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The Locus of Lexical Preference Effects in Sentence Comprehension: A Time-Course Analysis

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The retrieval and use of syntactic information associated with verbs during on-line comprehension was examined with reaction time (Experiment 1) and speed–accuracy tradeoff (Experiment 2) variants of a grammaticality judgment task. In three different syntactic environments, the preferred (most frequent) syntactic frame associated with a verb facilitated sentence processing relative to less-preferred (more infrequent) frames. Speed–accuracy tradeoff measures were used to explicitly examine whether the preferred frame associated with the verb has a higher probability of retrieval from the mental lexicon or whether it induces a serial parsing strategy. SAT analysis indicated that (i) in most contexts, less-preferred frames have a lower probability of retrieval, and (ii) verb preference does not induce a serial parsing strategy in the processing of lexically realized arguments, but may induce a serial assignment of possible filler–gap relations.

This paper examines how the syntactic information associated with verbs is used in the assignment of grammatical relations in a sentence. The focus is on how syntactic information is retrieved when a verb is encountered in a sentential context and, once retrieved, how this information is used by subsequent processes that assign structural representations to the elements in a sentence. The former processes are typically referred to as lexical retrieval routines whereas the latter are referred to as parsing procedures. The studies reported here examine how differences in the frequency with which various syntactic frames are associated with a verb impact on lexical retrieval routines and parsing procedures. Recent studies (outlined below) have indicated that sentence processing is facilitated when a verb occurs in its most frequent or preferred syntactic environment as compared to a less frequent, less preferred environment. Here, reaction time (RT) and speed–accuracy trade-off (SAT) variants of a rapid grammaticality judgment task are used to examine the temporal unfolding of preferred and less preferred syntactic information associated with a verb. SAT measures provide a strong empirical test of whether the syntactic preference of a verb induces serial parsing procedures in which the parser attempts to compute the preferred structure before various less preferred structures.

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Verb Preferences

The syntactic information associated with a verb is thought to be critical in the assignment of grammatical relations. Yet most English verbs can occur in a variety of syntactic environments, admitting a number of syntactic complements. The implication for parsing is straightforward: While some structural relations may be immediately ruled out by the occurrence of a particular verb, often a number of alternative structures remain to be considered.

Many verbs, however, appear to be strongly associated with one particular structural relation, even though compatible with a number. The sentence production norms of Connine, Ferreira, Jones, Clifton, and Frazier (1984), for example, show that

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the verb *watch* is more likely to be used in a transitive (1a) rather than in an intransitive (1b) context (77% vs 15% of the time) whereas the verb *rush* shows the opposite pattern, occurring more often in an intransitive (2a) rather than transitive (2b) context (65% vs 18% of the time).

1a. John watched the man.
1b. John watched with the man.
2a. John rushed to the man.
2b. John rushed the man.

Connine et al.'s subjects generated a sentence that incorporated a given verb and a relatively unconstrained topic (e.g., *sports, travel, work,* etc.) or setting (e.g., *home, downtown,* or *school*). Analysis of the subject-generated sentences revealed that many verbs, such as the examples in (1) and (2), showed strong preferences for a particular grammatical structure. These preferences are thought to reflect the statistical regularities that exist in natural language use.

Studies have demonstrated that the syntactic preference of a verb affects (i) the cognitive load associated with processing particular verb complement structures (Clifton, Frazier, & Connine, 1984; Shapiro, Nagel, & Levine, 1993), (ii) the ultimate or temporary interpretation given to ambiguous complements (Ford, Bresnan, & Kaplan, 1982; Mitchell & Holmes, 1985; Holmes, 1987), and (iii) the processing of constructions with displaced arguments or filler–gap relations (Fodor, 1978; Clifton et al., 1984; Tanenhaus & Carlson, 1988; Tanenhaus, Garnsey, & Borland, 1990).

Clifton et al. (1984) used RT for a secondary task (a lexical decision on an unrelated word) as a measure of the processing load shortly after the processing of a verb. RT was significantly faster following the reading of a verb plus closed class item uniquely specifying a preferred verb complement (e.g., *John watched the . . .*) as compared to a less-preferred complement (e.g., *John watched with . . .*). Using a cross-modal variant of the lexical decision task, Shapiro et al. (1993) replicated these results and further demonstrated that the preferences of dative and complement verbs similarly affect processing load.

Verb preference also appears to affect the processing of structurally ambiguous sentences. Ford, Bresnan, and Kaplan (1982) used a questionnaire designed to identify which interpretation of a globally ambiguous sentence occurred to subjects first. When different verbs were substituted into the same ambiguous sentence frame, subjects most often reported first interpretations that accorded with the experimenter's intuitions concerning the preferences of the respective verbs. An on-line variant of Ford et al.'s study was reported by Mitchell and Holmes (1985). Reading times were measured for a critical passage that uniquely resolved a prior structural ambiguity stemming from optional readings of a verb. Reading times for the critical passages were significantly increased when the preference of the verb mismatched the manner in which the critical passage resolved the local ambiguity, suggesting that local ambiguities are temporarily resolved according to the verb's structural preference. Similar results have been reported by Holmes (1987) using a self-paced, word-by-word reading time task.

Finally, verb preference appears to guide the analysis of sentences with dislocated arguments, the so-called filler-gap constructions. Fodor (1978) and Tanenhaus and colleagues (Tanenhaus & Carlson, 1988; Tanenhaus et al., 1990) argue that the syntactic preference of a verb determines the initial assignment of a filler item to a vacant argument position or gap following the verb. For example, Tanenhaus and Carlson (1988) report an experiment in which a self-paced, word-by-word reading task was used to examine sentences like (3) and (4).

3. The district attorney found out which *witness/church* the reporter asked P_1 anxiously about P_2.
4. The physical therapist wasn't sure which *doctor/bed* the orderly hurried P_1 rapidly towards P_2.

In both sentences, there is a potential gap in constituent structure at the point marked P_1, but the italicized filler item must be eventually assigned to the gap at position P_2. (For example, the witness in (3) is understood as the person the reporter asked about rather than the person the reporter asked.) In sentences like (3), a preferred transitive verb (e.g., *asked*) preceded the potential gap; while in sentences like (4), a preferred intransitive verb (e.g., *hurried*) preceded the potential gap. Two filler items were used in each type of construction. One item (e.g., *witness* in (3) and *doctor* in (4)) was a plausible filler for the potential gap in the direct object position (P_1), while the other (e.g., *church* in (3) and *bed* in (4)) was inanimate and hence implausible as the direct object of verbs such as *asked* and *hurried*. Tanenhaus and Carlson found that the plausibility of the filler item had an effect on reading times for constructions with preferred transitive verbs (3) but not for constructions with preferred intransitive verbs (4). The results indicate that subjects attempted to immediately assign the filler to the direct object role (P_1) after processing a preferred transitive verb but not after a preferred intransitive verb. This study provides strong evidence for an initial filler–gap assignment based on verb preference.

The Locus of Verb Preference Effects

Verb preference effects originate from underlying differences in the *strength* with which various syntactic frames are associated with particular verbs (Ford et al., 1982; Mitchell & Holmes, 1985; Fodor, 1978; Clifton et al., 1984). As with other types of lexical information (e.g., phonological, orthographic, morphological information), syntactic information is assumed to be stored under a word's entry in the language user's mental lexicon. A preference results from the frequent co-occurrence of the verb and a particular syntactic environment which serves to increment the relative strength of the syntactic frame within the verb's lexical representation (Ford et al., 1982). While prior research supports the notion that verb preferences impact on sentence comprehension, there is little evidence that clearly identifies what specific processes are affected.

To date, explanations of the verb preference effect have relied primarily on the assumption that parsing procedures are intrinsically serial—the parser computes a single structural alternative at a time. The dominate explanation assumes that the strength of different syntactic frames associated with a verb determine the order in which each structural alternative is considered by the parser (Ford, 1986; Ford et al., 1982; Fodor, 1978; Holmes, 1984; Mitchell & Holmes, 1985; Shapiro et al., 1993). Processing of a verb results in the retrieval of all permissible syntactic frames stored in the lexicon. From this set, the parser selects as its first choice the strongest syntactic frame associated with the verb. If the remainder of the clause or sentence is found to be inconsistent with this choice, lower-ranked structural assignments are sequentially tried until a match is found. This garden-pathing and subsequent backtracking of the parser necessarily slows processing down and increases processing load.

This approach to verb preferences can be instantiated in general parsing frameworks, such as Augmented Transition Networks (ATNs) (e.g., Kaplan, 1972; Woods, 1970) or lexical–functional parsers (Ford et al., 1982; Ford, 1986; Mitchell & Zagar, 1986). Wanner (1980) demonstrated that syntactic preferences can be modeled within the ATN framework by ranking optional transition arcs. In this scheme, the ranking of an arc determines the order in which input is tested against the conditions of the arc. Mitchell and Holmes (1985) have suggested specific types of information that need to be incorporated into the conditions of verb-related arcs in order to predict extant preference data. Within a related parsing framework, Ford et al. (1982) outlined sequentially ordered routines for a lexical–

functional parser that are explicitly conditioned on the strengths of functional frames associated with particular verbs.

The evidence for an impact of verb preference on processing load and filler-gap assignments is clearly consistent with models in which parsing procedures are serially guided by the syntactic preference of the verb. Evidence from the processing of structurally ambiguous constructions, however, is more complicated. Frazier and colleagues (Clifton, Speer, & Abney, 1991; Frazier, 1978; Frazier & Rayner, 1982; Ferreira & Henderson, 1990; Rayner, Carlson, & Frazier, 1983) argue that initial structural assignments are computed by procedures that primarily implement phrase structure rules. These procedures are supplemented by a set of heuristics or strategies for dealing with ambiguities in the application of phrase structure rules (e.g., Minimal Attachment and Late Closure, see below). The parser operates in a serial fashion, but its initial choices are controlled by strategies that are defined on the geometry of the phrase structure representation rather than idiosyncratic preferences of particular words. All lexical information other than a word's major syntactic category—including syntactic frames, whether preferred or not—is used later in processing to embellish and/or revise the first-pass analysis.

Frazier's phrase structure-driven parser differs from the lexically driven parser in the presumed order in which certain types of information are used, and perhaps in the particular form of the information embodied in the parser (e.g., context-free phrase structure rules vs argument structures). Nevertheless, this approach assumes that parsing is serial and that serial assignments can be determined by the preference of lexical items, albeit after an assignment based on phrase structure operations. A few studies have attempted to determine whether first-pass parsing decisions are controlled by purely syntactic strategies or by more specific lexical information (e.g., Clifton et al., 1991; Ferreira & Henderson, 1990; Holmes, 1987); however, no clear consensus has emerged (Clifton et al., 1991; Shapiro et al., 1993). This is certainly due in part to the fact that, even if it is used after phrase structure information, lexical information appears to be used very early in processing (e.g., Marslen-Wilson, Brown, & Tyler, 1988). The present paper evaluates the general notion of serial processing based on verb preferences, whether or not it is preceded by an earlier stage of phrase structure processing. Some evidence bearing on the phrase structure-driven model will be discussed under the General Discussion.

Serial parsing based on lexical preference is not the only hypothesis that is compatible with the data. An alternative explored here assumes that parsing procedures are capable of computing more than one alternative at a time. Much of the motivation for serial processing is, as in Ford (1986), the observation that subjects often get one reading of a structurally ambiguous sentence before another, if the latter is reached at all. Yet this observation provides little in the way of evidence for serial processing if the parser initially operates in a parallel fashion, computing various potential structures, but subsequently filters or suppresses all but one interpretation (Altman & Steedman, 1988; Waltz & Pollack, 1984).[1] Other arguments for serial parsing have been based on a failure to observe increases in processing load across locally ambiguous regions (e.g., Frazier & Rayner, 1982). This type of argument, however, depends critically on the capacity limits of the parser, as well as the sensitivity of the dependent measure used to assess processing load.

[1] Indeed, studies that have explicitly examined the processing of structurally ambiguous sentences have demonstrated that in some circumstances more than one interpretation may be computed in the immediate vicinity of the ambiguity but the probability of holding alternative interpretations decreases as a function of subsequent input (Warner & Glass, 1987).

Alternatively, greater processing loads and slower reading times for processing less preferred sentence structures may arise, not from an intrinsic serial constraint, but rather from limited information retrieval. Following the processing of a verb, the parser may test input against all retrieved structures in *parallel*. Sometimes, however, less-preferred syntactic frames are not retrieved from the lexicon and will not be available to subsequent parsing routines. The parser will be garden-pathed when encountering an unretrieved structure and may need to backtrack to reprocess the verb in order to compute the appropriate analysis. In this approach, the *strength* of a syntactic frame associated with a verb reflects simply the *probability* that it can be retrieved from the lexicon.

Of course, this parallel interpretation of preference effects reduces to a serial model when only one structural frame is retrieved from the lexicon. However, given the number of alternative structures that are associated with many common verbs, it is plausible that most of the time more than one option is retrieved. It is commonly assumed that all syntactic frames associated with a verb are retrieved from the lexicon when a verb is processed (Shapiro, Zurif, & Grimshaw, 1987; Shapiro, Zurif, & Grimshaw, 1989). The parallel interpretation of preference effects departs from this assumption in suggesting that the lexical retrieval routines may not recover the exhaustive set in every context. Such a view is consistent with the fact that many less-preferred frames appear to have a very low probability of occurrence. For example, examination of the Connine et al. (1984) norms shows that for many verbs some frames (although permissible) never occurred in the productions of some 68 subjects. By hypothesis, such frames may have a concomitantly low probability of retrieval. Additionally, some frames are restricted to specific *senses* of the verb that are used infrequently in discourse. (For example, compare the preferred intransitive form of *walk* as in *John walked to the store* with the less-preferred transitive form *John walked the dog*.) Some less-preferred frames may fail to be retrieved simply because they are associated with specific senses of the verb that are rare in most contexts. Such frames may need substantial cuing from a discourse context to ensure recoverability.

Preview of the Experiments

The studies reported here use a rapid grammaticality judgment task (e.g., Clifton et al., 1984; Frazier, Clifton, & Randall, 1983; Forster & Olbrei, 1973; Holmes, 1979; Warner & Glass, 1987) to examine processing differences between verbs in preferred and less-preferred sentential contexts. In this paradigm, subjects are presented a string of words to read and at some point required to rapidly determine (yes/no) whether the string is permissible. The effect of verb preference on grammatical judgments is measured in three types of linguistic environments, necessitating three distinct types of processing, specifically (i) simple expansion of a verbal complement, (ii) temporary resolution of an ambiguous postverbal noun phrase (NP), and (iii) resolution of a filler-gap dependency. Experiment 1 uses a RT variant of the task to demonstrate that in all three environments judgments are faster and more accurate when the syntactic structure of the sentence fragment accords with the preference of the verb. This RT study provides convergent evidence for the effects of verb preference on sentence processing. Like previous studies, however, these data do not discriminate between various hypotheses concerning what specific processes are affected by verb preference. Experiment 2 uses a multiple-response, speed–accuracy trade-off (SAT) paradigm to examine the full time course of grammaticality judgments involving preferred and nonpreferred frames of verbs. The SAT procedures provides a strong test of whether verb preference induces a serial parsing strategy or primarily affects retrieval from the lexicon.

Experiment 1: Reaction Time Measures

The first experiment shows that the structural preferences of verbs affect RT and/or error rates for grammatical judgments. Sets of verbs preferring either a transitive or intransitive complement were selected from the sentence production norms of Connine et al. (1984). The transitive/intransitive dichotomy was used strictly to facilitate experimental contrasts. Verb structures and their relative preferences may be represented formally as either strict subcategorization frames (Chomsky, 1965), argument structures (Grimshaw, 1990), or functional frames (Kaplan & Bresnan, 1982).

Preferred transitive and preferred intransitive verbs were judged in both transitive and intransitive (partial) sentence frames. Preference effects are best examined *within* a transitive or intransitive sentence frame since response time and accuracy may vary with the type of sentence frame independent of the verb type. While Clifton et al. (1984) and Shapiro et al. (1993) found no difference between transitive and intransitive frames with a secondary load task, the grammaticality judgment task appears to be more sensitive to differences in syntactic structure. Warner & Glass (1987) found that transitive frames were judged more accurately than intransitive frames.

Three different types of sentence constructions were used in order to explore how verb preference affects different types of syntactic processing. The contrasts are illustrated in Table 1. In the within-clause constructions, critical verbs were followed by either a simple determiner or a preposition uniquely denoting either a transitive (direct object) or an intransitive (prepositional phrase) complement, respectively. To ensure that observed differences were directly related to differences in the syntactic information associated with the respec-

TABLE 1
Illustrative Materials for Experiment 1

Sentence frame	Verb preference	Examples
		Within-clause constructions
Transitive	Preferred	John thought Bill ** watched the **
Transitive	Nonpreferred	John thought Bill ** rushed the **
Intransitive	Preferred	John thought Bill ** rushed for **
Intransitive	Nonpreferred	John thought Bill ** watched for **
		Early/late closure constructions
Transitive	Preferred	While Bill watched Mary ** at work **
Transitive	Nonpreferred	While Bill rushed Mary ** at work **
Intransitive	Preferred	While Bill rushed Mary ** started work **
Intransitive	Nonpreferred	While Bill watched Mary ** started work **
		Filler–gap clause constructions
Transitive	Preferred	This is who Bill ** watched *p* when **
Transitive	Nonpreferred	This is who Bill ** rushed *p* when **
Intransitive	Preferred	This is who Bill ** rushed with *p* **
Intransitive	Nonpreferred	This is who Bill ** watched with *p* **

Note. Words enclosed in asterisks were presented together and indicate the point at which subjects were required to make a rapid grammaticality judgment. The *p*'s denote a wh-gap in syntactic structure.

tive verbs, subjects read the sentence-initial material (e.g., *John thought Bill . . .*) one word at a time, were then presented the respective verb and critical closed class item simultaneously, and required to rapidly decide whether the two words represent a permissible continuation of the sentence fragment. Contextual and semantic information was minimal. By requiring a judgment immediate after the processing of the verb and closed class item, a subject's decision should be maximally sensitive to differences in information retrieved from the respective types of verbs. These materials are analogous to those of Clifton et al.'s (1984, Experiment 1) and Shapiro et al.'s (1993, Experiment 2) studies of processing load.

In the early/late closure constructions, the effect of preference on the analysis of an ambiguous postverbal noun phrase (NP) was examined. As illustrated in Table 1, the main verb of the subordinate clause in both sentence frames was followed by a proper noun that is temporarily ambiguous between a reading that incorporates the NP into the subordinate clause as a direct object or a reading that treats the NP as the subject of the subsequent matrix clause. Of course, this type of ambiguity is often avoided in natural text with the use of punctuation (e.g., a comma after either the verb or second NP). Here, as with other studies (e.g., Ferreira & Henderson, 1990; Mitchell & Holmes, 1985; Warner & Glass, 1987), punctuation was excluded in order to experimentally induce a local ambiguity. If verb preference serially guides parsing decisions, preferred transitive verbs should induce a late closure analysis while preferred intransitive verbs should induce an early closure option. The critical passages (enclosed in asterisks in Table 1) uniquely resolve the local ambiguity in one or the other way. If the local ambiguity is temporarily resolved in favor of verb preference, then judgment time and/or error rate should increase when the preference of the verb mismatches the manner in which the critical phrase resolves the ambiguity.

In the filler–gap constructions, a cleft construction was used to examine whether verb preference aids in associating a marked wh-element (e.g., *who*) with a vacant argument position or a gap in constituent structure (denoted by p in Table 1). Proper comprehension in the filler–gap constructions requires that the filler item is assigned the grammatical (or thematic) role of the gap in surface structure. Recent evidence suggests that processing a gap does indeed cause the reader to access a representation of the antecedent filler item, much like processing an explicit anaphor (Bever & McElree, 1988; McElree & Bever, 1989; Nicol & Swinney, 1989). The detection of a gap in constituent structure, however, can be subject to various degrees of ambiguity. Verb preference should affect the probability that the parser will initially detect or postulate a gap in surface structure (Fodor, 1978; Tanenhaus & Carlson, 1988). For example, a gap in the direct object position following a preferred intransitive verb may be overlooked if the preferred frame of the verb causes the subject to anticipate a gap in a secondary object position (e.g., following a preposition in a phrase of location, manner, time, etc.).

The explicit wh-element in the cleft constructions of Table 1 clearly denotes the presence of a filler item that must be bound to a subsequent argument position. The final word in the transitive filler–gap sentence frame (e.g., *when*) denotes the beginning of a temporal clause and thus forces a transitive reading of the matrix verb where *who* is bound to the direct object position. In contrast, the intransitive frame ends with a preposition (e.g., *with*) which may indicate that the verb is used in an intransitive frame and the wh-element is bound to the secondary object position. If verb preferences aid in postulating a gap in surface structure, then the match between preference and sentence frame should result in faster and/or more accurate grammaticality judgments. Mismatches between preference and the sentence frame, on the other hand, may cause the parser to initially or completely overlook the gap, thereby increasing RT and/or error rates.

Method

Subjects. The subjects were 20 Columbia University students who participated in order to fulfill an introductory psychology course requirement. All were native English speakers and had normal or corrected vision.

Materials. Ten preferred transitive (PT) and 10 preferred intransitive (PI) verbs were selected from the Connine et al. (1984) norms. The selected PT verbs occurred on average 73.3% of the time in transitive productions and 12.9% of the time in intransitive productions. The PI verbs were close to a mirror image of the PT verbs, occurring 67.7% of the time in intransitive productions and 12.6% of the time in transitive productions. Additionally, since direct contrasts concern different verbs in the same sentence frame, the sets of verbs selected were matched, as closely as possible, in terms of both length and frequency of occurrence in print. PT verbs were on average 6.5 letters long, whereas PI verbs were 6.9 letters long. PT verbs had average Kucera and Francis (1982) frequency counts (for the inflected form) of 108/million, while PI verbs had counts of 35/million.

The verbs of each set were combined into PT/PI pairs. All 10 pairs were used for within-clause and filler–gap construction types, while 8 pairs were used for early/late closure constructions. (Verbs such as *painted, swam,* and *pointed* were eliminated from the early/late closure condition since an animate NP is an implausible object phrase for these verbs.) A transitive and intransitive frame (illustrated in Table 1) for each of the three types of constructions were generated for each pair. Appendix I lists the verbs and critical passages for each experimental contrast.

In constructing the sentence frames, an attempt was made to minimize semantic and pragmatic information so that experimental effects could be directly attributed to differences in the syntactic information associated with the respective verbs. To this end, the constructions consisted almost exclusively of proper nouns, closed class items, and the critical verbs. There were, however, two notable exceptions. Some of the within-clause frames were introduced by either a subordinate or matrix clause with content items other than proper names. This was done to vary the length of the material before reading the critical region. However, in constructing these clauses an attempt was made to avoid pragmatically biasing one or the other reading of the verbs. The second exception was the critical fragments in the early/late closure construction (e.g., *at work/started work*). Here, content material was needed to clearly resolve the local ambiguity.

Each verb in a pair was inserted into both the transitive and intransitive frames of each of the three construction types. In an attempt to minimize potential memory effects owing to repetition of a frame, the frames were modified by changing the proper names. Combining the verbs with the respective sentence frames yielded a total of 10 experimental sentences for each combination of verb preference (PT and PI) and sentence frame (transitive and intransitive) for both within-clause and filler–gap construction types, and eight experimental sentences per combination of early/late closure constructions. The resulting 112 experimental sentences were combined and randomized with a set of 168 nonexperimental, distractor sentences. These 168 distractors consisted of 104 ungrammatical and 64 grammatical sentences. Ungrammatical lures were of various sorts, including subcategorization violation of strict transitive and strict intransitive verbs.

Procedure. Stimulus presentation, timing, and response collection were all carried out on a personal computer. The stimuli were presented on a CRT screen using a standard character set (approximately 6 × 4 mm).

A trial began with the presentation of the word *ready* and a fixation point (+) indicating the region where the stimuli were to be presented. After responding to the *ready* prompt with a key press, the subjects read the sentences one word at a time, with each word presented in the center of an otherwise clear screen in a normal mixture of upper and lower case characters. The subjects paced themselves through the sentences by pressing the space bar after reading each word. At a point unknown to the subject, a press of the space bar initiated the presentation of the two-word critical passage. The passage was enclosed by two asterisks on each side in order to clearly indicate to subjects that a rapid grammaticality judgment was required. The passage remained on the screen until the subject responded by pressing one of two keys designated as "yes" or "no."

Subjects were instructed to read the words of a sentence as they would normally read any text. They were instructed to respond to the two-word critical passages as quickly but as accurately as they could. Subjects were told to respond "yes" if the sentence fragment was an acceptable—albeit possibly incomplete—English sentence, and "no" otherwise. The first 16 trials consisted of an equal number of positive and negative distractor sentences that served as practice trials to familiarize the subject with the task and were not analyzed.

Results and Discussion

Grammatical fragments were correctly classified, on average, 86% of the time, with a latency of 813 ms. Ungrammatical fragments were correctly classified 85% of the time, with a latency of 1034 ms. The percentage correct and average correct RT as a function of sentence frame (transitive and intransitive) and verb preference (preferred and nonpreferred) is presented in Table 2 for each of three construction types.

In Table 2 and for subsequent analyses, average RT was calculated by including correct responses only and excluding trials where the response time fell below or exceeded 2.5 standard deviations of the subject's average (across sentence frame, verb preference, and construction type) correct response time. RTs and accuracy were analyzed with separate analysis of variance procedures that (i) collapsed across sentences and treated subjects as the random and repeated measures factor (denoted by F_1); and (ii) collapsed across subjects and treated individual verb pairs as the random and repeated measures factor (denoted by F_2). In each case, verb preference (preferred and nonpreferred) and sentence frame (transitive and intransitive) were within subject/verb-pair factors.

Within-clause constructions. RT and accuracy varied with the type of sentence frame: Responses to transitive completions were faster [$F_1(1,19) = 33.5, p = .000$ and $F_2(1,9) = 36.1, p = .000$] and more accurate (although marginally so by items) [$F_1(1,19) = 6.85, p = .017$ and $F_2(1,9) = 4.37, p = .065$] than responses to intransitive completions (714 vs 871 ms and 94% vs 87%, respectively). A similar result has been reported by Warner and Glass (1987).

TABLE 2
EXPERIMENT 1: MEAN REACTION TIME (IN MILLISECONDS) AND PERCENTAGE CORRECT

	Verb preference					
	Preferred		Nonpreferred		Mean	
Construction	RT	%C	RT	%C	RT	%C
Within-clause						
Transitive	706	95	722	92	714	94
Intransitive	810	92	932	81	871	87
Early/late closure						
Transitive	748	94	822	73	785	84
Intransitive	847	83	869	85	858	84
Filler–gap						
Transitive	849	90	916	69	882	80
Intransitive	732	95	805	88	769	92

Note that transitive completions are compatible with one immediate complement only, namely a noun phrase serving a direct object role. Intransitive completions are compatible with substantially more options, including prepositional phrases and clausal or S-complements of various sorts (e.g., [__infinitival-S], [__Wh-S], [__that-S], see Connine et al., 1984). The greater optionality in the latter case appears to increase the complexity of the decision process resulting in slower and less accurate judgments (cf. Fodor & Garrett, 1968).

Verb preference significantly affected RT [$F_1(1,19) = 20.1$, $p = .000$ and $F_2(1,9) = 12.9$, $p = .006$]. On average, correct grammatical responses were 69 ms faster when the preferred frame of the verb matched the sentence frame. Accuracy also varied with verb preference, although not significantly by items [$F_1(1,19) = 31.7$, $p = .000$ and $F_2(1,9) = 1.1$, ns]. When the preference of the verb matched the sentence frame, subjects were correct 94% of the time compared to 87% when the sentence frame mismatched the verb's preference. Inspection of Table 2 suggests that there was a tendency for preference to exert more of an influence on RT and accuracy in the intransitive sentence frames than in the transitive frames (122 vs 16 ms and 11% vs 3%, respectively). The interaction was significant in the subject analyses of RT and accuracy [$F_1(1,19) = 10.7$, $p = .004$ and $F_1(1,19) = 8.9$, $p = .008$, respectively] but not in either item analysis [$F_2(1,9) = 1.5$ ns and $F_2(1,9) \approx 1$, ns]. Given the baseline difference between transitive and intransitive frames and the fact that the magnitude of the preference effect directly varied with this baseline, this apparent interaction is subject to interpretative problems (Loftus, 1978). In the SAT study of Experiment 2, we find no evidence for this type of interaction but rather a uniform effect of preference on both sentence frames. The more conservative interpretation is therefore that preference exerts an influence in the processing of both types of sentence frame despite this marginal interaction.

Early/late closure constructions. Differences in RT and accuracy for the critical passages in these constructions reflect the tendency for a verb to induce one or the other structural analysis of the ambiguous NP. Constructions requiring a transitive reading of the verb were responded to faster than intransitive constructions. This 73 ms difference was significant by subject but marginal by the item analysis [$F_1(1,19) = 9.1$, $p = .007$ and $F_2(1,7) = 4.8$, $p = .064$]. The overall accuracy level for the two types of sentence frames were indistinguishable [$F_1(1,19) \approx 1$, ns and $F_2(1,7) \approx 1$, ns]. A main effect favoring a transitive reading of the verb would support a general syntactic strategy of *late closure* (Frazier, 1978; Holmes, 1987; Mitchell & Holmes, 1985). If such a strategy were employed, subjects would have had a bias (following both PT and PI verbs) to interpret the ambiguous proper noun as the direct object of the verb, thus keeping the subordinate clause open and thereby allowing direct incorporation of the prepositional phrase (e.g., *at work*) into the clausal unit. The same strategy in the intransitive frames, however, would result in a garden-path when the critical passage (e.g., *started work*) was encountered, necessitating a reanalysis of the proper noun in order to recover the correct structure. The marginally significant RT difference provides some evidence in support of such a strategy. Yet the approximately equal error rates suggest that any garden-path in parsing was quickly and efficiently overcome.

Within each type of construction, grammaticality judgments were faster when the critical passage resolved the potential ambiguity in a manner consistent with verb preference, suggesting that verb preference influences the structural analysis of the ambiguous NP. Collapsing across sentence frames, critical passages that were consonant with verb preference were responded to 48 ms faster than those that were incongruent [$F_1(1,19) = 10.0$, $p = .005$ and $F_2(1,7) = 10.3$, $p = .014$]. However, while the effect of preference clearly emerged on both RT and accuracy in the transitive frames, the effect in the intransitive frames is clouded by a potential speed–accuracy trade-off: Responses to PI verbs are faster than PT verbs but error rates are lower for PT verbs. (The interaction between sentence frame and verb preference was significant in the accuracy analysis [$F_1(1,19) = 19.5$, $p = .000$ and $F_2(1,7) = 6.3$, $p = 0.041$] but not in the RT analysis [$F_1(1,19) = 1.9$, $p = 0.183$ and $F_2(1,7) \approx 1$, ns] While a potential trade-off undermines the claim that verb preference affected the early closure strategy, the subsequent SAT study, which controls speed–accuracy trade-offs, reliably demonstrates differences as a function of verb preference in both sentence frames.

Filler–gap constructions. Differences between verb types in the two cleft sentence frames represent the relative difficulty of locating a gap in constituent structure coindexed with the explicit wh-filler item (e.g., *who*). In contrast to the patterns in the two previous constructions, responses to intransitive frames were faster [$F_1(1,19) = 28.4$, $p = .000$ and $F_2(1,9) = 17.3$, $p = .003$] and more accurate [$F_1(1,19) = 26.7$, $p = .000$ and $F_2(1,9) = 6.3$, $p = .034$] than responses to transitive frames. This pattern appears to reflect the fact that the argument position of the gap in the intransitive frame is clearly marked in surface structure by the preposition (e.g., *with*) whereas in the transitive frame the gap must be inferred from the beginning of a temporal clause. However, the simple presence of a preposition does not necessarily block a reading with a transitive gap in what are presumably intransitive frames (e.g., *This is who Bill rushed* p *with great impatience*), raising the possibility that this difference may be the result of two divergent readings of the construction. (In the next experiment, this artifact is eliminated by introducing an item denoting a temporal clause or phrase blocking the transitive reading.)

Despite the potential for two readings in the intransitive frame, verb preference had a significant effect on both RT [$F_1(1,19) = 12.7$, $p = .002$ and $F_2(1,9) = 7.2$, $p = .03$] and accuracy [$F_1(1,19) = 49.9$, $p = .000$ and $F_2(1,9) = 6.3$, $p = .039$]. There was some evidence for an interaction between preference and sentence frame in the accuracy levels [$F_1(1,19) = 7.8$, $p = .011$ and $F_2(1,9) = 8.3$, $p = .018$] but not in the corresponding latencies [Fs ≈ 1, ns]. This is directly attributable to the large number of incorrect (ungrammatical) judgments with PI verbs in transitive frames. This dramatic difference in accuracy supports the claim of Fodor (1978) that a mismatch between verb preference and syntactic frame causes the parser to overlook the potential gap in constituent structure.

Summary. Across the three construction types, a match between sentence frame and verb preference reliably facilitated rapid grammaticality judgments, either in terms of faster responses and/or improved accuracy. The contrasts in the within-clause constructions demonstrate that this facilitatory effect is rather immediate, affecting judgments of a simple closed class item uniquely denoting one or another verb complement in the absence of strong semantic or pragmatic cues. Differences in the early/late closure constructions indicate that verb preference also appears to affect the probability that either an early or late closure strategy is adopted to deal with a potentially ambiguous noun phrase constituent. Finally, the contrasts in the filler–gap constructions show that verb preference affects the likelihood that a gap is detected or postulated in surface structure.

EXPERIMENT 2: SPEED–ACCURACY TRADE-OFF (SAT) MEASURES

The RT and accuracy data of the previous experiment demonstrated that rapid grammaticality judgments are sensitive to differences in the strength with which various syntactic frames are associated with particular verbs. However, as with other simple timing measures (e.g., reading or processing load tasks), these data are not sufficient to isolate how or what processes are affected by verb preference. In particular, they are not sufficient to determine whether verb preference induces strength-governed differences in retrieval probability, serial parsing strategies, or a mixture of both. The SAT method provides a means of discriminating between these alternatives.

SAT methodology. The response–signal speed–accuracy trade-off procedure interrupts the judgment process with a cue to respond (typically a tone) after varying amounts of time (e.g., 100–3000 ms). Accuracy (usually d') as a function of processing time is the dependent measure of interest. Typical SAT functions show three qualitatively distinct phases, specifically (i) a period of chance performance, followed by (ii) a period of increasing accuracy, and finally (iii) a terminal or asymptotic level of performance beyond which no further improvement is seen. Standard functions can be quantitatively summarized by the exponential approach to a limit equation in [1] (Dosher, 1976, 1979; Reed, 1973, 1976; Wickelgren, 1977).

$$d'(t) = \lambda(1 - e^{-\beta(t-\delta)}),\quad t > \delta \text{ else } 0 \qquad [1]$$

The parameter λ in (1) describes the asymptotic level of performance—the ultimate level of accuracy for the judgment in question. The δ and β parameters jointly estimate the dynamics of the function. The intercept δ is the discrete point in time where performance begins to rise from chance. The β parameter indexes the speed or rate at which performance rises from chance to asymptote. The dynamic portions of the SAT function (δ and β) reflect either the rate of continuous information accrual or the distribution of finishing-times of a discrete or quantal process (Dosher, 1976, 1979, 1981, 1982; Meyer, Irwin, Osman, & Kounois, 1988; Ratcliff, 1988).

Analysis of the SAT function in terms of Eq. [1] allows an independent assessment of information availability (λ) and the dynamics of information accrual (β and δ). It is the latter that is of importance for evaluating serial processing claims. In general, experimental manipulations that are presumed to affect the number of serial processes will impact on the dynamics of information accrual independent of potential effects on asymptotic accuracy levels (Dosher, 1976, 1982; McElree & Dosher, 1989, in press; Ratcliff, 1981, 1987). This follows from the fact that either the rate of information accrual (assuming a series of continuous processes) or the overall distribution of finishing times (assuming a series of discrete processes) is controlled by the number (and hence the overall duration) of serially ordered component processes. Differences in the rate of information accrual or the distribution of finishing times will engender SAT functions that rise to asymptote disproportionally or at different rates, perhaps coupled with shifts in SAT intercept (McElree & Dosher, 1989, in press). This procedure has been profitably used to critically examine serial processing claims in a number of distinct domains including short-term item recognition (McElree & Dosher, 1989; Reed, 1976), judgments of recency (McElree & Dosher, in press), perceptual matching (Ratcliff, 1981, 1987), sentence recognition (Dosher, 1982), and semantic-verification tasks (Corbett & Wickelgren, 1978).

The logic extends directly to the present issue. The accuracy of retrieving syntactic information from the lexicon may vary with verb preference so that less preferred frames are unavailable to parsing routines on a proportion of trials. In these cases, less preferred sentence structures will be incorrectly judged as ungrammatical. The net result will be lower SAT asymptotes for less-preferred structures. The predicted form of the dynamics of the SAT functions depends on how those frames that *are* retrieved from the lexicon are matched to subsequent input in the course of making a rapid grammaticality judgment. If available frames are not matched in parallel but rather serially tested against subsequent input, then the SAT dynamics (δ and β) for a particular contrast will vary according to the order in which the correct frame was compared to the input. Explicit predictions for a serial parsing strategy are derived below.

SAT predictions. For expository purposes, assume that rapid grammaticality judgments are mediated by a series of discrete (quantal) matches of input against retrieved syntactic frames.[2] Under the discrete assumption, the SAT function will reflect the underlying distribution of finishing-times for the decision process, coupled with increments in accuracy due to guessing when processing is incomplete.

Consider, by way of illustration, the verbs *watched* and *rushed* presented in the transitive frames in (5).

5a. Bill thought John watched the . . .
5b. Bill thought John rushed the . . .

The norms of Connine et al. (1984) specify the following ordinal ranking of preferences for the immediate complements of the verb *rushed:* (i) a prepositional phrase [_PP]; (ii) an infinitival clause [_infinitival-S]; and (iii) a direct object [_NP]. A serial parsing hypothesis dictates that, for judgment of the fragment (5b), the transitive frame will be the third match attempted conditioned on the failure of the first two matches ([_PP], [_infinitival-S]). The first two ranked preferences for the verb *watched* are both transitive, specifically a simple noun phrase[_NP] and a noun phrase with prepositional phrase [_NP PP]. (The intransitive prepositional phrase [_PP] is ranked third along with a noun phrase with a wh-clause [_NP wh-S].) In judgments of fragment (5a), the first match attempted for the PT verb *watched* will lead to a successful judgment.

The predicted impact of a serial parsing strategy on SAT dynamics can be quantitatively illustrated by adopting standard distributional assumptions for a multicomponent serial stage model (e.g., Townsend & Ashby, 1983). For expository convenience, assume that individual comparisons of retrieved syntactic frames with the input are independently and identically exponentially distributed with rate β. Then the finishing-time distribution of any judgment will be gamma-distributed with an order α equal to the number of (exponentially distributed) serial comparison processes needed to reach a successful match. SAT functions represent the growth of accuracy over processing time, t, and are thus modeled by the cumulative form of the gamma distribution offset by a base encoding time (δ):

$$P(T \leq t) = \frac{\beta^{\alpha}}{(\alpha - 1)!} \int_0^{t-\delta} e^{-\beta t'} t'^{\alpha-1} dt', \quad t > \delta \textit{ else } 0. \qquad [2]$$

Verb preference is a statistical generalization across subjects and/or items. Realistically, for some subjects or on some trials a normatively determined nonpreferred frame may be in fact the first or second option tested even though it is ranked third in the norms. We can model this in SAT by assuming that the probability of a correct match as a function of processing time is a probabilistic mixture of gammas with differing orders.

Figure 1 presents hypothetical SAT functions that illustrate the serial hypothesis construed in this fashion. The solid line represents a d' SAT function for a transitive completion containing a verb that prefers this frame, like *watched* in (5a). Here the parser correctly matched the retrieved frame to the input (i) 75% of time on its first (serial) attempt; (ii) 15% of the time on its second attempt; and (iii) 10% of the time on its third attempt. (Hence, a mixture of 75%

[2] Similar, perhaps more extreme predictions result from the assumption that the matching process is continuous in nature as in, for example, a diffusion process (Ratcliff, 1978, 1988).

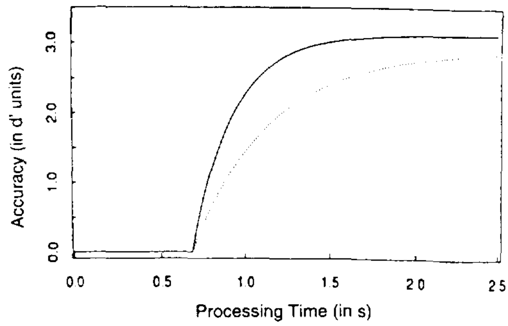

FIG. 1. Predicted SAT functions (d' as a function of processing time) under the serial parsing hypothesis for grammaticality judgments of a transitive sentence fragment (e.g., *Bill thought John watched/rushed the . . .*) containing a preferred transitive (PT) verb (solid curve) or preferred intransitive (PI) verb (dashed curve). Predicted d' accuracy was computed by the method outlined in the text.

gamma with $\alpha = 1$, 15% gamma with $\alpha = 2$, and 10% gamma with $\alpha = 3$.) Each implicit match in the comparison process had a 5% error rate. The probability correct at time t derived from the mixtures of Eq. [2] was incremented by a guessing process (0.5 accuracy) for the proportion of cases that any particular matching process had not completed by t. The overall hit rate was scaled against a false alarm rate for ungrammatical lures. (For simplicity, the false alarm rate was generated assuming three mismatch processes, each with a 5% chance of false alarm rate.)

The dashed line represents a d' SAT function for the same sentence fragment with a PI verb like *rushed* in (5b). This function was generated in the same manner as the previous one except the mixture probabilities were inverted to simulate the ordinal ranking of preference in the Connine et al. (1984) norms. That is, 75% of the time the third comparison process yielded a successful match (conditioned on failed matches for the [__PP] and the [__infinitival-S] frames); 15% of the time the second comparison yielded a successful match (conditioned on failed matches of either the [__PP] or [__infinitival-S] frame); and 10% of the time the first frame compared to input yielded a successful match.

The critical point illustrated in Fig. 1 is the predicted difference in SAT dynamics. Under the serial parsing hypothesis, the dynamics for judgments involving a PI verb in a transitive sentence frame are substantially slower than the same judgments with a PT verb. (This difference in dynamics can be seen in Fig. 1 by comparing the temporal point at which the functions reach two-thirds of their respective asymptotes.) Equation [1] provides a means of quantifying the differences in SAT dynamics. Fitting this equation to the simulated functions yielded a 47% decrement in the rate (β) parameter for the PI as compared to PT verbs.[3] This is, of course, independent of the differences in asymptotic accuracy. If the temporal differences between PT and PI verbs observed in Experiment 1 (and related studies with reading and processing load tasks) are indeed due to serial processing, then dynamics differences of this approximate magnitude should be observed.

Uniform or proportional SAT dynamics—equal SAT rates (βs) and intercepts (δs)—for PT and PI verbs are direct evidence against a serial processing hypothesis. Uniform dynamics are indicative of a parallel comparison model (see McElree & Dosher, 1989, in press; Ratcliff, 1981, 1987).[4] The parallel interpretation of verb

[3] The magnitude of the predicted rate difference could vary in either direction depending on a number of factors. More dramatic differences could result from either the inclusion of more matches (hence higher order gammas) or more extreme probability mixtures. These two factors may also serve to introduce intercept (δ) differences since the slope near the intercept is the region of maximal difference as either the order of the gamma is increased or high order gammas are weighted more strongly. Decreasing the number of matches or less extreme probability mixtures serves to reduce the difference in SAT dynamics. However, even with only two ordered matches (say, a transitive and an intransitive frame), differences are still detectable with the descriptive Eq. [1]. For example, probability mixtures of .90/.10 yield a 23% decrement in rate, dropping to 15% with a .75/.25 mixture and to 7% with a .60/.40 mixture.

[4] Parallel models with capacity limits or certain decision rules may be consistent with differences in SAT rate, although not large differences in SAT intercept (see General Discussion and McElree & Dosher, in press).

preference effects assumes that all syntactic frames retrieved from the lexicon are matched in parallel to subsequent input. Since all frames are matched in parallel, no single (i.e., preferred) frame temporarily suppresses the processing of another (i.e., less preferred) frame. The straightforward prediction of this type of model is that SAT functions for PI and PT verbs will display nearly identical SAT dynamics. Less preferred frames, however, are retrieved with less accuracy. Failures in retrieval will manifest as proportionally lower accuracy across the entire SAT function, reflected in a lower asymptotic parameter (λ) only.

SAT contrasts. The experimental conditions are directly modeled on the previous experiment: Preferred transitive and intransitive verbs are orthogonally combined with transitive and intransitive sentence frames in within-clause, early/late closure, and filler–gap constructions. The contrasts are illustrated in Table 3. A few changes were made to the materials of the previous experiment in order to derive more information about factors affecting the grammaticality judgment task. Because there was an indication from the previous study that the type of sentence frame (transitive vs intransitive) had an effect on judgment time and/or accuracy independent of particular verb preferences, sentence frames for each of the three construction types were constructed around sets of verbs with strictly transitive (e.g., *coaxed*) or strictly intransitive (e.g., *arrived*) subcategorization re-

TABLE 3
ILLUSTRATIVE MATERIALS FOR EXPERIMENT 2

Sentence frame	Verb preference	Examples
		Within-clause constructions
Transitive	Strict	John thought Bill ** coaxed the **
Transitive	Preferred	John thought Bill ** watched the **
Transitive	Nonpreferred	John thought Bill ** rushed the **
Intransitive	Strict	John thought Bill ** arrived for **
Intransitive	Preferred	John thought Bill ** rushed for **
Intransitive	Nonpreferred	John thought Bill ** watched for **
Lure		John thought Bill ** coaxed/arrived/watched/rushed was **
		Early/late closure constructions
Transitive	Strict	While Bill coaxed Mary ** around the house **
Transitive	Preferred	While Bill watched Mary ** around the house **
Transitive	Nonpreferred	While Bill rushed Mary ** around the house **
Intransitive	Strict	While Bill arrived Mary ** left the house **
Intransitive	Preferred	While Bill rushed Mary ** left the house **
Intransitive	Nonpreferred	While Bill watched Mary ** left the house **
Lure		While Bill coaxed/arrived/watched/rushed Mary ** were the house **
		Filler–gap constructions
Transitive	Strict	This is who Bill ** coaxed *p* when the **
Transitive	Preferred	This is who Bill ** watched *p* when the **
Transitive	Nonpreferred	This is who Bill ** rushed *p* when the **
Intransitive	Strict	This is who Bill ** arrived with *p* when **
Intransitive	Preferred	This is who Bill ** rushed with *p* when **
Intransitive	Nonpreferred	This is who Bill ** watched with *p* when **
Lure		This is who Bill ** coaxed/arrived/rushed/watched when was **

Note. Words enclosed in asterisks were presented together and indicate the point at which subjects were required to make a rapid grammaticality judgment. The *p*'s denote a wh-gap in syntactic structure.

quirements. Comparison of transitive and intransitive frames involving nonoptional, strictly subcategorized verbs allows a direct assessment of how rapidly one frame is processed with respect to the other without the potentially contaminating effects of optionality in verb structure. Second, as illustrated in Table 3, ungrammatical fragments (lures) specifically formed around the sets of experimental verbs were generated. The inclusion of these lures has the desirable property of allowing d' scaling of the grammatical conditions, enabling direct comparison of various conditions without the contaminating effects of various biases. Finally, critical passages in the filler–gap and early/late closure constructions were expanded by one item. In the latter case, this was done simply to allow more flexibility in constructing materials. In the former case, the additional item was used to block a potentially transitive reading of a nominally intransitive filler–gap sentence frame. As illustrated in Table 3, a subordinating conjunction (e.g., *when*) followed by a noun-phrase specifier was used to indicate the beginning of a temporal adjunct phrase (e.g., *when the phone rang*), thereby forcing a reading in which the wh-element is understood as the secondary object of the verb.

Method

Subjects. Six subjects were paid $20.00 for their participation in four 1-hr sessions. All were native English speakers with normal or corrected vision. None had participated in Experiment 1.

Materials. The 10 PT and 10 PI verbs from the previous experiment were used for the main contrasts. Additionally, 10 strict transitive (ST) and 10 strict intransitive (SI) verbs were generated in order to examine differences between the processing of transitive and intransitive sentence frames in the three construction types. These were culled from various sources, including the materials of Mitchell and Holmes (1985), Clifton et al. (1984), and Kucera and Francis (1982) frequency norms. The sets were matched to each other as closely as possible in terms of frequency of occurrence in print and letter length. On average, ST verbs had frequency counts of 31.8/million and were 7.9 letters long while SI verbs had counts of 32.2/million and were 7.7 letters long.

Illustrative sentence frames are presented in Table 3. Three sets of materials were constructed, with each set serving as the experimental material for one session. Each set consisted of 100 within-clause, 100 filler–gap, and 70 early/late closure constructions. In the case of within-clause and filler–gap constructions, the 100 sentences were composed of 30 transitive, 30 intransitive, and 40 ungrammatical frames. The transitive frames were composed using 10 ST, 10 PT, and 10 PI verbs while the intransitive frames were composed using 10 SI, 10 PI, and 10 PT verbs. For each of the 40 verbs, one ungrammatical frame was constructed. The early/late closure constructions were composed in an analogous fashion; however, in this case only 7 ST, SI, PT, and PI verbs were used. Thus, each set was composed of 21 transitive, 21 intransitive, and 28 ungrammatical frames.

As with Experiment 1, each sentence frame consisted of two parts, namely introductory material and the critical passage. Since the primary contrast concerns verbs with different preferences (PT and PI) in the same sentence frame (either transitive or intransitive), the particular items in the critical passages were balanced across the three sets. In the case of early/late closure constructions, critical passages denoting either a transitive or an intransitive sentence frame were counterbalanced over the three sessions across the three appropriate verb set (i.e., ST, PT, and PI verb sets for transitive passages and SI, PI, and PT verb sets for intransitive passages). In the case of within-clause and filler–gap constructions, critical passages included the verb of interest and therefore could not be exactly counterbalanced. In this case, however, the items in the critical passage other than the verb were counterbalanced across the three appropriate sets of verbs. Across the three sets of materials, the items used to denote one or the other frame occurred equally often in the appropriate verb set. The same counterbalancing procedure was followed in constructing the lures of ungrammatical fragments in each of the construction types. The complete set of verbs and critical fragments is presented in Appendix I.

The counterbalancing procedure for critical passages ensures that differences can be attributed to the presence of the respective verbs and not to potential differences in the respective difficulty of items in the critical passages. The introductory material was similarly balanced across sets of material. However, to avoid potential memory artifacts, the rotation of introductory material was decoupled from the rotation of critical passages. This was done so that subjects could not anticipate specific critical passages from recognition of the introductory material.

Procedure. Stimulus presentation, timing, and response collection were all carried out on an Apple IIe computer supplemented by a Superclock II timer and peripheral tone generator. Stimuli were presented on a CRT screen using a mixture of upper and lower case letters from a standard character set (approximately 6 × 4 mm).

The standard cued-response SAT paradigm (e.g., Reed, 1973) requires a prohibitively large number of trials for present purposes. Instead, a multiple-response variant of the SAT procedure was used. Wickelgren, Corbett, and Dosher, (1980) demonstrated that reliable SAT functions can be generated by this method. Barbara Dosher and I (unpublished) have explicitly compared retrieval functions in a Sternberg item-recognition paradigm generated by both single- and multiple-response methods and found the same qualitative patterns.

The procedure is illustrated in Fig. 2. A trial began with the presentation of the word *ready* and a fixation point (+) indicating the region where the stimuli were presented. Subjects initiated the presentation of sentence fragment by pressing a key on the computer keyboard. Like the previous experiment, the words of a sentence fragment were presented one at a time in the center of an otherwise clear screen. However, here subjects did not control the presentation rate or reading time of each word; rather each word was presented for a fixed 300-ms interval. This was done both to equate reading times across the various conditions and to increase the difficulty of the task. An initial tone sounded 300 ms after presentation of the final word prior to the critical passage. The critical passage (enclosed in asterisks in Table 3) was presented 200 ms after this tone sounded. The tone was repeated nine times at 300 ms intervals. Thus the second and final tone spanned a duration of 100 ms to 2600 ms after presentation of the critical passage.

An initial 1-h practice session trained subjects to respond "yes" or "no" to each tone. Responses were made by pressing one of two keys on the keyboard: The "9" and the "1" keys were used so that subjects could comfortably rest the index finger of each hand on the keys throughout a trial. The initial (precritical passage) tone served to alert subjects to the presentation of the critical passage and to define the pacing of subsequent responses. Subjects were instructed to respond to the first tone by randomly selecting one of the two response keys. Following this first response, they tapped one or the other key in synch with the tone in a manner that best reflected their current assessment of the grammatical status of the critical passage. During the practice session, subjects were explicitly trained to switch response keys while maintaining the 300 ms pacing of responses. All subjects reported finding the task to be easy after 10 or 15 min of practice.

All subjects served in four 1-h sessions, one practice and three experimental sessions. Each experimental session consisted

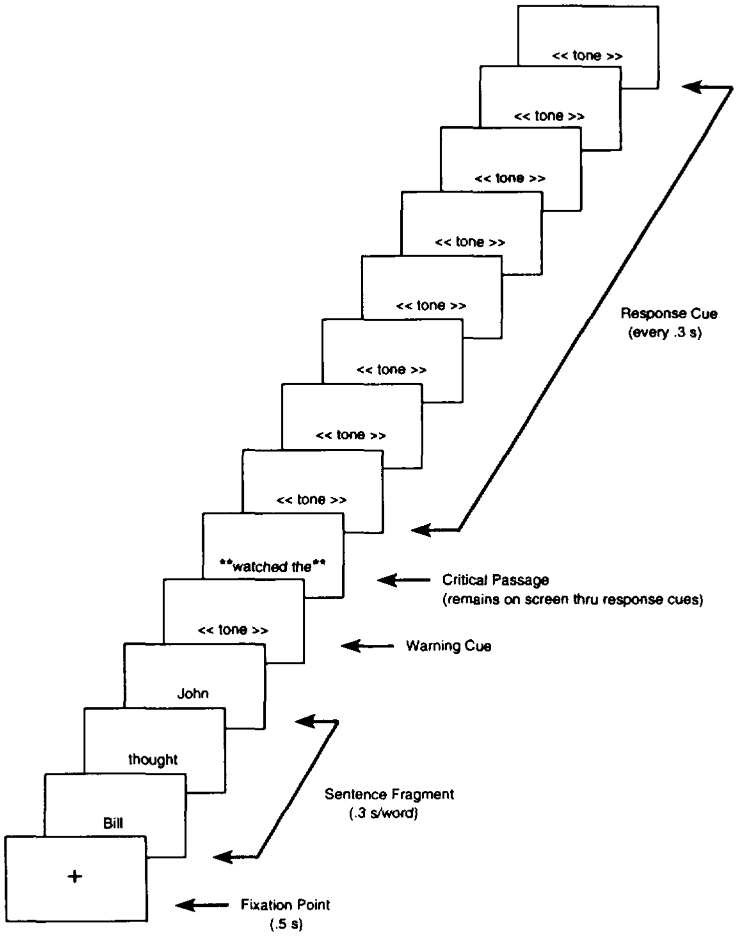

FIG. 2. A sample trial sequence illustrating the multiple-response, speed–accuracy trade-off (SAT) variant of the rapid grammaticality judgment task.

of one full set of materials with 270 trials. Across the six subjects, the order of the three sets of materials was balanced across the session, with two subjects receiving one of the three possible orders.

Design and data analysis. For each of the three types of constructions (within-clause, filler–gap, and early/late closure constructions), there were two contrasts of interest: (i) the comparison of transitive and intransitive frames with ST and SI verbs exclusively, and (ii) the comparison of PT and PI verbs within transitive and intransitive frames. In all cases, the dependent measure was d' accuracy at each of the tone lags.

For each subject, the percentage correct for each condition at each lag was calculated by pooling the accuracy of all responses that occurred in ± 150 ms of the eight absolute tone lags. This 300 ms window around the tone at each lag ensures that all responses are included in the analysis. A standard d' measure (equal variance–Gaussian model) was calculated for each condition by scaling responses to grammatical fragments against appropriate ungrammatical fragments. For contrasts of the two types of sentence frames, transitive and intransitive, with ST and SI verbs, respectively, d' was computed by scaling the hits in the grammatical conditions against the respective false alarm rates for the ungrammatical conditions containing the corresponding verbs. For contrasts of the two verb types (PT and PI), the hit rates within sentence types were scaled against a common false alarm rate estimated from pooling all ungrammatical fragments involving both PT and PI verbs. Perfect performance in any condition was adjusted by a minimum-error correction: d' was calculated assuming that the error rate was 0.5%. This correction ensures that the resulting d' values are in fact measurable. Potential interactions between this correction procedure and the exponential model fits are discussed in Appendix II.

The empirical SAT functions were fit with the descriptive exponential Eq. [1] using an iterative hill climbing algorithm (Reed, 1976), similar to Stepit (Chandler, 1969), that minimized the squared deviations of predicted from observed data. Sets of competitive fits, varying the three parameters of Eq. [1], were used to isolate differences between various SAT functions. The quality of the respective fits were assessed by three criteria, as follows: (i) The value of an R^2 statistic,

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(d_i - \hat{d}_i)^2/(n - k)}{\sum_{i=1}^{n}(d_i - \bar{d})^2/(n - 1)}, \quad [3]$$

where d_i represents the observed data values, $\hat{d}_i$ the predicted values, $\bar{d}$ the mean, n the number of data points, and k the number of free parameters (Reed, 1973). This R^2 statistic is the proportion of variance accounted for by the fit, adjusted for the number of free parameters (k). It is the same equation for *adjusted* r^2 often cited in multiple linear regression (e.g., Judd & McClelland, 1989). (ii) Evaluation of the consistency of parameter estimates across the six subjects. (ii) Most importantly, examination of whether a fit yielded systematic (residual) deviations that could be accounted for with more parameters.

Additionally, the empirical functions were also fit with a descriptive equation that derives from a time-bounded diffusion process, as developed by Ratcliff (1978):

$$d'(t) = \frac{\lambda}{\sqrt{1 + v^2/(t - \delta)}}, \; t > \delta, \; else \; 0. \quad [4]$$

Equation [4], like the exponential Eq. [1], is a three-parameter equation: λ represents the asymptotic accuracy level, δ the intercept, and v^2 is the combined random-walk variance term formed by the ratio of drift rate variance (S^2) over item relatedness variance (η^2). v^2, like β in 1, indexes the speed with which accuracy rises from chance to asymptotic level. Although this equation yielded slightly lower R^2 statistics when compared to Eq. [1] (see McElree & Dosher, 1989), the pattern of results was the same across conditions. This suggests that the conclusions drawn here are not restricted to the exponential form, but generalize to at least one other three-parameter equation that provides an adequate description of time-course data. To conserve space, the results are reported and discussed for Eq. [1] only. (The parameter estimates for the best fits of Eq. [4] are available from the author.)

Results and Discussion

All analyses are performed on individual subject's data. Consistent patterns or trends across subjects are summarized with analyses and graphs of the average (over subjects) data.

Within-clause constructions. Figure 3 shows the average empirical SAT data (symbols) and the best fitting exponential functions (lines) for within-clause sentence fragments with strictly subcategorized verbs (Fig. 3A) and optionally subcategorized verb (Fig. 3B). The data are quite unequivocal. Independent of verb preference, transitive constructions are more accu-

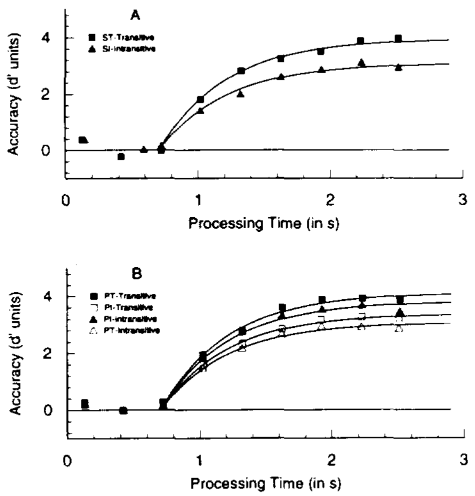

FIG. 3. Average (over subjects) d' accuracy as a function of processing time for judgments of within-clause constructions. (A) Filled squares show observed performance on transitive sentence fragments with strict transitive (ST) verbs; Filled triangles show observed performance on intransitive sentence fragments with strict intransitive (SI) verbs. (B) Square symbols show observed performance on transitive sentence fragments with preferred transitive (PT) verbs (filled squares) and preferred intransitive (PI) verbs (open squares); Triangular symbols show observed performance on intransitive sentence fragments with preferred intransitive (PI) verbs (filled triangles) and preferred transitive (PT) verbs (open triangles). Smooth curves in each panel show fits of Eq. [1] with (the average) parameters listed in Table 3.

rately judged as grammatical than are intransitive constructions. Independent of sentence type (transitive or intransitive), a mismatch between sentence frame and verb preference resulted in lower overall (asymptotic) accuracy. Neither sentence type nor verb preference affected the dynamics of the SAT functions. Details of the fits are outlined below.

A series of contrasts were performed on transitive and intransitive sentence constructions with strictly subcategorized verbs in order to isolate differences in the time course of processing. Inspection of the d' values at the longer lags in Fig. 3A shows that accuracy is higher for transitive sentence frames. Exponential fits that ignored this difference in asymptote produced systematic deviations in the fits of individual subject's data, reflected by relatively low R^2 values in the average data and across the six subjects (average R^2 = .938, ranging from .800 to .921 across subjects). Allowing separate asymptotic (λ) parameters for each frame (i.e., a $2\lambda - 1\beta - 1\delta$ fit) improved the quality of fit for all subjects, increasing R^2 in the average and each individual subject's data (average R^2 = .986, ranging from .930 to .980 across subjects). The average asymptote for transitive frames with ST verbs was estimated at 3.95 d' units compared to 3.08 units for intransitive frames with SI verbs. All subjects but one showed a consistent asymptotic advantage for transitive frames ranging from .76 to 1.54 d' units. (The one exception, subject TR, showed a relatively small reversal in the pattern with a .65 d' advantage for intransitive frames. However, this difference occasioned only a 1% increase in R^2 over the fit with a common asymptote, in contrast to the average 10% increase in the other five subjects.) Subsequent fits that systematically varied dynamics parameters, rate (β) and/or intercept (δ), over and above the 2-λ fit failed to increase the overall quality of the fit. Most importantly, they did not reveal any consistent differences in condition-specific dynamics parameters across individual subjects and in the average data.

In Experiment 1, a significant accuracy and RT advantage was found for within-clause transitive frames as compared to intransitive frames. The present experiment demonstrates that judgments of the two frames differ even with strictly subcategorized verbs and that this difference is restricted to overall levels of accuracy rather than dynamics. As previously noted, transitive completions are more structurally constrained than are intransitive completions, consisting exclusively of a direct object NP as compared to the range of possibilities that comprise the class of elements which may follow intransitive verbs. Differences in SAT asymptote appear to reflect this constraint, indicating that judgments are more accurate when less optionality in complements is permitted by a given verb.

How does the preference of a verb impact on the time course of processing? As with strictly subcategorized verbs, inspection of the late d' values in Fig. 3B, shows that transitive frames yielded higher overall accuracy levels than intransitive frames. Furthermore, within sentence frames, verbs whose preference matched the sentence frame yielded higher d' levels than verbs whose preference mismatched the sentence frame. Consequently, a fit with separate asymptotes for each condition (a $4\lambda - 1\beta - 1\delta$ fit) produced a dramatically better quality of fit (average $R^2 = .993$, ranging from .937 to .986 across subjects) than fits with a single asymptote (average $R^2 = .958$, ranging from .857 to .954 across subjects), an asymptote for each of the two sentence frames (average $R^2 = .962$, ranging from .857 to .961 across subjects), or an asymptote for preferred and nonpreferred verbs (average $R^2 = .988$, ranging from .904 to .984 across subjects). Within transitive frames, the average advantage in asymptote with a preferred verb (PT) was estimated at .73 d' units, ranging from .36 to 1.2 units across the six subjects. Similarly, within intransitive frames, the average advantage with PI verbs was estimated at .73 d' units, with five of the six subjects showing advantages that ranged from .43 to 1.18 units. (One subject (LB) showed a small and relatively minor reversal of this pattern by .25 d' units.)

The differences in asymptote within the respective sentence frames indicate that less-preferred structural information associated with verbs is less available than preferred information. This demonstrates that the retrieval of syntactic information associated with particular verbs is less than complete or perfect. Subsequent fits were applied to the data to examine whether there was any evidence that the functions differed in dynamics as predicted by the serial parsing hypothesis.

Fits that varied β and/or δ with either verb preference (preferred or nonpreferred), sentence frame (transitive or intransitive), or all four conditions reduced overall R^2 values from those observed with the $4\lambda - 1\beta - 1\delta$ fits. Moreover, these more embellished fits produced no consistent differences in the estimated dynamics parameters across subjects. This latter fact is evidenced in the average data where both the estimated rate (β) and intercept (δ) parameters were highly similar when separately allotted to sentence frames irrespective of verb preference (β(transitive) = 1.95 and β(intransitive) = 2.17; δ(transitive) = 701 ms and δ(intransitive) = 701 ms) or to fragments with preferred and nonpreferred verbs across sentence frames (β(preferred) = 1.99 and β(nonpreferred) = 2.07; δ(preferred) = 696 ms and δ(nonpreferred) = 707 ms).

The similar dynamics for preferred and nonpreferred verbs is inconsistent with the serial parsing hypothesis. The pattern of data suggests that verb preference determines the likelihood that a particular structural frame is retrieved, but does not cause the parser to suppress processing the less-preferred frame in favor of the preferred frame. The overall pattern of differences in judgments of within-clause fragments was summarized with a single exponential model applied to each subject's data. The estimates of the individual subject's dynamics parameters were remarkably stable across the separate contrasts involving nonoptional (ST and SI) and optional (PT and PI) verbs. This stability is directly reflected in the average data, where the rate (β) and intercept (δ) were estimated at 1.81 and 710 ms for ST and SI verbs and 2.05 and 700 ms for PT and PI verbs. Given this stability, all six within-clause conditions were fit with common dynamics but different asymptotic levels, i.e., a $6\lambda - 1\beta - 1\delta$ fit. The parameter estimates for the fit are presented in Table 4 for the average data and each individual subject. The parameter values from the average data were in turn

TABLE 4
EXPERIMENT 2: PARAMETER ESTIMATES FOR EXPONENTIAL MODEL FITS (WITHIN-CLAUSE CONSTRUCTIONS)

		Subject					
Parameters	Average	CL	GR	LB	PR	TR	PW
Asymptotes (λ)							
Transitive ST	3.95	4.07	4.29	3.77	2.88	3.91	4.84
Transitive PT	4.11	4.41	3.43	4.16	4.22	4.19	4.22
Transitive PI	3.38	3.86	3.07	3.25	3.34	2.99	3.71
Intransitive SI	3.08	2.73	2.75	3.01	1.98	4.56	3.31
Intransitive PI	3.81	3.93	4.04	2.72	3.98	3.88	3.72
Intransitive PT	3.08	3.45	3.11	2.97	3.12	2.70	3.04
Dynamics							
Rate (β)	1.97	2.38	4.10	2.16	2.89	1.55	1.50
Intercept (δ)	.704	.853	.710	.725	.708	.790	.697
R^2	.991	.966	.972	.958	.946	.936	.963

used to generate the smooth functions for each of the conditions in Fig. 3.

Early/late closure constructions. When PT and PI verbs are replaced by ST and SI verbs in this construction, the inherent ambiguity associated with postverbal NP is removed. Accordingly, processing differences between transitive and intransitive sentence frames simply reflect temporal differences in the processing of the critical passages. Figure 4A presents the average empirical SAT points and the best-fitting exponential function for transitive and intransitive sentence frames with strictly subcategorized verbs. As is evident from the average, no systemic differences were found across subjects. The average data were well approximated with a simple three-parameter fit, a $1\lambda - 1\beta - 1\delta$ fit [R^2 = .985]. This fit reflects the fact that no systematic trend emerged across subjects. The data from two subjects, GR and PW, mirrored the average in that the two functions virtually superimposed. These data were fit well with the three-parameter fit [R^2 of .970 and .965, respectively]. Two other subjects, CL and LB, showed modest asymptotic differences favoring transitive frames (.37 and .9 d' units) that were better modelled by a $2\lambda - 1\beta - 1\delta$ fit [R^2 of .964 and .946, respectively]. The remaining two subjects, PR and TR, showed higher asymptotic values for intransitive frames (1.8 and .93 d' units) that were also modeled well by a $2\lambda - 1\beta - 1\delta$ fit [R^2 of .931 and .896, respectively]. No subject showed evidence for any clear dynamics differences. The parameter estimates for the respective fits for the average data and each individual subject are presented in the top panel of Table 5. The parameter estimates for the average data were used to generate the smooth function in Fig. 4A.

Figure 4B presents the average empirical SAT points for conditions involving PT and PI verbs. Inspection of the late d' values, as with main clause constructions, suggests that both the type of sentence frame and verb preference affected terminal accuracy levels. This pattern was clearly evident in systematic misfits when either factor was ignored. A $4\lambda - 1\beta - 1\delta$ fit improved the quality of fit for all subjects as indexed by higher R^2 values [average R^2 = .984, ranging from .899 to .971 across subjects] than what was observed with fits with a single asymptote [average R^2 = .932, ranging from .740 to .937], an asymptote for each of the two sentence frames [average R^2 = .933, ranging from .778 to .953], or an asymptote for preferred and nonpreferred verbs [average R^2 = .977, ranging from .871 to .943]. Across all six subjects, verbs in a preferred sentence frame yielded con-

TABLE 5
EXPERIMENT 2: PARAMETER ESTIMATES FOR EXPONENTIAL MODEL FITS
(EARLY/LATE CLOSURE CONSTRUCTIONS)

		Subject					
Parameters	Average	CL	GR	LB	PR	TR	PW
			Strict subcategorization				
Asymptotes (λ)							
Transitive ST	4.37*	4.74	4.08*	5.00	3.58	3.77	4.24*
Intransitive SI	4.37*	4.37	4.08*	4.06	4.50	4.70	4.24*
Dynamics							
Common Rate (β)	1.67	1.57	3.49	1.52	2.00	1.48	1.96
Common Intercept (δ)	.680	.648	.751	.618	.677	.900	.675
R^2	.985	.964	.970	.946	.931	.896	.965
			Optional subcategorization				
Asymptotes (λ)							
Transitive PT	3.97	3.15	4.21	4.50	3.88	4.48	4.04
Transitive PI	2.91	3.04	2.71	3.47	3.38	3.38	2.03
Intransitive PI	3.83	4.50	4.50	4.49	4.23	4.00	2.61
Intransitive PT	3.24	3.81	4.29	3.56	2.93	3.93	2.08
Dynamics							
Transitive Rate (β)	2.07	1.56	3.34	2.41	2.31	.988	1.99
Intransitive Rate (β)	1.54	1.13	3.22	1.24	1.19	.720	1.88
Common Intercept (δ)	.669	.707	.681	.671	.665	.540	.679
R^2	.986	.962	.959	.914	.950	.894	.965

* Fit with a common λ.

sistently higher λ estimates than verbs in a less-preferred frame. Estimated λ differences between PT and PI verbs in transitive frames averaged 1.1 d' units and ranged from .1 to 1.9 units across subjects. Differences between PI and PT verbs in intransitive frames were slightly lower, averaging .59 d' units that ranged from .1 to 1.14 units across subjects.

Lower asymptotic levels for verbs in a less-preferred construction indicate that subjects overlook the less-preferred structural analyses of the ambiguous NP a commensurate proportion of the time. This finding is consistent with the retrieval failures found in the within-clause constructions. With locally ambiguous constructions, however, lower asymptotes for less-preferred verbs do not necessarily imply retrieval failures: Subjects may retrieve both syntactic frames with equal probabilities but first analyze the ambiguous NP according to the preference of the verb. Such a strategy would result in a garden-path whenever the preferred interpretation was selected but the critical passage forced a less preferred reading. Yet, if the less-preferred frame was equally available, then it is reasonable to suppose that subjects could rapidly recover from an inappropriate analysis, given the close proximity of the NP to the critical passage (cf. Warner & Glass, 1987). An initial misanalysis followed by recovery would serve to depress the overall rise portion of the SAT function, manifesting as a SAT rate (β) difference.

In the model fits of all but one subject, there was no indication that preferred and nonpreferred functions diverged in dynamics. In five of the six subjects, no systematic trend favoring the β (or δ) parameter for preferred verbs emerged, and these fits did not serve to improve the overall quality of the fit. (One subject, PR, showed a 53%

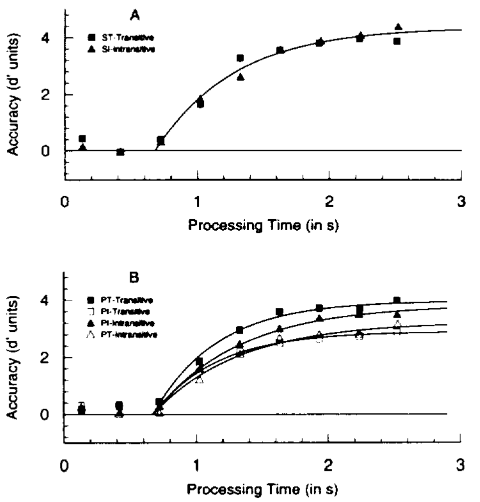

FIG. 4. Average (over subjects) d' accuracy as a function of processing time for judgments of early/late closure constructions. (A) Filled squares show observed performance on transitive sentence fragments with strict transitive (ST) verbs; filled triangles show observed performance on intransitive sentence fragments with strict intransitive (SI) verbs. (B) Square symbols show observed performance on transitive sentence fragments with preferred transitive (PT) verbs (filled squares) and preferred intransitive (PI) verbs (open squares); triangular symbols show observed performance on intransitive sentence fragments with preferred intransitive (PI) verbs (filled triangles) and preferred transitive (PT) verbs (open triangles). Smooth curves in each panel show fits of Eq. [1] with (the average) parameters listed in Table 4. (In A, both conditions are fit with a common set of parameters, see text.)

advantage in the β estimate for preferred verbs. However, this was due to perfect performance at the middle to late lags in the preferred conditions. As such, this rate difference is likely a consequence of the d' correction process forcing what is a real asymptotic difference into an artificial rate estimate; see Appendix II.) The absence of a dynamics difference demonstrates that subjects did not reach a less-preferred analysis via an initial misanalysis based on verb preference. Thus, the overall lower levels of accuracy with nonpreferred verbs appear to reflect simple failures to retrieve less-preferred syntactic frames—failures that subjects do not appear to recover from, at least over the time course sampled.

While dynamics did not vary with preference, fits that varied β as a function of sentence frame (transitive or intransitive) did yield a consistently higher rate estimate for transitive frames, specifically a 26% advantage in the average data, ranging from 4 to 49% across the six subjects. The parameter estimates for the $4\lambda - 2\beta - 1\delta$ fit are presented in the lower panel of Table 5. The estimates from the average data were used to generate the smooth functions in Fig. 4B.

Note that no comparable β difference was found with ST and SI verbs. This rate difference is not, therefore, simply a consequence of differences in the processing of the respective critical passages, but has its source in the inherent optionality of the PT and PI verbs. The higher β for transitive frames indicates that subjects favor a direct object analysis of the NP when such an option is available. The tendency to adopt this strategy appears to temporarily suppress the alternative, early closure analysis. This difference in dynamics is certainly suggestive of a general strategy of late closure (Frazier, 1987; see General Discussion). Note, however, that this difference is independent of verb preference. Thus, the data suggest that while verb preference affects the probability that syntactic information is retrieved, it does not appear to induce a late closure strategy. Equal dynamics for the two verb types within sentence frames indicate that alternative syntactic analyses are equally computable provided such information had been retrieved.

Filler-gap constructions. Figure 5A presents the average empirical SAT points for cleft constructions with ST and SI verbs. In the average data, the functions virtually superimpose and consequently were fit well by a $1\lambda - 1\beta - 1\delta$ fit [$R^2 = .988$]. Three of the six subjects, GR, LB, and TR, mirrored this pattern with R^2 ranging from .897 to .959. Two subjects, CL and PR, showed late d' values that favored constructions with a transitive gap that were better captured by a $2\lambda - 1\beta - 1\delta$ fit [R^2s of .956 and .968, respectively]. The remaining subject,

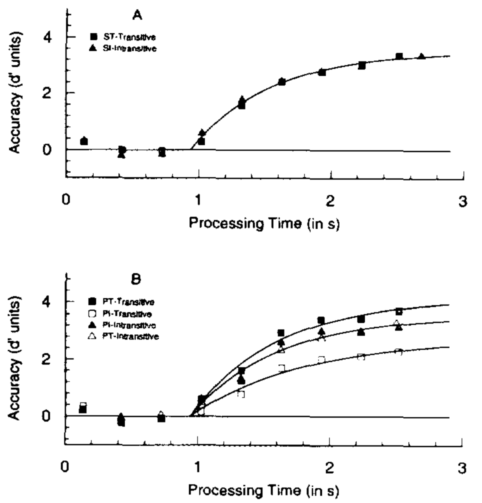

FIG. 5. Average (over subjects) d' accuracy as a function of processing time for judgments of Filler-Gap constructions. (A) Filled squares show observed performance on transitive sentence fragments with strict transitive (ST) verbs; filled triangles show observed performance on intransitive sentence fragments with strict intransitive (SI) verbs. (B) Square symbols show observed performance on transitive sentence fragments with preferred transitive (PT) verbs (filled squares) and preferred intransitive (PI) verbs (open squares); triangular symbols show observed performance on intransitive sentence fragments with preferred intransitive (PI) verbs (filled triangles) and preferred transitive (PT) verbs (open triangles). Smooth curves in each panel show fits of Eq. [1] with (the average) parameters listed in Table 4. (In A, both conditions are fit with a common set of parameters. In B, PI and PT verbs in intransitive sentence fragments (filled and open triangles, respectively) are fit with a common set of parameters.)

PW, showed late d' values favoring the transitive construction with ST verbs, again adequately captured by a $2\lambda - 1\beta - 1\delta$ fit [$R^2 = .922$]. No subject showed evidence of any dynamics difference between sentence frames. The parameter estimates for the respective fits are presented in the upper panel of Table 6. The estimates from the average data were used to generate the single function in Fig. 5A. The lack of a consistent difference across subjects suggests that the two sentence frames can be processed with approximately equal ease in the context of verbs that unambiguously denote the correct filler-gap assignment.

Figure 5B presents the average empirical SAT points for transitive and intransitive frames formed around PT and PI verbs. Across all subjects and in the average data, there was no evidence that the functions for PI and PT verbs in intransitive frames differed in either asymptote or dynamics. In contrast, all subjects showed dramatically higher asymptotes for PT verbs as compared to PI verbs in transitive frames. The four functions were initially fit with a $3\lambda - 1\beta - 1\delta$ fit, with one λ for intransitive frames irrespective of verb preference and one λ for each of the verb types in transitive frames [average R_2 of .981, ranging from .915 to .979]. Across all subjects, transitive frames with PI verbs resulted in dramatically lower λ estimates than with PT verbs, averaging 1.73 d' units, ranging from 1.13 to 2.16 across subjects.

Subsequent fits contrasting the dynamics of the respective functions found no evidence for a difference as a function of sentence frame. However, within transitive frames, five of the six subjects showed a consistently lower rate parameter for the PI verbs. The estimates of the rate parameters for intransitive frames with both types of verbs and transitive frames with PT verbs were nearly identical. Consequently, the difference in dynamics was adequately captured by a $3\lambda - 2\beta - 1\delta$ fit, where one β was allotted to PI verbs in transitive frames and one to the other three SAT functions. The fit occasioned only slightly higher or equivalent R^2 from the simple 3-λ fit [ranging from .915 to .980].[5] The rate parameter for transitive frames with nonpreferred verbs was estimated on average at 25%

[5] The $3\lambda - 2\beta - 1\delta$ fit is clearly more representative of the data than the $3\lambda - 1\beta - 1\delta$ fit when one considers (i) the consistent rate advantage for PT verbs in five of the six subjects and (ii) that the 1-β fit systematically overshoots observed accuracy for the first two rising points (1.0 to 1.5 s) on the PI-Transitive function. The similarity of R^2 estimates for the 1-β and 2-β fits, while at odds with (i) and (ii), is a consequence of the fact that systematic misfits of 2 points out of a total of 36 points (4 conditions $\times$ 9 lags) do not offset the cost of an additional parameter in Eq. [3].

TABLE 6
EXPERIMENT 2: PARAMETER ESTIMATES FOR EXPONENTIAL MODEL FITS (FILLER–GAP CONSTRUCTIONS)

	Subject						
Parameters	Average	CL	GR	LB	PR	TR	PW
			Strict subcategorization				
Asymptotes (λ)							
Transitive ST	3.53*	3.91	3.46*	3.78*	3.26	4.90*	3.36
Intransitive SI	3.53*	2.41	3.46*	3.78*	1.15	4.90*	4.20
Dynamics							
Common Rate (β)	1.64	3.45	4.99	1.10	2.36	.639	1.85
Common Intercept (δ)	.937	1.203	.948	1.007	.908	.904	.920
R^2	.988	.956	.959	.909	.968	.897	.922
			Optional subcategorization				
Asymptotes (λ)							
Transitive PT	4.17	4.12	4.37	4.50	3.87	4.14	4.47
Transitive PI	2.79	2.49	2.55	3.04	2.88	2.57	3.71
Intransitive PI & PT	3.58	2.94	3.73	3.30	4.09	4.49	3.51
Dynamics							
Common Rate (β)	1.52	1.01	1.77	1.67	1.36	1.01	1.92
Transitive-PI Rate (β)	1.14	1.17	1.21	1.36	1.23	.943	.698
Common Intercept (δ)	.939	.875	.679	1.00	.943	1.00	.963
R^2	.981	.934	.979	.934	.955	.913	.933

* Fit with a common λ.

lower than with preferred verbs or with either type of verb in an intransitive frame. This decrement ranged from 19 to 64% across the five subjects, with one subject, CL, showing a reversal of the pattern by 13%. (Subject CL also showed a lower R^2 (.933) as compared with the simple 3λ fit (.936) suggesting that the additional parameter was not accounting for any systematic deviations.) The parameter estimates for the $3\lambda - 2\beta - 1\delta$ fit are presented in the lower panel of Table 6. The estimates from the average data were used to generate the smooth functions in Fig. 5B.

Several empirical features of the functions for filler–gap constructions are markedly distinct from the other two construction types. First, the estimated intercepts for judgments of filler–gap constructions are substantially longer (approximately 250 ms) than for either within-clause or early/late closure constructions. With filler–gap relations, processes must be invoked to bind the dislocated filler item to the argument position of the gap in surface structure. The delayed intercepts for judgments of the cleft constructions are consistent with the recruitment of additional processes.

Second, judgments of intransitive frames show no evidence for an effect of verb preference on asymptotic performance. This is likely due to the clear surface markings of the NP–gap position resulting from the juxtaposition of a preposition and a subordinating conjunction (e.g., *with* p *when* in Table 2). When such marking was absent, as in the transitive filler–gap frames, verb preference had a clear effect on asymptotic accuracy, indicating that subjects tended to overlook the less-preferred syntactic expansion that postulates a gap in the verb's direct object position. The lack of a preference effect in intransitive constructions suggests that the retrieval deficits that are characteristically observed in other contexts can be eliminated by strong surface cues.

Finally, in the absence of strong surface cues, the effect of verb preference was not restricted to asymptotic performance but also impacted on the rate of information accrual. This rate difference indicates that verb preference has an effect on filler–gap processing that extends beyond the simple probability that a particular syntactic form was retrieved from the lexicon. This difference is consistent with claims that verb preferences are used to serially guide the processing of filler–gap relations. Alternative notions are explored below.

General Discussion

Retrieval failures. With one exception (discussed below), asymptotic accuracy in the SAT paradigm was consistently lower when the syntactic preference of the verb mismatched the sentence context. The small but reliable differences in asymptote demonstrate that less-preferred structural frames are less available to parsing routines than the dominant, preferred frame associated with the verb. These failures in retrieval do not necessarily indicate that less-preferred frames were unknown to readers; rather, only that such frames were not recoverable given the prior processing of the sentence context and the particular range of times allowed for the judgment (0.1 to 2.5 s). Given the simplicity of the materials, no doubt near-perfect performance would have been observed in most conditions if subjects had the opportunity to backtrack to reanalyze the entire sentence fragment. Backtracking, as evidenced by regressive eye movements (Frazier & Rayner, 1982; Rayner et al., 1983), occurs frequently in natural reading. The variant of the rapid grammaticality judgment task used here intentionally disallowed backtracking in order to measure the upper limit on performance given a one-pass processing of the sentence fragment. The increase in errors for nonpreferred sentence structures indicates that, contrary to some assumptions (e.g., Shapiro et al., 1987, 1989), lexical retrieval routines do not recover the exhaustive set of syntactic frames associated with a verb on a one-pass parse.

The probability of recovering a less-preferred frame is likely to depend on the overall sentence context, perhaps even discourse context. Some (albeit indirect) evidence for the impact of contextual cues on the retrievability of less-preferred frames was found in judgments of cleft constructions with a gap in the secondary object position (intransitive constructions). There it was observed that preferred transitive verbs yielded performance levels that were indistinguishable from preferred intransitive verbs, despite the fact that the same verbs yielded lower performance in all other types of intransitive constructions. The lack of an effect of verb preference in the intransitive cleft constructions appears to be related to the clear surface markings of the intransitive gap (viz, the juxtaposition of a preposition and a subordinating conjunction). By extension, it is conceivable that other syntactic, semantic, and discourse cues may serve similarly to reduce the type of retrieval deficit associated with recovering a less-preferred verb frame.

Serial and parallel parsing strategies. The accuracy of retrieving syntactic information from the lexicon is logically independent of the question of whether parsing is serial or parallel. The latter concerns the issue of how retrieved syntactic information is applied to incoming words. In two of the three contexts examined here, no evidence was found to support the claim that the parser is serially guided by the most dominant syntactic frame associated with a verb. SAT measures of the dynamics (growth) of rapid grammaticality judgments demonstrated that in the case of processing both (i) a closed class item uniquely denoting either a transitive or intransitive fragment (within-clause constructions) and (ii) an ambiguous NP (early/late closure constructions), there was no tendency for the preferred analysis to temporarily suppress a less-preferred analysis. Rather, both preferred and nonpreferred analyses displayed near identical temporal dynamics. These data are at odds with the general claim that the parser is serially guided by lexical information and with specific serial parsing models of the form proposed by Ford et al. (1982; Kaplan & Bresnan, 1982). The data are more compatible with the view that all frames retrieved from the lexicon are matched in parallel to subsequent input.

While no evidence was found for serial processing in cases where all potential arguments are realized in surface structure, some evidence for serial guidance based on verb preference was found in the processing of constructions with filler–gap dependencies. Preferred intransitive verbs in constructions with a missing argument in the direct object position yielded slower SAT dynamics than the same constructions with preferred transitive verbs. This temporary suppression of the processing of nonpreferred verb frames is consistent with a serial assignment of filler–gap relations based on verb preference.

As noted previously, the intercepts for judgments of all filler–gap constructions were delayed on average 250 ms relative to all nongapped constructions. This increased processing time clearly indicates that constructions with filler–gap dependencies involve processing beyond what is required when all arguments are realized in surface structure. Recent evidence from the probe-recognition task (Bever & McElree, 1988; McElree & Bever, 1989) and the cross-modal priming task (Nicol & Swinney, 1989) indicate that resolving a filler–gap dependency involves a type of anaphoric processing that is similar to determining explicit anaphoric relations: Once the gap in constituent structure has been identified, an antecedent (filler) must be retrieved and assigned to the argument position of the gap. A serial processing strategy may dramatically reduce the additional memory and processing resources needed to test all potential filler–gap dependencies.

Unfortunately, however, the difference in SAT rate observed for filler–gap constructions is not unequivocal evidence for a serial process. SAT rate differences may result from parallel comparison models in which the rate of information accumulation differs for various comparisons (see, McElree & Dosher, 1989, in press). We may expect to find SAT rate differences of the form observed here if, for example, the parser processed alternative expansions in parallel but at rates determined by the strength to which the alternatives are associated with the verb. (In particular, if strong or preferred alternatives are processed at faster rates than weak or less-preferred alternatives.) In some cases, we can discriminate serial from rate-varying parallel models (see McElree & Dosher, in press). The intercepts of SAT functions are the key data. While rate-varying parallel models predict differences in SAT rate, all comparisons are associated with a common intercept, since, by definition, all comparisons are initiated at the same time. Simple serial models usually predict large differences in SAT intercepts. However, differences in intercept will be masked if, as in the present case, the overall SAT function represents a probabilistic mixture of various orders and/or numbers of serial comparison processes (see Fig. 1 and accompanying text). In these cases, the differences arising from the serial component will be expressed in the rate rather than intercepts of the functions (as in Fig. 1). We are forced to conclude, therefore, that while the observed difference in SAT rate is suggestive of a serial process guided by lexical preferences, it is nevertheless possible that potential filler–gap relations are processed in parallel but at rates determined by verb preference.

Within the limits of the types of sentence structures tested here, the SAT data indicate that it is only in the case of filler–gap processing that verb preference may induce a serial parsing strategy. It is important to note, however, that this data primarily address the issue of serial parsing based on verb preferences. It is possible that other sorts of serial parsing strategies exist. Indeed, much recent research has been devoted to examining various serial strategies to deal with structural ambiguities. Frazier and colleagues (Frazier, 1978, 1987; Frazier & Rayner, 1982; Rayner et al., 1983; Rayner & Frazier, 1987) have argued that various types of attachment ambiguities are serially parsed according to, for example, a minimal attachment or a late closure strategy. Minimal attachment is a strategy that instantiates the principle "use the smallest number of phrase structure rule applications to attach each incoming word into the structure currently being built" (Frazier, 1987). This strategy explains why, for example, the prepositional phrase *with the binoculars* in the sentence *The cop saw the man with the binoculars* tends to attach to the VP (in which case, the cop has the binoculars) rather than to the object NP (in which case, the man has the binoculars). Late closure is a strategy that states whenever possible "attach each incoming word into the phrase currently being analyzed" (Frazier, 1987). Late closure is presumed to apply to the local ambiguities in the early/late closure constructions.

While there was no evidence in Experiment 2 to support the claim that verb preference induced either an early or late closure of the ambiguous NP, there was some evidence in support of a general late closure strategy. Independent of verb preference, SAT dynamics were substantially faster for critical passages that forced a late closure reading of the ambiguous NP as compared to those that forced an early closure reading. These data are certainly suggestive of a general, serial strategy. However, they are subject to the same interpretative ambiguity as discussed above: We can not rule out the possibility that the parser operates in parallel but processes the late closure analysis at a faster rate than the early closure analysis. Moreover, the specific contrasts employed here, in particular the deliberate absence of punctuation, may have biased the parser to give more weight to a late as opposed to early closure analysis. For example, it would be quite natural to assume that *Mary* in *While Bill watched/rushed Mary . . .* is the direct object of either *watched* or *rushed* when the verb is not followed by a comma. Additional SAT contrasts without this bias are needed to further test this and other possible serial parsing strategies.

Appendix I: Verbs and Critical Passages Used in Experiments 1 and 2

Experiment 1

Version *a* of each verb pair lists the transitive sentence frame, whereas version *b* lists the intransitive sentence frame. In each case, the preferred transitive (PT) verb is followed by the preferred intransitive (PI) verb.

Within-clause constructions

Illustrative sentence-initial material. Everyone realized that Bill . . .

1.a watched/rushed the
1.b watched/rushed for
2.a passed/jumped the
2.b passed/jumped over
3.a painted/hurried the
3.b painted/hurried for
4.a visited/escaped the
4.b visited/escaped with
5.a pushed/raced the
5.b pushed/raced by
6.a pulled/cheated the
6.b pulled/cheated at
7.a wrote/walked the
7.b wrote/walked with
8.a kicked/swam the
8.b kicked/swam with
9.a cleaned/lectured the
9.b cleaned/lectured with
10.a called/pointed the
10.b called/pointed to

Early/late closure constructions

Illustrative sentence-initial material. While Bill . . .

1.a watched/rushed Mary at dinner
1.b watched/rushed Mary started dinner
2.a visited/hurried Mary at home
2.b visited/hurried Mary arrived home
3.a pushed/raced Mary at school
3.b pushed/raced Mary left school
4.a pulled/cheated Mary at work
4.b pulled/cheated Mary left work
5.a wrote/walked Mary about school
5.b wrote/walked Mary began school

6.a kicked/lectured Mary in class
6.b kicked/lectured Mary left class
7.a called/escaped Mary at home
7.b called/escaped Mary left home
8.a passed/jumped Mary in school
8.b passed/jumped Mary began school

Filler–gap constructions

Illustrative sentence-initial material. This was who/what/where Bill . . .

1.a watched/rushed when
1.b watched/rushed for
2.a passed/jumped while
2.b passed/jumped over
3.a painted/hurried when
3.b painted/hurried for
4.a visited/escaped before
4.b visited/escaped with
5.a pushed/raced until
5.b pushed/raced at
6.a pulled/cheated when
6.b pulled/cheated with
7.a wrote/walked before
7.b wrote/walked with
8.a kicked/swam when
8.b kicked/swam at
9.a cleaned/lectured after
9.b cleaned/lectured with
10.a called/pointed when
10.b called/pointed at

Experiment 2

Version *a* of each verb pair lists the transitive sentence frame, version *b* lists the corresponding intransitive sentence frame, and version *c* lists the ungrammatical (control) sentence frame. In contrasts of optionally subcategorized verbs, the preferred transitive (PT) verb is followed by the preferred intransitive (PI) verb.

Within-clause constructions: Preferred Transitive/Intransitive Verbs

Illustrative sentence-initial material. Everyone realized that Bill . . .

1.1.a watched/rushed the
1.1.b watched/rushed for
1.1.c watched/rushed has
1.2.a watched/rushed a
1.2.b watched/rushed at
1.2.c watched/rushed will
1.3.a watched/rushed those
1.3.b watched/rushed with
1.3.c watched/rushed was
2.1.a passed/jumped the
2.1.b passed/jumped over
2.1.c passed/jumped are
2.2.a passed/jumped a
2.2.b passed/jumped on
2.2.c passed/jumped has
2.3.a passed/jumped these
2.3.b passed/jumped at
2.3.c passed/jumped why
3.1.a painted/hurried the
3.1.b painted/hurried for
3.1.c painted/hurried did
3.2.a painted/hurried a
3.2.b painted/hurried on
3.2.c painted/hurried had
3.3.a painted/hurried these
3.3.b painted/hurried to
3.3.c painted/hurried are
4.1.a visited/escaped the
4.1.b visited/escaped with
4.1.c visited/escaped has
4.2.a visited/escaped a
4.2.b visited/escaped to
4.2.c visited/escaped were
4.3.a visited/escaped this
4.3.b visited/escaped from
4.3.c visited/escaped could
5.1.a pushed/raced the
5.1.b pushed/raced by
5.1.c pushed/raced why
5.2.a pushed/raced a
5.2.b pushed/raced with
5.2.c pushed/raced did
5.3.a pushed/raced those
5.3.b pushed/raced on
5.3.c pushed/raced has
6.1.a pulled/cheated the
6.1.b pulled/cheated at
6.1.c pulled/cheated else
6.2.a pulled/cheated a
6.2.b pulled/cheated by
6.2.c pulled/cheated was
6.3.a pulled/cheated this
6.3.b pulled/cheated with
6.3.c pulled/cheated went
7.1.a wrote/walked the
7.1.b wrote/walked with
7.1.c wrote/walked should
7.2.a wrote/walked a
7.2.b wrote/walked by
7.2.c wrote/walked would
7.3.a wrote/walked those
7.3.b wrote/walked about
7.3.c wrote/walked must
8.1.a kicked/swam the
8.1.b kicked/swam with
8.1.c kicked/swam may
8.2.a kicked/swam a
8.2.b kicked/swam about
8.2.c kicked/swam should
8.3.a kicked/swam this
8.3.b kicked/swam at
8.3.c kicked/swam has
9.1.a cleaned/lectured the

9.1.b cleaned/lectured with
9.1.c cleaned/lectured has
9.2.a cleaned/lectured a
9.2.b cleaned/lectured on
9.2.c cleaned/lectured had
9.3.a cleaned/lectured this
9.3.b cleaned/lectured about
9.3.c cleaned/lectured might
10.1.a called/pointed the
10.1.b called/pointed to
10.1.c called/pointed were
10.2.a called/pointed a
10.2.b called/pointed from
10.2.c called/pointed are
10.3.a called/pointed this
10.3.b called/pointed with
10.3.c called/pointed was

Strict Transitive/Strict Intransitive Verbs

Illustrative sentence-initial material. Everyone realized that Bill . . .
1.1.a warned the
1.1.b complained to
1.1.c warned/complained went
1.2.a warned a
1.2.b complained at
1.2.c warned/complained will
1.3.a warned those
1.3.b complained about
1.3.c warned/complained was
2.1.a coaxed the
2.1.b sauntered over
2.1.c coaxed/sauntered has
2.2.a coaxed a
2.2.b sauntered to
2.2.c coaxed/sauntered are
2.3.a coaxed these
2.3.b sauntered at
2.3.c coaxed/sauntered why
3.1.a appraised the
3.1.b excelled in
3.1.c appraised/excelled did
3.2.a appraised a
3.2.b excelled on
3.2.c appraised/excelled had
3.3.a appraised this
3.3.b excelled at
3.3.c appraised/excelled are
4.1.a destroyed the
4.1.b agreed with
4.1.c destroyed/agreed has
4.2.a destroyed a
4.2.b agreed to
4.2.c destroyed/agreed of
4.3.a destroyed this
4.3.b agreed about
4.3.c destroyed/agreed could
5.1.a reminded the
5.1.b arrived by
5.1.c reminded/arrived why
5.2.a reminded a
5.2.b arrived with
5.2.c reminded/arrived did
5.3.a reminded those
5.3.b arrived on
5.3.c reminded/arrived did
6.1.a reassured the
6.1.b tiptoed at
6.1.c reassured/tiptoed else
6.2.a reassured a
6.2.b tiptoed by
6.2.c reassured/tiptoed was
6.3.a reassured this
6.3.b tiptoed by
6.3.c reassured/tiptoed went
7.1.a guarded the
7.1.b prayed with
7.1.c guarded/prayed should
7.2.a guarded a
7.2.b prayed by
7.2.c guarded/prayed would
7.3.a guarded those
7.3.b prayed about
7.3.c guarded/prayed must
8.1.a notified the
8.1.b quarrelled with
8.1.c notified/quarrelled may
8.2.a notified a
8.2.b quarrelled about
8.2.c notified/quarrelled should
8.3.a notified this
8.3.b quarrelled at
8.3.c notified/quarrelled must
9.1.a initiated the
9.1.b testified with
9.1.c initiated/testified has
9.2.a initiated a
9.2.b testified on
9.2.c initiated/testified had
9.3.a initiated this
9.3.b testified about
9.3.c initiated/testified might
10.1.a convinced the
10.1.b abstained with
10.1.c convinced/abstained has
10.2.a convinced a
10.2.b abstained on
10.2.c convinced/abstained had
10.3.a convinced this
10.3.b abstained about
10.3.c convinced/abstained might

Early/late closure constructions: Preferred Transitive/Intransitive Verbs

Illustrative sentence-initial material: While Bill . . .
1.1.a watched/rushed Mary at the dinner

1.1.b watched/rushed Mary started the dinner
1.1.c watched/rushed Mary are the dinner
1.2.a watched/rushed Mary around the house
1.2.b watched/rushed Mary left the house
1.2.c watched/rushed Mary were the house
1.3.a watched/rushed Mary during the class
1.3.b watched/rushed Mary began the class
1.3.c watched/rushed Mary each the class
2.1.a visited/hurried Mary during the holidays
2.1.b visited/hurried Mary celebrated the holidays
2.1.c visited/hurried Mary have at holidays
2.2.a visited/hurried Mary at the mass
2.2.b visited/hurried Mary attended the mass
2.2.c visited/hurried Mary both the mass
2.3.a visited/hurried Mary at the resort
2.3.b visited/hurried Mary enjoyed the resort
2.3.c visited/hurried Mary much the resort
3.1.a pushed/raced Mary to the fence
3.1.b pushed/raced Mary climbed the fence
3.1.c pushed/raced Mary went the fence
3.2.a pushed/raced Mary in the yard
3.2.b pushed/raced Mary cleaned the yard
3.2.c pushed/raced Mary of a yard
3.3.a pushed/raced Mary towards the car
3.3.b pushed/raced Mary left the car
3.3.c pushed/raced Mary none the car
4.1.a pulled/cheated Mary into the class
4.1.b pulled/cheated Mary left the class
4.1.c pulled/cheated Mary very the class
4.2.a pulled/cheated Mary in the race
4.2.b pulled/cheated Mary quit the race
4.2.c pulled/cheated Mary seem the race
4.2.a pulled/cheated Mary in the game
4.3.b pulled/cheated Mary watched the game
4.3.c pulled/cheated Mary are the game
5.1.a wrote/walked Mary about the park
5.1.b wrote/walked Mary entered the park
5.1.c wrote/walked Mary appeared the park
5.2.a wrote/walked Mary about the beach
5.2.b wrote/walked Mary about the beach
5.2.c wrote/walked Mary are the beach
5.3.a wrote/walked Mary about the town
5.3.b wrote/walked Mary drove to town
5.3.c wrote/walked Mary aid the town
6.1.a kicked/lectured Mary in the meeting
6.1.b kicked/lectured Mary left the meeting
6.1.c kicked/lectured Mary more the meeting
6.2.a kicked/lectured Mary in the office
6.2.b kicked/lectured Mary left the office
6.2.c kicked/lectured Mary go the office
6.3.a kicked/lectured Mary in the library
6.3.b kicked/lectured Mary entered the library
6.3.c kicked/lectured Mary few the library
7.1.a called/escaped Mary during the game
7.2.b called/escaped Mary left the game
7.1.c called/escaped Mary easy the game
7.2.a called/escaped Mary in the kitchen
7.2.b called/escaped Mary cleaned the kitchen
7.3.c called/escaped Mary any the kitchen
7.3.a called/escaped Mary in the yard
7.3.b called/escaped Mary exit the yard
7.3.c called/escaped Mary hard the yard

Strict Transitive/Strict Intransitive Verbs

Illustrative sentence-initial material. While Bill . . .
1.1.a warned Mary at the dinner
1.1.b complained Mary started the dinner
1.1.c warned/complained Mary are the dinner
1.2.a warned Mary about the house
1.2.b complained Mary left the house
1.2.c warned/complained Mary were the house
1.3.a warned Mary about the class
1.3.b complained Mary began the class
1.3.c warned/complained Mary each the class
2.1.a coaxed Mary during the holidays
2.1.b prayed Mary celebrated the holidays
2.1.c coaxed/prayed Mary have at holidays
2.2.a coaxed Mary at the mass
2.2.b prayed Mary attended the mass
2.2.c coaxed/prayed Mary both the mass
2.3.a coaxed Mary at the resort
2.3.b prayed Mary enjoyed the resort
2.3.c coaxed/prayed Mary much the resort
3.1.a reminded Mary about the fence
3.1.b agreed Mary climbed the fence
3.1.c reminded/agreed Mary went the fence
3.2.a reminded Mary about the yard
3.2.b agreed Mary cleaned the yard
3.2.c reminded/agreed Mary of a yard
3.3.a reminded Mary about the car
3.3.b agreed Mary left the car
3.3.c reminded/agreed Mary none the car
4.1.a reassured Mary about the class
4.1.b arrived Mary left the class
4.1.c reassured/arrived Mary very the class
4.2.a reassured Mary about the race
4.2.b arrived Mary quit the race
4.2.c reassured/arrived Mary seem the race
4.3.a reassured Mary about the game
4.3.b arrived Mary left the game
4.3.c reassured/arrived Mary are the game
5.1.a guarded Mary in the park
5.1.b abstained Mary entered the park
5.1.c guarded/abstained Mary appeared the park
5.2.a guarded Mary on the beach
5.2.b abstained Mary visited the beach
5.2.c guarded/abstained Mary are the beach
5.3.a guarded Mary in the town
5.3.b abstained Mary drove around town
5.3.c guarded/abstained Mary aid the town
6.1.a notified Mary in the meeting
6.1.b testified Mary left the meeting
6.1.c notified/testified Mary more the meeting
6.2.a notified Mary in the office
6.2.b testified Mary left the office
6.2.c notified/testified Mary go the office
6.3.a notified Mary in the library

6.3.b testified Mary entered the library
6.3.c notified/testified Mary few the library
7.1.a convinced Mary during the game
7.1.b quarrelled Mary left the game
7.1.c convinced/quarrelled Mary easy the game
7.2.a convinced Mary in the kitchen
7.2.b quarrelled Mary cleaned the kitchen
7.2.c convinced/quarrelled Mary any the kitchen
7.3.a convinced Mary in the yard
7.3.b quarrelled Mary exited the yard
7.3.c convinced/quarrelled Mary hard the yard

Filler-gap constructions: Preferred Transitive/Intransitive Verbs

Illustrative sentence-initial material. This was who/what/where Bill . . .
1.1.a watched/rushed when the
1.1.b watched/rushed for when
1.1.c watched/rushed was when
1.2.a watched/rushed while the
1.2.b watched/rushed with while
1.2.c watched/rushed are while
1.3.a watched/rushed during the
1.3.b watched/rushed for during
1.3.c watched/rushed has during
2.1.a passed/jumped after the
2.1.b passed/jumped over after
2.1.c passed/jumped are after
2.2.a passed/jumped when the
2.2.b passed/jumped over when
2.2.c passed/jumped were when
2.3.a passed/jumped while the
2.3.b passed/jumped under while
2.3.c passed/jumped else while
3.1.a painted/hurried when the
3.1.b painted/hurried for when
3.1.c painted/hurried had when
3.2.a painted/hurried until the
3.2.b painted/hurried for until
3.2.c painted/hurried were until
3.3.a painted/hurried during the
3.3.b painted/hurried on during
3.3.c painted/hurried has during
4.1.a visited/escaped before the
4.1.b visited/escaped with before
4.1.c visited/escaped have before
4.2.a visited/escaped after the
4.2.b visited/escaped with after
4.2.c visited/escaped will after
4.3.a visited/escaped during the
4.3.b visited/escaped with during
4.3.c visited/escaped why during
5.1.a pushed/raced until the
5.1.b pushed/raced on until
5.1.c pushed/raced are until
5.2.a pushed/raced before the
5.2.b pushed/raced around before
5.2.c pushed/raced went before
5.3.a pushed/raced while the
5.3.b pushed/raced on while
5.3.c pushed/raced could while
6.1.a pulled/cheated when the
6.1.b pulled/cheated with when
6.1.c pulled/cheated were when
6.2.a pulled/cheated after the
6.2.b pulled/cheated at after
6.2.c pulled/cheated are after
6.3.a pulled/cheated while the
6.3.b pulled/cheated on while
6.3.c pulled/cheated has while
7.1.a wrote/walked before the
7.1.b wrote/walked with before
7.1.c wrote/walked could before
7.2.a wrote/walked until the
7.2.b wrote/walked with until
7.2.c wrote/walked should until
7.3.a wrote/walked during the
7.3.b wrote/walked about during
7.3.c wrote/walked must during
8.1.a kicked/swam when the
8.1.b kicked/swam at when
8.1.c kicked/swam might when
8.2.a kicked/swam while the
8.2.b kicked/swam with while
8.2.c kicked/swam are when
8.3.a kicked/swam before the
8.3.b kicked/swam at before
8.3.c kicked/swam did before
9.1.a cleaned/lectured after the
9.1.b cleaned/lectured with after
9.1.c cleaned/lectured do after
9.2.a cleaned/lectured before the
9.2.b cleaned/lectured with before
9.2.c cleaned/lectured done before
9.3.a cleaned/lectured during the
9.3.b cleaned/lectured with during
9.3.c cleaned/lectured are during
10.1.a called/pointed when the
10.1.b called/pointed at when
10.1.c called/pointed went when
10.2.a called/pointed during the
10.2.b called/pointed at when
10.2.c called/pointed went when
10.3.a called/pointed while the
10.3.b called/pointed at while
10.3.c called/pointed have while

Strict Transitive/Strict Intransitive Verbs

Illustrative sentence-initial material. This was who/what/where Bill . . .
1.1.a warned when the
1.1.b complained about when
1.1.c warned/complained was when
1.2.a warned while the
1.2.b complained about while
1.2.c warned/complained are while

1.3.a warned during the
1.3.b complained to during
1.3.c warned/complained has during
2.1.a coaxed after the
2.1.b sauntered to after
2.1.c warned/sauntered are after
2.2.a coaxed when the
2.2.b sauntered by when
2.2.c warned/sauntered were when
2.3.a coaxed while the
2.3.b sauntered to while
2.3.c warned/sauntered else while
3.1.a appraised when the
3.1.b excelled in when
3.1.c appraised/excelled had when
3.2.a appraised until the
3.2.b excelled in until
3.2.c appraised/excelled were until
3.3.a appraised during the
3.3.b excelled in during
3.3.c appraised/excelled has during
4.1.a destroyed before the
4.1.b agreed with before
4.1.c destroyed/agreed have before
4.2.a destroyed after the
4.2.b agreed with after
4.2.c destroyed/agreed will after
4.3.a destroyed during the
4.3.b agreed with during
4.3.c destroyed/agreed why during
5.1.a reminded until the
5.1.b arrived in until
5.1.c reminded/arrived are until
5.2.a reminded before the
5.2.b arrived with before
5.2.c reminded/arrived went before
5.3.a reminded while the
5.3.b arrived for while
5.3.c reminded/arrived could while
6.1.a reassured when the
6.1.b tiptoed by when
6.1.c reassured/tiptoed were when
6.2.a reassured after the
6.2.b tiptoed at after
6.2.c reassured/tiptoed are after
6.3.a reassured while the
6.3.b tiptoed on while
6.3.c reassured/tiptoed has while
7.1.a guarded before the
7.1.b prayed with before
7.1.c guarded/prayed could before
7.2.a guarded until the
7.2.b prayed with until
7.2.c guarded/prayed should until
7.3.a guarded during the
7.3.b prayed about during
7.3.c guarded/prayed must during
8.1.a notified when the
8.1.b quarrelled with when
8.1.c notified/quarrelled might when
8.2.a notified while the
8.2.b quarrelled with while
8.2.c notified/quarrelled are when
8.3.a notified before the
8.3.b quarrelled with before
8.3.c notified/quarrelled did before
9.1.a initiated after the
9.1.b testified about after
9.1.c initiated/testified do after
9.2.a initiated before the
9.2.b testified with before
9.2.c initiated/testified done before
9.3.a initiated during the
9.3.b testified to during
9.3.c initiated/testified are during
10.1.a convinced when the
10.1.b abstained from when
10.1.c convinced/abstained went when
10.2.a convinced during the
10.2.b abstained from when
10.2.c convinced/abstained went when
10.3.a convinced while the
10.3.b abstained from while
10.3.c convinced/abstained have while

Appendix II: Issues Concerning d' Correction

In constructing the d' scale for all SAT functions, perfect performance was truncated by assuming an error rate of 0.5%. (Thus a score of 100% was replaced by a value of 99.5%.) This set a limit on estimated d' values to ensure that all are measurable given the present sample sizes. If, however, true d' values, based on extremely large samples, were demonstrably higher than the present maximally allowed value, then the correction process utilized here will have introduced a systematic artifact into the model fits. Specifically, it will have forced what is a true asymptotic effect into estimates of the dynamics parameters.

There are two points to note about such a possibility. First, this potential artifact is unidirectional, serving only to inflate dynamics estimates. Consequently, *failure* to find a dynamics difference cannot be attributed to the correction process. Secondly, the two rate differences that were found involved contrasts of PT and PI verbs scaled against a common false alarm rate. Thus, corrections on ungrammatical conditions could not have served to introduce fit artifacts.

In both cases where the model fits isolated rate differences, there is good evidence that argues against an artifactual account. First, in the comparison of early/late closure constructions where the rate for transitive frames was found to be faster than that for intransitive frames, separate fits were performed on nonpreferred transitive and intransitive frames for the four subjects (CL, LB, TR, PW) whose data were well below the correction point. All subjects showed a comparable rate difference to that observed in the original fits including conditions subject to the correction process [specifically, 28% vs 24%, 49% vs 54%, 27% vs 56%, and 5% vs 9%, respectively, where the first percentage is the difference reported in Table 4 and the second is the estimate from uncorrected conditions only]. In comparisons of PT and PI filler–gap transitive constructions, three subjects' (GR, TR, and PW) data were not subject to correction but nevertheless show the appropriate differences. Moreover, in the remaining subjects the overall level of performance is lower than in other conditions that did not introduce rate differences. Consequently, it is argued that the differences in rate estimates in both conditions are in fact genuine and not introduced by the correction process.

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