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Taking on Semantic Commitments: Processing Multiple Meanings vs. Multiple Senses

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When does the human language processor take on semantic commitments? This question has two parts: (1) for what class of semantic decisions will the processor make a decision rather than leaving the developing interpretation vague or unspecified?; and (2) at what point during sentence analysis will a decision be made if insufficient information is available to guarantee an accurate decision? Neither question has been answered (or even posed in a fully explicit general form) in the psycholinguistic literature. We recorded readers' eye movements in a study designed to explore these questions. The data indicated that delaying the presentation of disambiguating information until after the occurrence of an ambiguous target lengthened fixation times for words with multiple meanings (the concrete vs. abstract meaning of *ball, ring*), but not for words with multiple senses (the concrete vs. abstract sense of *library, poem*). This finding is taken as initial support for the view that semantic commitments are minimized, occurring only when mutually incompatible choices are presented by the grammar or when forced by the need to maintain consistency between the interpretation of the current phrase and any already processed contextual material. However, decisions forced by either of these circumstances occur immediately with associated effects appearing in the eye movement record long before the end of the sentence.

Very little is known about the general principles underlying grammatical aspects of semantic processing. For example, how do people interpret phrases when the information available is not sufficient to identify a referent or to assign a completely specified interpretation at the point when the phrase is encountered? More generally, faced with an ambiguity where an input could be structured in two or more mutually incompatible ways, what behavior does the processor exhibit, and why? In the case of constituent structure processing, numerous models of the processing device exist and a variety of experimental studies have examined the nature of the processor's strategies (see Frazier, 1987, and references therein). But in the case of semantic processing, the question has not usually been posed in this way. The existing literature on semantic processing focuses on nongrammatical aspects of interpretation. This includes the role of world knowledge or discourse context in determining anaphoric assignments (Corbett & Chang, 1983; Garnham, 1981), nongrammatical inferences (Clark & Clark, 1977), or performance in reasoning tasks (Johnson-Laird, 1977, 1983).

Isolated shreds of evidence in the literature could be used to argue for any of several conflicting semantic processing principles, including strategies of immediate semantic interpretation, delayed interpretation (at least in invoking clause and

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sentence-final "wrap up" effects), completely-specified (maximal) commitments, minimal commitments, or a default assignment strategy where a particular option is selected based on frequency or pragmatic plausibility. Given that many of these "strategies" are not compatible with each other when cast in a form rendering them applicable in general, what this suggests is that the operation of the processor depends on the type of decision at hand. Whether the processor makes a default assignment in the absence of secure information about some aspect of interpretation, on the one hand, or instead makes a minimal commitment by specifying only the semantic decisions or relations which can be determined securely at that point in the processing of the sentence may depend on the nature of the decision or relation involved. If so, then one of the central tasks for investigations of language comprehension must be to determine which class of decisions falls under which strategy, and why. Here we will begin to address this question by testing the validity of two general hypotheses which we will call the *Immediate complete interpretation* and the *Immediate partial interpretation* hypotheses.

According to the Immediate complete interpretation hypothesis, the processor maximizes its immediate semantic commitments by interpreting each phrase fully as the phrase is encountered. For example, for each referential phrase a referent is identified in the existing representation of discourse, or a new discourse entity is introduced, as soon as the phrase is encountered. Many investigators seem to agree that semantic interpretation occurs rapidly (see, in particular, Crain & Steedman, 1985; Marslen-Wilson & Tyler, 1980; and the discussion of the immediacy assumption in Just & Carpenter, 1980). Reading the psychological literature, one might get the impression that most if not all investigators implicitly adopt this position. However, evidence favoring quick semantic interpretation does not by itself discriminate between this hypothesis and the possibility that some but not all decisions occur immediately.

According to the Immediate partial interpretation hypothesis, the processor may delay semantic commitments, if this does not result in either (a) a failure to assign any semantic value whatsoever to a word or major phrase, or to its relation to other major phrases or (b) the need to maintain multiple incompatible values for a word, phrase, or relation.

What happens when the existence of incompatible values for an expression forces the processor to make some immediate commitment? The Immediate partial interpretation hypothesis is consistent either with partial specification of a meaning for the expression under these circumstances, or alternatively with selection of whatever meaning is chosen by some default mechanism. Here we pursue the *Partial specification* hypothesis, which claims that minimal commitments occur at choice points involving partially compatible specifications, as when two options overlap, sharing some but not all features. We assume overlap in the feature set of two items will be relevant, or noticed, *only* when the items are formally related. In cases of no feature overlap, presumably an assignment of a single analysis or semantic value is selected by "default" (e.g., on the basis of frequency or plausibility).

The above hypotheses are not fully explicit in the absence of a theory of the semantic decisions encountered by the human processor during language interpretation. Developing such a theory is by no means trivial since it will presumably depend on a clarification of the distinction between ambiguity and vagueness, one of the murkiest areas of contemporary linguistics. Nevertheless, the above hypotheses are far from vacuous.

The spirit behind the Immediate complete interpretation hypothesis is clear. If a decision about the interpretation of a phrase is made at all during the comprehension of a text containing the phrase, then it is made (correctly or not) immediately upon encountering the phrase. This hypothesis is one strong explicit form of what seems to be the dominant, if implicit, view of semantic processing in psychological studies. We suspect it is incorrect, and therefore have tried to formulate a plausible and informative alternative hypothesis.

In contrast with the Immediate complete interpretation hypothesis, the Immediate partial interpretation hypothesis specifies that some semantic commitments may be delayed. The Partial specification hypothesis specifies that the particular set of commitments which are delayed concern a natural class of decisions involving overlapping specifications. The effect of this is to confine "default" assignments to the class of choices involving alternatives which share no common features with each other. For example, in a sentence like "John hit the wall" *John* may be assigned an agent relation to the predicate without specifying whether the act was intentional or not. Hence, according to the Partial specification hypothesis, we do not expect a default to be assigned in the absence of secure evidence. The processor may assign the role of agent to "John" in (i) to (iii), without immediately committing itself to a value for [+/− intentional] thereby remaining vague about whether "John" is an intentional or unintentional agent. Eventually the processor might assign a value to the feature [+/− intentional] in sentences (i) and (ii), but not in (iii). To interpret the adverb in (i), *John* must be an unintentional agent. In (ii), in order to interpret the rationale ("in order to") clause with *John* as the subject of *frighten, John* must be an intentional agent of *hit*. But in (iii), the decision about whether *John* is an intentional or an unintentional agent may not occur at all. Perhaps the value of the feature simply remains unspecified in examples like (iii).

(i) John accidentally hit the wall.
(ii) John hit the wall to frighten the assistant.
(iii) John hit the wall, bruising or possibly breaking his elbow.

Whether some or all delayed commitments correspond to optional decisions in language processing (i.e., ones which need not be made at all in some sentences) is an interesting but entirely open question.

Here we report an experiment conducted to evaluate these hypotheses. Specifically, we investigated whether words with two meanings (assumed to have two lexical representations, see below) are processed differently than words with two senses. The Immediate partial interpretation hypothesis implies that the processor will be forced to make a "semantic selection" for meaning ambiguities, but not for sense ambiguities. A single analysis will be selected immediately for words with multiple meanings since the alternative entails that the processor maintains two incompatible representations. However, the semantic value for words with multiple senses may be determined by the features shared by both senses. Hence, a minimal commitment is permissible in this case, since it will not result in either multiple analyses or failure to assign an analysis.

By contrast, the Immediate complete interpretation hypothesis implies that immediate semantic selection will be required for both types of words since it enforces strictly immediate decisions for all semantic commitments. Therefore, according to the Immediate partial interpretation hypothesis, but not the Immediate complete interpretation hypothesis, prior disambiguation of words with meaning-ambiguities should show greater facilitation than prior disambiguation of words with sense-ambiguities. If it is true that immediate selection of a meaning is required (as predicted by both hypotheses), then prior disambiguation will prevent a garden-path in the case of multiple meanings. This should result in substantial savings in terms of processing resources, due to those occasions when premature selection results in an inappropriate choice. Words with multiple senses may also benefit from prior disambiguation. But in this case, if the processor commits itself only to the overlapping features shared by the two senses of a word, no garden path is expected to occur in the absence of disambiguating information. Hence, the difference between prior disambiguation and following disambiguation should be greater for words with multiple meanings than for words with (comparable) multiple senses only according to Immediate partial interpretation.

Words with multiple meanings differ from each other, possibly in ways relevant for the interplay of meaning selection and the positioning of disambiguating context. It seems to matter, for example, whether one meaning of an ambiguous word is dominant or subordinate, especially if extreme differences exist in the relative frequency of the meanings (cf. Rayner & Duffy, 1986; Simpson, 1981). A dominant meaning may be chosen over an infrequently occurring subordinate meaning whether or not information favoring the dominant meaning has already been encountered. However, the processor might opt for subordinate meanings or meanings that are equally likely only in the presence of evidence favoring one meaning over the alternative possibilities. It is possible that factors other than frequency matter as well. In principle, at least, intrinsic aspects of meaning might also influence the selection process. The processor might have some standing preference, say for concrete meanings, opting for abstract meanings only when evidence specifically favored a particular abstract meaning.

To address questions concerning possible variability within the set of items with multiple meanings, we tested two sets of ambiguous words: one set in which the meanings varied along the same dimension as the words with multiple senses (abstract/concrete) and one which varied on a different dimension (animate/inanimate). To further differentiate the animate/inanimate ambiguities from the abstract/concrete ambiguities, the former also exploited systematic selectional disambiguation rather than merely using strong pragmatic disambiguation. Thus, in various respects the words with multiple senses (*book, library*) were more like the ambiguous words with abstract/concrete meanings (*match, racket*) than were the ambiguous words with animate/inanimate meanings (*fans, club*). In short, the variation within the set of words with multiple meanings was greater (comparing the animacy set with the concreteness set) than the variation between the two animacy sets—those with multiple meanings vs. those with multiple senses. This was done to insure that our results would not be determined simply by the particular words chosen as examples of meaning vs. sense ambiguities.

Subjects' eye movements were recorded as they read sentences containing words with multiple meanings (e.g., Sentences 1 and 2 in Table 1) vs. words with multiple senses (e.g., Sentence 3 in Table 1). The important contrast was between *Prior Disambiguation* forms (form a and b in Table 1), in which the biasing material preceded the ambiguous word and *Late Disambiguation* forms (form c and d in Table 1), where the bias followed.

The central prediction of the experiment concerns the relation between prior disambiguation and following disambiguation. On the basis of existing studies, (Duffy, Morris, & Rayner, 1988; Rayner & Frazier, 1989) we expected the prior condition to be easier than the late condition for words with multiple meanings because prior disambiguation should prevent a garden path. Assuming there is immediate selection of one meaning of an ambiguous word (dictated by the Immediate complete interpretation hypothesis, consistent with the Immediate partial interpretation hypothesis) prior disambiguation will permit the appropriate meaning to be selected on all occasions, not just on some random half of the sentences where the chosen meaning does prove to be consistent with later disambiguation. The real question is whether comparable effects are observed for words with multiple senses, as predicted by the Immediate complete interpretation hypothesis, because it precludes minimal commitments. Alternatively the difference between prior and late disambiguation conditions may be much smaller for words with multiple senses, as predicted by the Immediate partial interpretation hypothesis because assignment of only those features common to both senses will prevent garden-pathing even in late disambiguation sentences.

The predictions were tested by examining reading times for the target word, the post-target region, and the disambiguating region (see below for definitions). Reading times for the disambiguating region in particular should be long in the late disambiguation condition, but only for words with multiple meanings, if partial interpretation is possible.

METHOD

Subjects

Twenty undergraduate students at the University of Massachusetts were paid to participate in the experiment. All of the subjects had normal uncorrected vision and they were all naive with respect to the purpose of the experiment.

Apparatus

Subjects were asked to read sentences presented on a Hewlett-Packard 1300A Cathode Ray Tube (CRT) interfaced with a Hewlett-Packard 2100 computer which controlled the experiment. The computer, in turn, was interfaced with a Stanford Research Institute Dual Purkinje Eyetracker, which was used to record the subjects' eye movements. The eyetracker has a resolution of 10 min of arc, and eye movements were recorded from the right eye (although viewing was binocular). The signal from the eyetracker was sampled every millisecond by the computer so that a complete record of the sequence of eye movements and the duration (and location) of eye fixations was obtained for every sentence.

The letters making up the sentences were presented on the CRT in lower case (except for the first letter of the sentence and proper nouns). A subject's eyes were positioned 46 cm from the CRT and three letters equaled 1° of visual angle. A nylon mesh screen covered the CRT so that the letters appeared clear and sharp to the subjects. The room was dark, except for a dim indirect light source that enabled the experimenter to record the accuracy of the subjects' responses to questions that were asked throughout the experiment. Luminance on the CRT was adjusted to a comfortable level for each subject and held constant throughout the experiment.

Procedure

When a subject arrived for the experiment, a bite bar was prepared that eliminated head movements during reading. The eyetracking system was then calibrated for the subject; this procedure generally required no more than 5 min. Before each sentence was presented, the experimenter checked the calibration of the eye movement system to ensure that accurate records were being obtained. Across all of the conditions of the experiment, 5% of the data were lost because the eyetracking system did not accurately track the eye.

Each subject read 10 warm-up sentences and then the experimental and filler sentences. The subjects were told that the purpose of the experiment was to determine what people look at when they read and that they should read the sentences as they would normally do to understand them. They were further instructed that they would periodically be asked questions about the sentences. These questions were quite simple and involved a "yes" or "no" response from the subject. They were asked on a random basis that corresponded to 25% of the sentences being questioned. The subjects were able to answer these questions correctly 96% of the time. Elimination of those trials when subjects did not correctly answer the question did not alter the pattern of results.

Materials

Three sets of experimental sentences were constructed with 16 sentences in each set and four versions of each sentence (see Table 1). Set 1 and Set 2 sentences contained ambiguous target words with more than one meaning, while Set 3 sentences contained target words with multiple senses. In addition, a set of sentences (Set 4 sentences) which contained unambiguous target words and which were similar in surface form to the sentences in the other three sets were used as controls. All of the sentences consisted of two clauses that could be reversed, with minimal change in the wording of the sentences, and still maintain the grammatical and semantic integrity of the sentence. The clause which contained the target word was neutral with respect to the meaning of the ambiguous target word. All disambiguating information was contained in the other clause. Because the clause order could be reversed, disambiguating information appeared either before or after the target word. For the three experimental sets, two versions of each sentence consisted of *prior disambiguation* forms (sentences a and b in Table 1) in which disambiguating information preceded the ambiguous target word; whereas in the *late disambiguation* forms (sentences c and d in Table 1) the disambiguating information followed the target word. In Set 1, the ambiguous word had one animate and one inanimate meaning. In the animate sentence forms, the selectional restriction of the main verb disambiguated the sentence because a violation would result if the verb were combined with an inanimate subject. In Set 2, the ambiguous word had one abstract and one concrete meaning. Pragmatic biases, rather than some common systematic selectional feature (animacy in Set 1) disambiguated these sentences, as well as those in Set 3. In Set 3, the target word had both an abstract sense and a concrete sense. The abstract sense usually referred to an organization or a product of conceptual or artistic labor characterized in terms of its content; the concrete sense of the word generally referred to a physical object either instantiating the abstract sense or uniquely associated with it.

The sentences that were eventually used in the experiment, as well as a number of other sentences of the same form as those in each of the three sets, were presented to 16 subjects (none of whom participated in the main experiment) in an initial rating task. These subjects were presented with booklets containing both the abstract and the concrete versions of Set 2 and Set 3 sentences (or animate and inanimate versions in Set 1) printed one below the other on a page. For a given subject, half of the

TABLE 1
EXAMPLE SENTENCES USED IN THE EXPERIMENT

1a.	Being so elegantly designed, the pitcher pleased Mary.
b.	Throwing so many curve balls, the pitcher pleased Mary.
c.	Of course the pitcher pleased Mary, being so elegantly designed.
d.	Of course the pitcher pleased Mary, throwing so many curve balls.
2a.	After they were scratched, the records were carefully guarded.
b.	After the political takeover, the records were carefully guarded.
c.	The records were carefully guarded after they were scratched.
d.	The records were carefully guarded after the political takeover.
3a.	Lying in the rain, the newspaper was destroyed.
b.	Managing advertising so poorly, the newspaper was destroyed.
c.	Unfortunately the newspaper was destroyed, lying in the rain.
d.	Unfortunately the newspaper was destroyed, managing advertising so poorly.
4a&b.	Because the pirates sank the ship, the treasure was lost.
c&d.	Apparently, the treasure was lost because the pirates sank the ship.

sentences had prior disambiguation and half had late disambiguation, but both sentences on a page had either prior or late disambiguation. Subjects were asked to put a check by the sentence that they thought best expressed (or was most consistent with) the meaning of the target word. From these ratings, the different versions of the sentences were categorized as being consistent with either the preferred or unpreferred meaning of the target word. We were able to obtain 16 sentences that were eventually used in Set 1 where the preferred reading of the sentence coincided with the animate interpretation half of the time and the inanimate reading half of the time; likewise, in Sets 2 and 3 half of the sentences had the preferred reading consistent with the abstract interpretation and half with the concrete interpretation. For Sets 1 and 3, the average preferred reading was chosen 74% of the time across the sentences; in Set 2 it was chosen 72% of the time.

The experimental sentences were divided into four lists, with an equal number of each of the four versions; more than one version of the same sentence never appeared within a given list. The 16 control sentences (Set 4 sentences) were also equally distributed in the four lists. However, since these sentences did not contain an ambiguous target word there was not a preferred–unpreferred dimension for them and thus each sentence appeared in only two versions. One had the clause containing the target word at the beginning of the sentence and one had the target-containing clause at the end. As a result, half of the sentences with the target word in the second clause were arbitrarily chosen for comparison with the preferred-prior disambiguation experimental sentences and the other half were chosen for comparison with the unpreferred-prior disambiguation experimental sentences; the same procedure was used for the sentences with the clause containing the target word at the beginning of the sentences. The set of 64 experimental and control sentences were embedded in 56 (including the 10 warm-up sentences) filler sentences, which consisted of a wide variety of sentence types. The experimental sentences are presented in Appendix 1.

Results

The dependent variable used in the experiment was the *reading time per character*. This measure was obtained by summing the duration of fixations in a target region and dividing by the number of character spaces in the region to equate for differences in the number of words and the length of words within a given region. In particular, reading time per character was determined for the following: (1) target word, (2) post-target region, and (3) disambiguating region. Since the number of letters/words within each region was fairly comparable, we believe this measure to be the best of the alternative scoring measures that could be used (Rayner, Sereno, Morris, Schmauder, & Clifton, in press).

All fixations made in a left-to-right manner and all within-region regressions were totaled as *first-pass reading time*. For the target word region, if the subject did not make a fixation directly on the target word, then the closest fixation within 4 character spaces to the left and 1 to the right of the word was counted as the fixation during which the target word was processed. This procedure was based on research on the perceptual span which demonstrates that when readers do not fixate on a target word they identify it on the prior fixation, but that this takes place within a very limited region (Rayner & Pollatsek, 1987). A total of 2% of the trials yielded unusable data for the target word region due to the lack of a fixation near the target word. The post-target word region consisted of all words in the clause containing the target word from after the target word until the end of the clause; the disambiguating region was defined as consisting of the word which disambiguated the target word to the end of the clause. In addition to computing the first pass reading time, the *total reading time* for the entire sentence was also computed and analyzed. This measure included all regressions to previously read material, as well as re-reading of sentences.

Preliminary analyses of the data revealed that the abstract-concrete and animate-inanimate dimensions did not discriminate between reading performance across the different versions of the sentences in Sets 1, 2, or 3. However, the preferred-unpreferred dimension did yield major differences in reading performance. Since the abstract-concrete and animate-inanimate dimensions did not interact with any other variable, we collapsed across these dimensions in the major analyses that we will report.

A 4 (Set) × 2 (Location of disambiguating information: prior vs. late) × 2 (Preference: preferred vs. unpreferred meaning of the target word) analysis of variance (ANOVA) was carried out for the total reading time per character for the entire sentence, as well as for the reading time per character for first pass reading in each of the three critical regions. In this ANOVA, subjects were treated as a random effect and all variables were manipulated within subjects. In addition, a 4 (Set) × 2 (Location) × 2 (Preference) ANOVA was carried out on the means for each sentence (for each of the dependent variables examined in the subjects' ANOVA) with Set treated as a between-items variable. We will begin by discussing the total reading time for the entire sentence.

Total Reading Time for the Sentence

Table 2 presents the reading time per character for the entire sentence in each of the four sets of sentences. The striking effect in these data is that the reading time for Set 3 and Set 4 sentences did not differ as a function of whether or not the disambiguating clause preceded or followed the target word or as a function of whether or not the disambiguating information instantiated the preferred or unpreferred meaning of the target word. On the other hand, for both Sets 1 and 2, there was a strong asymmetry such that subjects read the sentences much faster when (1) the disambiguating clause preceded the target word than when it followed the target word and (2) the preferred meaning was instantiated.

The ANOVAs yielded significant main effects of set, $F1(3,57) = 11.04$, $p < .001$ and $F2(3,60) = 8.52$, $p < .001$, and preference, $F1(1,19) = 31.77$, $p < .001$ and $F2(1,60) = 25.13$, $p < .001$, with preferred sentences read faster (49 ms per character) than unpreferred (53 ms per character). A Neuman–Keuls test revealed that the overall reading rates were much faster ($p < .01$) for Set 3 and Set 4 sentences (which did not differ from each other; 47 ms per character for Set 3 and 46 ms per character for Set 4) than for Set 1 and Set 2 (which also did not differ from each other, 55 ms per character for both sets). In addition to the two significant main effects, there were also two significant interactions. The Set × Location interaction, $F1(3,57) = 2.94$, $p < .05$ and $F2(3,60) = 3.46$, $p < .05$, and the Set × Preference interaction, $F1(3,57) = 8.64$, p

TABLE 2
MEAN READING TIME PER CHARACTER (IN MS) FOR THE ENTIRE SENTENCE AS A FUNCTION OF SENTENCE SET, LOCATION OF THE DISAMBIGUATING INFORMATION, AND PREFERRED VS. UNPREFERRED INTERPRETATION OF THE TARGET WORD

	Prior disambiguation		Late disambiguation	
Sentence set	Preferred reading	Unpreferred reading	Preferred reading	Unpreferred reading
Set 1	50	56	54	63
Set 2	49	55	55	64
Set 3	47	48	48	47
Set 4	45	45	43	43

< .001 and $F2(3,60) = 7.66, p < .001$, were due to the fact that for Set 3 and Set 4 sentences neither the location of the disambiguating information nor whether or not the disambiguating information was consistent with the preferred interpretation influenced overall reading time on the sentence. By contrast, both of these factors influenced the overall reading time for Set 1 and Set 2 sentences.

The important point to be gleaned from the total sentence reading time is that Set 3 sentences containing target words with multiple senses yielded a very different data pattern from Set 1 and Set 2 sentences containing target words which were ambiguous and which had more than one meaning. The theoretically crucial Set × Location interaction was significant. Longer reading times due to delaying disambiguation were found only in Sets 1 and 2, as predicted by Immediate partial interpretation. This same pattern emerged in the other more localized analyses as well. Indeed, the overall reading times for Set 3 sentences were very much like the reading times for the control sentences (Set 4). However, as will be seen below in the analysis of Target Word Spillover Effects, the effect of preference was present, though small, even in Set 3. It reached significance only in a very local analysis including the target word together with the following word (see below).

Target Word Reading Time

The pattern of data for the target word reading time is shown in Table 3. There was a significant main effect of set, $F(3,57) = 18.34, p < .001$ and $F2(3,60) = 16.44, p < .001$, which was again due to the fact that Set 1 and Set 2 sentences (49 and 53 ms per character, respectively) yielded longer reading times than Set 3 and Set 4 sentences (42 ms per character for both). Subjects spent less time on the target word when the disambiguating information followed (44 ms per character) than when it preceded (48 ms per character) the target word, $F1(1,19) = 7.73, p < .05$ and $F2(1,60) = 6.22, p < .05$. In the subject analysis (but not in the items analysis), there was some indication that subjects spent less time on the target when it was consistent with the preferred reading than when it was consistent with the unpreferred interpretation of the target word, $F1(1,19) = 4.12, p = .054$. While the pattern of data seem to suggest a three-way interaction, it was not significant ($p < .15$). However, when a two-way ANOVA (Set × Preference) was run on the prior disambiguation data, the interaction was marginally significant, $F1(3,57) = 2.53, p < .10$. A similar ANOVA on the late disambiguation data yielded $F < 1$.

There was considerable variability across subjects in how long they looked at the tar-

TABLE 3
MEAN READING TIME PER CHARACTER (IN MS) FOR THE TARGET WORD AS A FUNCTION OF SENTENCE SET, LOCATION OF THE DISAMBIGUATING INFORMATION, AND PREFERRED VS. UNPREFERRED INTERPRETATION OF THE TARGET WORD

	Prior disambiguation		Late disambiguation	
Sentence set	Preferred reading	Unpreferred reading	Preferred reading	Unpreferred reading
Set 1	47–42 (218)	56–45 (252)	46–43 (207)	46–43 (207)
Set 2	49–40 (230)	59–44 (277)	51–43 (240)	51–43 (240)
Set 3	43–42 (244)	45–46 (252)	39–42 (218)	41–42 (230)
Set 4	43–41 (240)	43–41 (240)	39–41 (218)	40–40 (224)

Note. The first value in each column represents the reading time for the target word and the second value represents spillover. Values in parentheses are gaze durations (in ms) on the target word.

get word. In comparison to the other dependent measures discussed here, the target reading time data were much less stable. Obviously, the other measures involve larger areas of text and hence a number of eye fixations would be included whereas it was generally the case that there was only a single fixation on the target word. Furthermore, our experimental sentences in Set 1 and 2 contained a mix of target words with (1) two equally likely alternative meanings and (2) one strongly dominant interpretation. This variable has been shown to interact with location of the disambiguating information (Duffy et. al., 1988; Rayner & Frazier, 1989) and, hence, we should expect some added variability due to this fact. Finally, there may have been some variability added due to the amount of relatedness between the target word and the disambiguating clause. However, all of these sources of variability existed within each set of stimuli, and there is no indication that any of them could by itself account for the overall pattern of results.

The issue of variability associated with processing the target word is even more apparent if the reading time on the target word is not divided by the number of letters in the word. A measure commonly associated with processing times for words in reading is the gaze duration (Just & Carpenter, 1980), which is the sum of all fixations on a word prior to an eye movement to another word. In essence, our measure of first pass reading time for the target word is equivalent to the gaze duration (divided by the number of letters in the word). When the gaze duration on the target word was examined, the main effect of set vanished (see Table 3). While the target words across the four sets of sentences were fairly similar on word frequency (with means between 60 and 80 per million in the Francis & Kucera, 1982 norms), there was a systematic bias for the words in Sets 3 and 4 to be on average one letter longer than those in Sets 1 and 2. This bias in word length resulted in the effect of set disappearing. The main effect of location of the disambiguating information remained highly significant.

We suspect that the longer reading times for the target word when the disambiguating clause preceded that word reflect the fact that readers spent more time integrating the meaning of the word with the rest of the sentence with prior disambiguation than when disambiguation followed the target (Duffy et al., 1988; Rayner & Frazier, 1989; Schustack, Ehrlich, & Rayner, 1987).

Target Word Spillover Effects

Because it seemed important to establish whether or not there was any evidence of increased processing associated with the Set 3 stimuli, we carried out an additional analysis in which the reading time for the word following the target word was examined (see Table 3). Although there was no significant difference between reading time for the preferred or unpreferred reading of the target word for the Set 3 stimuli, there was a tendency for the unpreferred reading to take longer to read (2 ms per character) than the preferred reading. When the reading time for the word following the target word was examined, in the prior disambiguation condition it took subjects 4 ms per character longer to read the following word when the unpreferred interpretation was instantiated than when the preferred interpretation was instantiated by the disambiguating context $t(19) = 2.03, p < .06$. When the time on the target word and the time on the following word were averaged, the longer reading time for the unpreferred interpretation was significant, $t(19) = 2.77, p < .05$. There was no such difference in the late disambiguation condition of the Set 3 sentences (with means of 42 ms per character in each condition). Likewise, there was no such effect for the Set 4 sentences in the prior disambiguation condition as the means for target words which were arbitrarily designated as the preferred and unpreferred interpretations were virtually identical (41 ms per character). Thus, when spillover effects (Rayner & Duffy, 1986) are

TABLE 4
MEAN READING TIME PER CHARACTER (IN MS) FOR THE POST-TARGET REGION AS A FUNCTION OF SENTENCE SET, LOCATION OF THE DISAMBIGUATING INFORMATION, AND PREFERRED VS. UNPREFERRED INTERPRETATION OF THE TARGET WORD

	Prior disambiguation		Late disambiguation	
Sentence set	Preferred reading	Unpreferred reading	Preferred reading	Unpreferred reading
Set 1	46	58	43	42
Set 2	52	63	40	38
Set 3	50	52	38	38
Set 4	50	49	40	40

taken into account, it does appear that there was some extra processing involved when the prior disambiguating context instantiated the unpreferred interpretation of the Set 3 sentences. This suggests that readers do commit themselves to a particular sense of a word when the intended sense is implied by the content of prior context.

Reading Time for the Post-Target Region

Table 4 shows the first pass reading time in the post-target region[1] for each of the sentence sets. The post-target region was read more quickly (40 ms per character) when the disambiguating information followed the target word than when it preceded (53 ms per character) the target word, $F1(1,19) = 52.09$, $p < .001$ and $F2(1,60) = 27.44$, $p < .001$. This result primarily reflects sentence wrap-up processes (Duffy et al., 1988; Just & Carpenter, 1980) since when the disambiguating information preceded the target, the post-target region coincided with the end of the sentence. It was also the case that the post-target region was read more quickly (45 ms per character) when the sentence was consistent with the preferred reading than when it was consistent with the unpreferred (48 ms per character) reading of the sentence, $F1(1,19) = 8.21$, $p < .01$, and $F2(1,60) = 7.33$, $p < .01$. These effects were modulated by a significant two-way interaction of Location × Preference, $F1(1,19) = 8.38$, $p < .01$ and $F2(1,60) = 7.11$, $p < .01$, and by the significant three-way interaction, $F1(3,57) = 3.19$, $p < .05$, and $F2(3,60) = 2.99$, $p < .05$. The latter interaction is most relevant and was due to the fact that for the late disambiguation conditions there was little difference in reading times between the preferred and unpreferred reading across all four sets of sentences. On the other hand, in the prior disambiguation conditions the preferred–unpreferred difference was virtually nonexistent in Sets 3 and 4 but was quite large in Sets 1 and 2 (with the preferred reading read much faster than the unpreferred reading).

Disambiguating Region

Table 5 shows the first pass reading time in the disambiguating region[2] for each of the four sets of sentences. The disambiguating region was read more quickly when the disambiguating information preceded the target word (38 ms per character) than when it followed (51 ms per character) the target word, $F1(1,19) = 24.59$, $p < .001$ and $F2(1,60) = 15.13$, $p < .001$. This result again reflects sentence wrap-up processes

[1] Across the different conditions, the size of the average post-target region was fairly comparable with the range being 16 to 18 character spaces.

[2] Across the different conditions, the size of the average disambiguating region was fairly comparable with the range being 27 to 31 character spaces.

TABLE 5
MEAN READING TIME PER CHARACTER (IN MS) FOR THE DISAMBIGUATING REGION AS A FUNCTION OF SENTENCE SET, LOCATION OF DISAMBIGUATING INFORMATION, AND PREFERRED VS. UNPREFERRED INTERPRETATION OF THE TARGET WORD

	Prior disambiguation		Late disambiguation	
Sentence set	Preferred reading	Unpreferred reading	Preferred reading	Unpreferred reading
Set 1	37	38	51	56
Set 2	40	40	54	58
Set 3	38	38	46	45
Set 4	38	38	46	46

since when the disambiguating information followed the target word, the disambiguating region was located at the end of the sentence. There was also a significant main effect of set, $F1(3,57) = 11.57, p < .001$ and $F2(3,60) = 8.11, p < .001$. A Neuman–Keuls test again indicated that Sets 1 and 2 did not differ from each other (46 ms per character for Set 1 and 48 ms per character for Set 2), but they did differ ($p < .05$) from Sets 3 and 4 (which again did not differ from each other, 42 ms per character for both).

In the analysis of the first pass reading time for the disambiguating region, none of the interactions was significant. However, the lack of such interactions was largely due to the manner in which the data were scored. That is, we only scored reading time for first pass fixations and when subjects made regressions to other parts of the sentence the time involved in re-reading these other regions (or the disambiguating region itself) was not included in the first pass reading time. An alternative way of scoring the data for the post-target region and the disambiguating region is to score the total reading time once the critical region is fixated (Duffy et al., 1988). Thus, the reading time is calculated as the sum of all fixations within a region beginning with the first fixation in the region and ending when the subject went to the next clause (when the critical region was in the first clause) or when the subject pressed the response button to terminate the sentence (when the critical region was in the second clause of the sentence). This latter sum can be thought of as the total time needed to understand the information in the second clause in the context of the information which preceded it and includes any regressions made from the second clause to other parts of the sentence. Notice that by definition, reading time for the first clause remains unchanged from the first pass reading times as shown in Tables 4 and 5.[3] However, the reading time for the second clause (which, again, does include regressions to other parts of the sentence) does change considerably with this alternative scoring procedure. Table 6 shows the reading time for the second clause when the alternative scoring procedure was used.

A 4 (Set) × 2 (Preference) × 2 (Location of disambiguating information) ANOVA was carried out for the post-target region and the disambiguating region using the alternative scoring procedure for the second clause. The ANOVA on the post-target region data revealed that all of the effects discussed above for the post-target region remained significant with this scoring procedure. In addition, the main effect of set was also significant, $F1(3,57) = 10.62, p < .001$ and $F2(3,60) = 7.45, p < .01$. The same

[3] The first clause corresponds to the post-target region in the late disambiguation conditions in Table 4 and to the disambiguating region in the prior disambiguation conditions in Table 5.

TABLE 6
MEAN READING TIME PER CHARACTER (IN MS) TO READ THE SECOND CLAUSE OF THE SENTENCE

Sentence set	Prior disambiguation: Preferred reading	Prior disambiguation: Unpreferred reading	Late disambiguation: Preferred reading	Late disambiguation: Unpreferred reading
Set 1	63	75	58	70
Set 2	60	75	56	70
Set 3	56	58	50	50
Set 4	54	54	48	49

type of ANOVA on the disambiguating region data indicated that the two main effects discussed above remained significant and the main effect of preference was also significant, $F1(1,19) = 20.26, p < .001$, and $F2(1,60) = 7.92, p < .01$. More importantly, the interaction of Location × Preference, $F1(1,19) = 5.59, p < .05$, and $F2(1,60) = 5.26, p < .05$, and the three-way interaction, $F1(3,57) = 3.99$), $p < .05$ and $F2(3,60) = 4.17, p < .05$, both were significant and again confirm a very different pattern for Sets 1 and 2 vs. Sets 3 and 4.

Probability of a Regression

Table 7 shows the probability of making a regression from the end of the sentence to the target word or from the target word region back to another part of the sentence. As Table 7 documents, subjects made considerably more regressions when the disambiguating information followed the target word than when it preceded the target, $F1(1,19) = 19.72, p < .001$, and $F2(1,60) = 14.26, p < .001$, and they made more regressions when the unpreferred reading of the target word was instantiated, $F1(1,19) = 32.66, p < .001$ and $F2(1,60) = 16.27, p < .001$. There was also a main effect of set, $F1(3,57) = 10.23, p < .001$, and $F2(3,60) = 7.26, p < .01$, and once again a Neuman–Keuls test revealed that Sets 1 and 2 (.38 and .33, respectively) differed from Sets 3 and 4 (.23 and .21, respectively). In addition, the two-way interaction of Set × Preference, $F1(3,57) = 14.88, p < .001$, and $F2(1,60) = 16.27, p < .001$, and Location × Preference, $F1(1,19) = 10.28$, and $F2(1,60) = 4.09, p < .05$, were significant. Most importantly, the three-way interaction was again significant, $F1(3,57) = 2.97, p < .05$, and $F2(3,60) = 2.86, p < .05$, indicating a different pattern in terms of how frequently subjects made a regression as a function of these variables.

DISCUSSION

First we will say what the data suggest

TABLE 7
MEAN PROBABILITY OF A REGRESSION AS A FUNCTION OF SENTENCE SET, LOCATION OF THE DISAMBIGUATING INFORMATION, AND PREFERRED VS. UNPREFERRED INTERPRETATION OF THE TARGET WORD

Sentence set	Prior disambiguation: Preferred reading	Prior disambiguation: Unpreferred reading	Late disambiguation: Preferred reading	Late disambiguation: Unpreferred reading
Set 1	.23	.39	.28	.60
Set 2	.20	.38	.22	.53
Set 3	.20	.21	.24	.26
Set 4	.21	.20	.23	.20

about precisely how the experimental sentences are processed. Then we will turn to the implications of the findings for the general hypotheses discussed in the introduction.

In the prior disambiguation condition, there is evidence that a particular meaning or sense is selected on or shortly after fixating the ambiguous target word. Reading times were longer on the target word and in the post-target region for the prior disambiguation forms of *all* the experimental sentence sets than for the following disambiguation forms. This shows that resolving the interpretation of the current phrase with already processed contextual information occurs essentially immediately regardless of whether there exists an actual ambiguity involving multiple grammatical representations. The processor does not simply interpret each individual phrase, delaying interpretation of the relation between phrases until, say, the end of the sentence. If interpretation of the relation between phrases was delayed until the end of the sentence we would expect reading times on the target word and post-target regions, as well as the overall sentence reading times, to be the same in the prior disambiguation and the late disambiguation conditions.

What is most interesting about the prior disambiguation condition is the similarity between the ambiguous words with multiple meanings and those with multiple senses. Both show effects of immediate interpretation with faster reading times associated with preferred interpretations. By contrast, in the late disambiguation condition, the patterning of the data depends on whether a word has multiple meanings or multiple senses. With multiple meanings (Sets 1 and 2), apparently a default assignment or selection of a single meaning has occurred when the target is first encountered, as indicated by the long reading times associated with the disambiguating region in this condition and by the overall longer means for late disambiguation sentences in Sets 1 and 2. These long reading times are due to the cost of reanalysis on those occasions when the default assignment proves to be incompatible with subsequent context, as indicated by the long reading times for the sentence forms containing the unpreferred meaning of a word.

Turning to words with multiple senses, a different pattern emerges. In the disambiguating region of these sentences, we still see longer reading times in the late disambiguation forms (where this coincides with the end of the sentence) than in the prior disambiguation forms (where it does not). But the size of the difference between the prior and late disambiguation forms was much smaller than in Sets 1 and 2, suggesting the effect is not due to the existence of a garden-path but only additional specification of the intended sense of the target word together with end of sentence effects. Indeed, examining overall sentence reading times for prior vs. late disambiguation sentences, there was no difference between the two for Set 3, as expected if no garden-path occurs in processing these sentences. (Recall that there was a large difference in overall sentence reading times between prior and late disambiguation for Sets 1 and 2.) This pattern, together with the shorter reading time on the target in the late disambiguation forms than in the prior disambiguation forms, suggests the shared or overlapping features of the various senses of the target are assigned as the initial semantic value or interpretation of the target phrase in the late disambiguation condition. In this condition, nothing in the prior context invites or requires additional specification of the interpretation of the phrase. However, once the disambiguating region is reached, additional specification of this interpretation is possible, apparently at a computational cost no greater than when the disambiguation preceded the target word.

The results of the experiment clearly disconfirm the Immediate complete interpretation hypothesis, which led us to expect Set 3 would behave just like Sets 1 and 2. The finding that there was no difference between prior and late disambiguation for words with multiple senses, together with the absence of any indication of garden paths for sentences containing these words, supports the Immediate partial interpretation hypothesis. In fact, the evidence is particularly impressive given the indications that readers apparently are choosing a particular sense for the target words in Set 3 immediately upon encountering them in the prior disambiguation sentence forms, as indicated by the longer times associated with the unpreferred sense than the preferred sense in the analysis of target spillover effects.

The Immediate partial interpretation hypothesis, which led us to expect minimal commitments for words with multiple senses (Set 3), specifies that premature semantic commitments made in advance of or in the absence of relevant evidence will occur only when prompted by the avoidance of the presumably dreaded situation posed by no interpretation of processed material or multiple interpretations with necessarily incompatible entailments. Establishing the generality of the Partial interpretation principle clearly requires testing the hypothesis in domains other than that tested here. For example, one might compare thematic assignments involving overlapping features (intentional vs. nonintentional agents, as illustrated in examples (i) and (ii) in the Introduction) with thematic assignments involving incompatible features, such as a competition between an agent and a patient assignment.

Further evidence is also required to securely choose between the following two versions of an immediacy hypothesis:

Weak Immediacy: Immediate commitments (rather than minimal commitments) occur *only if* two incompatible grammatical representations would otherwise be required (or if the commitment is required to maintain consistency with already processed context).

Strong Immediacy: Immediate commitments occur *if* and *only if* two incompatible grammatical representations would otherwise be required. The issue here is whether incompatible grammatical representations present choice points which can be resolved by immediate commitments (as in Weak Immediacy) or whether such choices are *always* resolved by immediate selection (as in Strong Immediacy). Strong Immediacy obviously is not warranted as a conclusion or empirical claim until many domains have been studied (i.e., all areas representing diverse aspects of semantic and pragmatic interpretation). However, as a research strategy, it is clearly preferable to try to maintain Strong Immediacy since it is a stronger claim and thus will help to highlight any circumstances under which delays of interpretation are documented.

We turn now to one possible alternative account of our data—one not in line with the Immediate partial interpretation hypothesis. Consider the possibility that the processor has committed itself to a specific meaning and a particular sense of a word as soon as the word is encountered. Then it must be assumed that on later encountering the disambiguating region in the late disambiguation sentence forms, it takes longer to revise the sentences containing words with multiple meanings than those with multiple senses to account for the greater difference between prior and late disambiguation for the multiple meaning (vs. multiple sense) sentences. Perhaps there is a reanalysis effect for words with multiple senses but our experimental technique is not sufficiently sensitive to detect such a minor difference. However, this cannot be correct. The fact that the reading time differences were observed between the preferred vs. unpreferred sense of target words with preceding disambiguation (see section entitled Target Word Spillover Effects) makes it implausible to argue that revision times for these words (where disambiguation follows) are too small to be observed because of the slight difference between the two meanings/senses involved.

The general view of semantic processing

which is encouraged by the present study is intuitively appealing. The language processor minimizes its processing by minimizing its semantic commitments. It takes on commitments only if required to do so, either by the grammar presenting it with a choice point in the analysis or by the need to continually maintain consistency between its interpretation of current material and interpretation of material already processed. However, if some decision or commitment is required for either purpose, it can apparently be made (initiated) immediately without waiting to see if helpful information will follow. Where, then, do semantic decisions occur in advance of the information needed to make them securely? If we are correct, they occur only when partial specification of the semantic value for an expression (word, phrase, etc.) or relation is impossible because no independently licensed grammatical representation unites the possible alternatives.

APPENDIX 1

Set 1 Sentences

a = prior-preferred, b = prior-unpreferred, c = following-preferred, d = following-unpreferred

1a. Walking in late, her date surprised Jane.
b. Tasting so bitter, her date surprised Jane.
c. Yesterday her date surprised Jane, by walking in late.
d. Yesterday her date surprised Jane, by tasting so bitter.

2a. Playing so loudly, the wedding band upset the groom.
b. Looking so tarnished, the wedding band upset the groom.
c. The wedding band upset the groom, by playing so loudly.
d. The wedding band upset the groom, by looking so tarnished.

3a. Wearing corduroy jackets and blue jeans, the press seemed out of date.
b. Looking rusty and out of repair, the press seemed out of date.
c. Obviously the press looked out of date, wearing corduroy jackets and blue jeans.
d. Obviously the press seemed out of date, looking rusty and out of repair.

4a. Apologizing for their behavior, the club was virtually useless.
b. Weighing almost thirty pounds, the club was virtually useless.
c. Unfortunately the club was virtually useless, apologizing for their behavior.
d. Unfortunately the club was virtually useless, weighing almost thirty pounds.

5a. Cheering happily for a change, the fans were very noisy.
b. Operating correctly for a change, the fans were very noisy.
c. Apparently the fans were very noisy, cheering happily for a change.
d. Apparently the fans were very noisy, operating correctly for a change.

6a. Being so elegantly designed, the pitcher pleased Mary.
b. Throwing so many curve-balls, the pitcher pleased Mary.
c. Of course the pitcher pleased Mary, being so elegantly designed.
d. Of course the pitcher pleased Mary, throwing so many curve-balls.

7a. Moving very quickly, the bug surprised John.
b. Being installed quietly, the bug surprised John.
c. It appears that the bug surprised John, moving very quickly.
d. It appears that the bug surprised John, being installed quietly.

8a. Screaming furiously, the coach terrified everyone.
b. Swaying dangerously, the coach terrified everyone.
c. Obviously the coach terrified everyone, screaming furiously.
d. Obviously the coach terrified everyone, swaying dangerously.

9a. Being difficult to use precisely, the ruler was unpopular.
b. Demanding obedience from everyone, the ruler was unpopular.
c. Apparently the ruler was unpopular, being difficult to use precisely.
d. Apparently the ruler was unpopular, demanding obedience from everyone.

10a. After warping and sagging for months, the panel finally gave in.
b. After studying the issue for months, the panel finally gave in.
c. Reportedly the panel finally gave in, after warping and sagging for months.
d. Reportedly the panel finally gave in, after studying the issue for months.

11a. Deciding that the theorem was too difficult to understand, the pupil appeared distant and far away.
b. Turning on the overhead lights abruptly and without warning, the pupil appeared distant and far away.

c. Naturally the pupil appeared distant and far away, after deciding that the theorem was too difficult to understand.
d. Naturally the pupil appeared distant and far away, after turning on the lights abruptly and without warning.

12a. Supporting such expensive equipment, the board received a lot of attention.
b. Revoking popular zoning laws, the board received a lot of attention.
c. Undoubtedly the board received a lot of attention, supporting such expensive equipment.
d. Undoubtedly the board received a lot of attention, revoking popular zoning laws.

13a. Being so bright despite the enormous distance, the star impressed everyone.
b. Being so humble despite all the publicity, the star impressed everyone.
c. Clearly the star impressed everyone, being so bright despite the enormous distance.
d. Clearly the star impressed everyone, being so humble despite all the publicity.

14a. Resembling a human skull closely, the head surprised us.
b. Resigning without warning the committee, the head surprised us.
c. In fact, the head surprised us, resembling a human skull closely.
d. In fact, the head surprised us, resigning without warning the committee.

15a. Stacked neatly in the hallway, the bats still disturbed Grandmother.
b. Sleeping quietly in the hallway, the bats still disturbed Grandmother.
c. The bats still disturbed Grandmother, stacked neatly in the hallway.
d. The bats still disturbed Grandmother, sleeping quietly in the hallway.

16a. Looking so tattered, the page seemed out of place.
b. Smiling so cheerfully, the page seemed out of place.
c. The page seemed out of place, looking so tattered.
d. The page seemed out of place, smiling so cheerfully.

Set 2 Sentences

1a. Burning for nearly an hour, the match surprised George.
b. Lasting for nearly an hour, the match surprised George.
c. Yesterday the match surprised George, burning for nearly an hour.
d. Yesterday the match surprised George, lasting for nearly an hour.

2a. Sounding so shrill, the ring infuriated Susan.
b. Looking so cheap, the ring infuriated Susan.
c. Everyone thought the ring infuriated Susan, sounding so shrill.
d. Everyone thought the ring infuriated Susan, looking so cheap.

3a. Arriving so early, the fall really upset Nina.
b. Breaking her arm, the fall really upset Nina.
c. Clearly the fall really upset Nina, arriving so early.
d. Clearly the fall really upset Nina, breaking her arm.

4a. Bouncing very high, the ball was a real success.
b. Lasting all night, the ball was a real success.
c. Luckily the ball was a real success, bouncing very high.
d. Luckily the ball was a real success, lasting all night.

5a. Tasting sweet, nevertheless the jam displeased Tom.
b. Ending quickly, nevertheless the jam displeased Tom.
c. Reportedly, the jam displeased Tom, tasting so sweet.
d. Reportedly, the jam displeased Tom, ending so quickly.

6a. Clashing with her furniture, that shade bothered Susan.
b. Tearing around the edges, that shade bothered Susan.
c. Clearly that shade bothered Susan, clashing with her furniture.
d. Clearly that shade bothered Susan, tearing around the edges.

7a. Because of its considerable political expertise, the cabinet impressed us.
b. Because of its very intricate carvings, the cabinet impressed us.
c. The cabinet impressed us because of its considerable political expertise.
d. The cabinet impressed us because of its very intricate carvings.

8a. After they were scratched, the records were carefully guarded.
b. After the political takeover, the records were carefully guarded.
c. The records were carefully guarded after they were scratched.
d. The records were carefully guarded after the political takeover.

9a. Wrinkling so easily, the suit bothered Dick.
b. Progressing so slowly, the suit bothered Dick.
c. It seems that the suit bothered Dick, wrinkling so easily.
d. It seems that the suit bothered Dick, progressing so slowly.

10a. Breaking very quickly, the tie didn't bother Tom.
b. Matching his shirt, the tie didn't bother Tom.
c. Apparently the tie didn't bother Tom, breaking very quickly.
d. Apparently the tie didn't bother Tom, matching his shirt.

11a. Lying around unused for years, the racket was finally broken.
b. Cheating people for many years, the racket was finally broken.
c. Finally the racket was broken, lying around unused for years.
d. Finally the racket was broken, cheating people for many years.

12a. Jingling loudly in Tom's pocket, the change was bothersome.
b. Influencing most everyone's life, the change was bothersome.
c. Reportedly the change was bothersome, jingling loudly in Tom's pocket.
d. Reportedly the change was bothersome, influencing most everyone's life.

13a. Snapping in half, the bar was indisputably useless.
b. Promoting new legislation, the bar was indisputably useless.
c. Indisputably the bar was useless, snapping in half.
d. Indisputably the bar was useless, promoting new legislation.

14a. Motivating him to help others, Sam's drive was admired by everyone.
b. Winding through the old oaks, Sam's drive was admired by everyone.
c. Clearly Sam's drive was admired by everyone, motivating him to help others.
d. Clearly Sam's drive was admired by everyone, winding through the old oaks.

15a. Because she didn't know why her brother would do such a crazy thing, the deed really upset Mary.
b. Because she couldn't locate it in the files, the deed really upset Mary.
c. The deed really upset Mary because she didn't know why her brother would do such a crazy thing.
d. The deed really upset Mary because she couldn't locate it in the files.

16a. Due to changing fads in card games, that type of poker has become rare.
b. Due to changing fads in wood stoves, that type of poker has become rare.
c. That type of poker has become rare due to changing fads in card games.
d. That type of poker has become rare due to changing fads in wood stoves.

Set 3 Sentences

1a. Lying in the rain, the newspaper was destroyed.
b. Managing advertising so poorly, the newspaper was destroyed.
c. Unfortunately, the newspaper was destroyed, lying in the rain.
d. Unfortunately, the newspaper was destroyed, managing advertising so poorly.

2a. After having so many pages torn, the book didn't sell.
b. After taking so long to write, the book didn't sell.
c. Apparently, the book didn't sell, after having so many pages torn.
d. Apparently, the book didn't sell, after taking so long to write.

3a. Burning down every other year, the library was never used.
b. Ordering fewer books every year, the library was never used.
c. In fact, the library was never used, burning down every other year.
d. In fact, the library was never used, ordering fewer books every year.

4a. Having taken no fire precautions, the city was destroyed.
b. Deciding to raise taxes substantially, the city was destroyed.
c. Unfortunately, the city was destroyed, having taken no fire precautions.
d. Unfortunately, the city was destroyed, deciding to raise taxes.

5a. Upsetting lots of people, the notice wasn't heeded.
b. Being written in small print, the notice wasn't heeded.
c. Predictably the notice wasn't heeded, upsetting lots of people.
d. Predictably the notice wasn't heeded, being written in small print.

6a. Ending early, the dinner wasn't very enjoyable.
b. Tasting burned, the dinner wasn't very enjoyable.
c. Apparently the dinner wasn't very enjoyable, ending early.
d. Apparently the dinner wasn't very enjoyable, tasting burned.

7a. Because it was incoherent, the article wasn't read by anyone.
b. Because it was illegible, the article wasn't read by anyone.
c. The article wasn't read by anyone because it was incoherent.
d. The article wasn't read by anyone because it was illegible.

8a. Because the actors forgot their lines, the play disappointed Marcia.

b. Because the plot was so tangled, the play disappointed Marcia.
c. The play disappointed Marcia because the actors forgot their lines.
d. The play disappointed Marcia because the plot was so tangled.

9a. After being a favorite for decades, the film didn't seem very good now.
b. After being repeatedly exposed to light, the film didn't seem very good now.
c. Clearly the film didn't seem very good now, after being a favorite for decades.
d. Clearly the film didn't seem very good now, after being repeatedly exposed to light.

10a. After being ripped apart over and over again, the dollar became useless.
b. After organizing the United States economy for years, the dollar became useless.
c. John implied that the dollar became useless, after being ripped apart over and over again.
d. John implied that the dollar became useless, after organizing the United States economy for years.

11a. After getting soaked by the coffee, the novel was ignored.
b. After getting some great reviews, the novel was ignored.
c. Actually the novel was ignored, after getting soaked by the coffee.
d. Actually the novel was ignored, after getting some great reviews.

12a. After being transmitted orally for many years, the poem was lost.
b. After being locked up in John's safe, the poem was lost.
c. Supposedly the poem was lost, after being transmitted orally for many years.
d. Supposedly the poem was lost, after being locked up in John's safe.

13a. Being so nasty, the letter upset the director.
b. Being so crumpled, the letter upset the director.
c. Reportedly the letter upset the director, being so nasty.
d. Reportedly the letter upset the director, being so crumpled.

14a. Expressing a common sentiment, the message was clear.
b. Glowing in bright red, the message was clear.
c. Undoubtedly the message was clear, expressing a common sentiment.
d. Undoubtedly the message was clear, glowing in bright red.

15a. Being horribly smudged, the pamphlet was never widely read.
b. Being officially outlawed, the pamphlet was never widely read.
c. The pamphlet was never widely read, being horribly smudged.
d. The pamphlet was never widely read, being officially outlawed.

16a. Despite being organized haphazardly, the lunch was very pleasant.
b. Despite being cooked haphazardly, the lunch was very pleasant.
c. The lunch was very pleasant, despite being organized haphazardly.
d. The lunch was very pleasant, despite being cooked haphazardly.

Set 4 Sentences

1a & b. Because the pirates sank the ship, the treasure was lost.
c & d. Apparently the treasure was lost because the pirates sank the ship.

2a & b. Jim felt he was being watched, when the door opened.
c & d. When the door opened, Jim felt he was being watched.

3a & b. After all the complaints, the window was closed.
c & d. Apparently the window was closed, after all the complaints.

4a & b. Before the fight had started, the referee had dropped the puck.
c & d. Obviously the referee had dropped the puck, before the fight had started.

5a & b. After the engine was repaired, the plane flew.
c & d. Luckily the plane flew, after the engine was repaired.

6a & b. While they watched the television, the new car was stolen.
c & d. Yesterday they new car was stolen, while they watched television.

7a & b. While her mother was watching, the infant took her first step.
c & d. Today the infant took her first step, while her mother was watching.

8a & b. While the children slept, the parents placed gifts under the Christmas tree.
c & d. Last night the parents placed gifts under the Christmas tree, while the children slept.

9a & b. Angry at the next-door neighbors, the old woman called the police.
c & d. Apparently the old woman called the police, angry at the next-door neighbors.

10a & b. While John waited anxiously, the filet broiled on the grill.
c & d. The filet broiled on the grill, while John waited anxiously.

11a & b. Tasting burned, the pie wasn't a big success.
c & d. Obviously, the pie wasn't a big success, tasting burned.

12a & b. After not being used for year, the fireplace was dangerous.
c & d. Obviously, the fireplace was dangerous, after not being used for years.

13a & b. Because it was so beautiful, the bracelet attracted much attention.
c & d. The bracelet attracted much attention because it was so beautiful.

14a & b. When it finally sailed, the boat was late leaving the dock.
c & d. Apparently the boat was late leaving the dock, when it finally sailed.

15a & b. While the children watched it, the cow grazed in the fields.
c & d. The cow grazed in the fields, while the children watched it.

16a & b. Because Peter pushed hard, the barrel finally rolled.
c & d. The barrel finally rolled because Peter pushed hard.

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