially, both the manipulations and results of Shapiro and his colleagues.

Table 1. Participant Role (PR) Complexity and Associated Reaction (Interference) Time (RT) Associated with Matched Verbs from the Studies of Shapiro and Colleagues°

2 PR	Length	Freq	RTI	RT2	3 PR	Length	Freq	RTI	RT2
fix	3	14	615	599	lend	4	4	673	633
solve	5	20	640		send	4	74	666	684
adopt	5	13	640		donate	6	3	657	687
measure	7	91	633	638	hand	4	431	618	
exhibit	7	25	638	593	entrust	7	2	599	
AVG	5.4	32.6	625		AVG	5	105	652	

2 PR = two-participant role; 3 PR = three-participant role; Freq = frequency; RTI = Peaction time l; RT2 = reaction time 2; AVG = average. If a verb has more than one reaction time value, this indicates it appeared in more than one study; both reaction times were used in these cases.

As a result, we decided to run a study directly contrasting the argument structure complexity hypothesis of Shapiro et al. (1987, 1991) with the participant role complexity hypothesis, utilizing the same on-line interference (dual-task) technique employed by Shapiro et al. (1987). This task involves the standard assumptions of dual cognitive tasks competing for the same limited resources (see, e.g., Clifton, Frazier, & Connine, 1984; Foss & Jenkins, 1973; Shapiro et al., 1987). In the present study, the method of holding one of the two variables constant and varying the other was employed to determine if interference reaction time would be shown to be a function of one, both, or none of these variables at the point of access of the verb in a sentence.

METHODS

Pretests

In order to obtain objective categorizations of the verbs to be examined in this study, 80 college-aged subjects (native English speakers with no exposure to any language other than English before the age of 6 and with no history of brain damage or learning disabilities) participated in evaluations of participant-role and argument-structure classifications. In this study, 100 verbs were evaluated. In one condition, 50 verbs were used in the argument structure evaluations and 50 in the participant role evaluations. In

a second condition, the verbs were switched so that verbs previously in the argument structure evaluation were in the participant role evaluation and visa versa. (Note that Shapiro and colleagues' verbs were included in these evaluations, as mentioned above.) Each subject participated in only one of the two conditions (40 in each) and thus each subject saw each verb only once. All subjects were randomly assigned to a condition, and within each condition the order of presentation of the two evaluations was rotated so that, overall, half of the subjects performed the argument structure evaluation first and the participant evaluation second, and half of the subjects performed the tasks in the reverse order.

Pretest for Number of Argument Structures. The number of argument structures associated with a verb was evaluated by asking each subject to create a "normal sentence for each verb-a sentence in which the subject might expect to hear the verb. Subjects were given more than sufficient time for this task, and were led to understand that neither brevity nor loquacity was being encouraged in this task; they were simply to give what they thought was a "typical" sentence for the verb. For each verb, all subcategorization frames that the verb was used in by any subject were counted in the tally. Additionally, it was determined whether prepositional phrases in each subcategorization frame for each verb were actual arguments of the verb or were adjuncts, based on standard linguistic tests.' After using these tests to determine which subcategorization information was an actual argument of the verb, the number of possible complement variations for each verb was determined. A verb's argument structure complexity was determined by calculating the total number of different arguments it supported. Hence a verb which could occur with two and with three arguments was rated as having an argument structure complexity of two, while a verb which could occur with one, two or three arguments was given an argument structure complexity of three (this following Shapiro et al., 1987).

Pretest for Number of Participant Roles. The number of roles associated with each verb was determined by asking subjects to determine how many people and props would be used if they were trying to describe the meaning of the verb to an alien who did not understand English. (This test was from A. Goldberg, following Fillmore, 1977). The props and people that are critical to describing the central meaning of each verb (the relevant participant roles) were calculated from this evidence. Subjects were also asked to explain the relationship of each prop or person cited. The number of roles

' Tests of adjuncthood and argument status were: (1) Is it optional? (2) Can more than one of the same type can occur? (3) Can it be left out of do so? (from Lakoff & Ross (1976). (4) Can it occur after an obvious adjunct? (5) Can it move to the front of a sentence without special pragmatics? (6) Does it modify the entire event? (Many tests supplied by A. Goldberg, personal communication.)

assigned to each verb was then determined by evaluating the total range of roles provided by all subjects, together with their explanations. Explanations that involved people and objects were counted as roles, but those that involved reasons, locations, or instruments were not counted toward the overall role count for a verb.

The goal of these two sets of pretests was (a) to provide a basis for reevaluating existing data with an objective verb classification criteria (see prior section of paper) and (b) to provide a set of verbs that could be used to contrast and examine the argument structure complexity hypothesis versus the participant structure complexity hypothesis in an on-line processing study. With regard to the latter, from the pretest data, the following matched sets of verbs were constructed: (la) 10 verbs that had two participant roles and only one possible argument structure variation, (lb) 10 verbs that had two participant roles and three possible argument structure variations, (2a) 10 verbs that had two argument structures and one participant role, and (2b) 10 verbs that had two argument structures and three participant roles. The verbs that fit these criteria are listed in Appendix 1 (argument structure complexity contrast, holding the number of participant roles constant) and Appendix 2 (participant role complexity contrast, holding numbers of argument structures constant). As can be seen, verbs were placed in a participant role classification relative to their predominantly judged most central participant role classification and in an argument structure classification relative to the total number of possible argument structures associated with the verb (following the Shapiro et al. approach). In each of the contrasting sets, the verbs were matched as closely as possible in terms of length and frequency. The direction of nonmatches on these variables was set to work against the participant role hypothesis.

On-Line Experiment

Subjects. One hundred fifty subjects (43 men and 102 women) participated in the on-line experiment. The subjects participate for course credit at the University of California, San Diego. All subjects were native English speakers by self-report. Subjects filled out a detailed subject questionnaire for screening purposes. Based on a priori criteria, subjects were excluded from data analysis if they were exposed to a language other than English before the age of 6, they had uncorrected visual or auditory impairments, they were not able to follow the instructions, they had two or more comprehension questions wrong (out of a total of five), and they made more than 20% lexical decision errors. This resulted in 80 viable subjects (23 men, 57 women) whose data were used in the analysis. (Of those rejected, 33 were eliminated for being bilingual; 3 for visual impairments, 5 for ig-

noting instructions, 14 for missing more than two of the five comprehension questions, and 14 for error rates greater than 20%.)

Materials. Materials development took advantage of the discussion in the literature between Shapiro et al. (1991) and Schmauder (1991) and Schmauder et al. (1991) on the fragility of the argument structure complexity effects and how best to achieve interference effects. In particular, the visual probe words and nonwords used in the current experiment were chosen to be phonologically complex in order to create a sufficiently high processing load so that differential effects of verbal complexity might be seen. In addition, the visual probes were matched for baseline reaction time and frequency, and the content words in the auditory sentence preceding the visual target were also matched for syllable length and frequency. Further, all experimental sentences had relative clauses preceding the verbs, because Shapiro et al. (1991) noted that this sentence type yielded the strongest results in his studies. In addition, many of the filler sentences had relative clauses in them, either preceding or following their verbs, so that the experimental sentences did not stand out in relation to the filler sentences and all of the sentences in the experiment were of approximately the same length and complexity. The following sentence is an example of the experimental sentences (in this case, for a one-argument structure, two-participant role verb: *consumed):*

The prosecutor who was rude, consumed the food in front of the judge.

The three content words preceding the visual probe in each sentence *(prosecutor, rude, consumed)* differed in each experimental sentence, in order to avoid repetition priming (or some similar effect) across the course of the study. Additionally, in order to control for other possible complexity differences among exemplars in the sentence, the first noun phrase of each sentence was always the name of a profession and the adjective in the relative clause phrase was always an abstract descriptive adjective. (See Shapiro et al., 1991, for a relevant discussion.) In addition, each type of content word (noun, adjective and, of course, the critical verb) was controlled for length and frequency between the contrasts of interest. Again, mismatches were set against the participant role hypothesis [for example, the frequency of the one-participant role verbs (30.6) was far lower than that for the three-participant role verbs (85.3), as the participant role hypothesis would predict faster reaction times (less interference) for the one-participant role verbs].

Forty visual (interference) lexical decision targets were chosen, and all were matched for isolated baseline lexical decision times as well as length and frequency (Francis & Kucera, 1982). These targets were assigned to each of the four groups (one-participant role-two-argument structure verbs, three-participant role-two-argument structure verbs, one-argument structure-two-participant role verbs, and three-argument structure-two-participant role verbs) via a latin square design so that no one visual probe was linked to a condition more than once, but each verb group appeared with all the visual targets. No group of targets differed from any other in average a priori reaction time by more than 2 ms.

The nonword lexical decision (interference) targets were phonologically complex and varied in syllable length from one to four syllables (five to nine letters). In addition, in more than half the cases, the first syllable of the nonword was a syllable of a real multisyllabic word.

The 40 experimental sentences were randomly intermixed with 60 filler sentences of approximately the same length and complexity as the experimental materials. These were recorded by a native English speaker (female) onto an audiotape. This script of 100 sentences was then digitized at 44 kHz and a 1-kHz tone was placed coincident with the offset of the critical verb in each sentence, but on a different audio track (a track inaudible to subjects). This tone was utilized by the RTLab software program to signal presentation of a target visual word on a computer monitor in front of the subject. This tone also initiated a clock counter in the computer that recorded reaction time to decide if the target was a word or not (indicated by a left or right button press by the subject).

Four different lists of target words (50 nonwords and 50 words in each list) were created to appear with the script. Each list was simply a different counterbalanced version of the matched target words (see above). In addition, 10 practice sentences and target words (half words and half nonwords) were created to precede this script.

Procedure. Subjects were seated in a response cubical with a button-press response box and a computer monitor in front of them. They were told that they would be required to perform two tasks: listen and understand the sentences they would be hearing over the headphones, while simultaneously making lexical (word/nonword) decisions to any string of visual letters that much appear on the screen in from of them. Subjects were instructed to keep their fingers on the buttons at all times, and to respond as fast as they could while still' being accurate. In addition, subjects were told that at certain points during the experiment, the experiment would be stopped and they would be asked questions about the sentences they just heard in order to ensure that they were paying attention. Five questions were asked to each subject concerning filler sentences interspersed throughout the experiment. The questions were multiple-choice questions for which subjects wrote down their answers on a response sheet. Target words appeared on the screen for 300 ms, subjects had up to 2 s to make a response.

RESULTS

Data from the 80 subjects were submitted to standard descriptive and inferential analysis. Means were calculated for all subjects for each item and for each of the critical conditions.

Means for the critical comparisons for the argument structure hypothesis (one-argument structure vs. three-argument structure verbs, holding participant roles constant) were as follows: Reaction time to make a lexical decision to a target following access of a one-argument structure verb was 650 ms and reaction tithe to make a lexical decision to a target following access of a three-argument structure verb was 652 ms. The number of participant roles for these verbs was held constant (at two) between these two groups. These data were then submitted to an analysis of variance. The 2-ms difference between conditions was not significant ($F_{(1,76)} = .111$, $p < .35$).

Means for the critical comparisons for the participant role hypothesis (one-participant role verbs vs. three-participant role verbs, holding number of argument structures constant) were as follows: Reaction time to make a lexical decision to an unrelated target following access of a one-participant role verb was 642 ms and reaction time to make a lexical decision to and unrelated target following access of a three-participant role verb was 653 ms. These data were then submitted to an analysis of variance which demonstrated a significant effect for this contrast ($F_{1,76} = 4.271$, $p < .02$).

CONCLUSIONS

The results of this experiment suggest, first, that the number of argument structure configurations in which a verb can occur does not seem to influence processing load at the point at which this verb is accessed, at least for the forms tested here. Note that this evidence does not mean that the list of argument structure configurations does not exist in the lexical entry of the verb, but, from a processing point of view, this study certainly provides no evidence they are made available to the processor upon access of the verb.

In contrast, it does appear that the number of participant roles associated with the central sense of the verb affects processing load at the point at which the verb is accessed. From this it can be inferred that the participant roles of a verb are stored in the representation of the verb and are critical for processing. Further, given that the participant roles of a verb are directly conceptually related to the meaning of the verb, that the number of possible participant roles is limited, and that the use of a verb in a novel construction does not change the number of participant roles associated with the central sense of the verb (as it does with arguments structures), it makes plausible

the idea that a verb's participant roles are stored, critically important, and used directly in sentence processing.

Overall, these data support the view that when a verb is accessed its basic (central) sense and the roles associated with this central sense of the verb are immediately accessed. It appears, then, that information available immediately upon access is largely concerned with the verb's meaning (the frame semantics-including the participant roles) and not the argument structures or the subcategorizational structures of the verb, at least for the configurations of verbs, argument structures, and participant roles tha, we have examined in this study.

APPENDIX I

Table Al. Frequency tallies of numbers of responses for participant roles (out of 40 possible) and for argument structures (out of 40) of verbs matched for use in the argument structure complexity experiment (holding participant role constant); any numbers not adding to 40 for a verb indicate that some responses involved mention of the wrong verb, responses we chose not to guess as to classification for,

Verbs	1 Role	2 Roles	3 Roles	(x)	(x,y)	(x,y,z)
		3 ArgS: 2 Role				
lifted		40		1	36	3
cooked	1	34	3	5	26	7
drew		40		1	34	4
knitted	3	37		3	21	16
surrendered	1	33	6	16	17	7
baked	3	37		4	31	5
pushed		40		4	34	1
sewed	1	38	2	8	24	7
kicked		39	1	4	32	4
adopted		30	10	1	38	1
Average	1.8	36.8	4.4	5	29.3	5.5
		1 ArgS: 2 Role				
consumed	1	39			39	
lowered	2	37	1		37	
blessed	2	35	3		39	
admired	1	39			40	
respected	1	36	3		40	
savored	2	38			40	
nudged		40			39	
devoured	1	39			40	
pulled		40			40	
solved		40			39	1
Average	1.4	38.3	2.3	0	39.3	1

ArgS = argument structure; I Role, 2 Roles, 3 Roles = one-, two-, and three-participant roles; (x), (x,y), (x,y,z) = argument structures.

APPENDIX 2

Table A2. Frequency tallies of numbers of responses for participant roles (out of 40 possible) and for argument structures (out of 40) of verbs matched for use in the participant role complexity experiment (holding number of argument structures constant); any numbers not adding to 40 for a verb indicate that some responses involved mention of the wrong verb, responses we chose not to guess as to classification for'

Verbs	I Role	2 Roles	3 Roles	(x)	(x,y)	(x,y,z)
			3 Role: 2 ArgS			
supplied		8	32		31	6
relayed		6	33		8	28
sent		12	28		8	32
donated	1	6	33		15	24
rented		5	35		33	7
sold		11	29		37	3
gave		3	37		3	37
lent			40		3	37
handed		5	34		7	31
delivered		8	32		32	8
Average		7.1	33.3		17.7	213
			1 Role: 2 ArgS			
breathed	34	6		33	6	
blinked	36	4		35		
whistled	31	9		18	21	
bathed	39	1		33	7	
ran	38	2		30	10	
bark	32	8		25	15	
sung	30	9		32	8	
laughed	30	10		16	23	
sighed	39	1		36	4	
wept	38	2		36	4	
Average	34.7	5.2	0	29	10.9	0

° ArgS = argument structure; I Role, 2 Roles, 3 Roles = one-, two-, and three-participant roles; (x), (x,y), (x,y,z) = argument structures.

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