# Time Course of Priming for Associate and Inference Words in a Discourse Context

Robert E. Till

University of North Dakota

Grand Forks, ND 58202

(701) 777-3451

Ernest F. Mross and Walter Kintsch

University of Colorado

Boulder, CO 80309

(303) 492-6991

Send proofs to: Dr. Robert E. Till

Department of Psychology

University of North Dakota

Grand Forks, ND 58202

Running head: PRIMING IN A DISCOURSE CONTEXT

Subject index terms: Lexical access

Priming, associates and inferences

Priming, time course

Sentence comprehension

Word recognition, context effects in

Abstract

Discourse context was manipulated in two experiments that conceptualized word identification as a process of sense activation, sense selection, and sense elaboration. Subjects read texts presented by RSVP and simultaneously performed a lexical decision on visually presented targets that followed ambiguous prime words. When the target was a word, it was either an associate of the prime word, a probable inference suggested by the discourse, or an unrelated word. For associates, lexical decisions related to appropriate and inappropriate senses of the ambiguous word were equally facilitated at stimulus onset asynchrony (SOA) of 300 and 333 msec. At longer SOAs, responses were faster to appropriate than to inappropriate associates. For inferences, there was no difference between thematic inferences and control words at short SOAs. At the longest SOA (1000 msec), however, inference words were strongly facilitated. The results are interpreted as support for a model of lexical processing in which sense activation functions as an independent module. Discourse context effects, whether on sense selection (suppression of inappropriate associates) or on sense elaboration (creation of inferences), are seen as postlexical.

# Time Course of Priming for Associate and Inference Words in a Discourse Context

It has long been taken for granted that word identification in a discourse context is highly context dependent: words that are expected are identified more rapidly and more accurately than words that do not fit into the discourse context. In recent years, some studies of priming effects in discourse contexts have challenged this conventional wisdom. In these priming experiments, subjects read or listen to discourse. At a certain point, a priming word is presented and followed by a secondary task. Typically, a letter string (the target) is presented visually and subjects either decide as rapidly as they can whether the string forms an English word (lexical decision, as in Swinney, 1979) or name the word (naming, as in Seidenberg, Tanenhaus, Leiman, & Bienkowski, 1982). Presentation of the text may be auditory (e.g., Swinney's cross-modal priming) or visual (e.g., Kintsch & Mross, 1985). Of interest is the reaction time to the target item in the lexical decision or naming task: if it is shortened relative to neutral control words, the target is said to be primed by the prime word and/or the general discourse context. The results of these experiments suggest that the general discourse context per se does not facilitate the identification of the target word, although associative relations between the prime and the target do.

We base this conclusion on two sets of observations. First, the context-appropriate and the context-inappropriate meanings of homographs are equally activated during initial perception;

discourse context merely serves to suppress the inappropriate meaning. This effect was first demonstrated by Swinney (1979) using a lexical decision task. It has since been replicated by Onifer and Swinney (1981) and Kintsch and Mross (1985); Simpson (1984) provides a review. Confirming results were also obtained by Seidenberg et al. (1982) with a naming task. Second, words that are contextually appropriate but are not associatively related to the target word are not primed in either a lexical decision task (Kintsch & Mross, 1985) or a naming task (Seidenberg et al., 1982) in the initial stage of word identification. Thus, the discourse context neither inhibits the identification of inappropriate words, nor does it facilitate the identification of appropriate words. In the initial stages of perception, all priming effects appear to be associative.

These results have inspired conceptions of word identification in which context plays no role in the initial stage of the process (Tanenhaus, Leiman, & Seidenberg, 1979; Seidenberg et al., 1982; Kintsch & Mross, 1985). Kintsch and Mross sketched a model in which the meaning of a word is not fully present immediately upon perception, but is constructed through the stages of sense activation, sense selection, and sense elaboration. They further distinguished between two kinds of contexts which may operate only at the later stages in the word identification process: "fixed" context, the associative network in which lexical nodes are embedded, and "variable" context, the discourse context in which word identification takes place.

In the sense activation phase, which appears to start within

50 msec after presentation (Fischler & Goodman, 1978), all lexical meanings corresponding to a certain phonemic or graphemic input are activated. Presumably, discourse and situational contexts play no role in this activation process, but the relatively fixed associative and semantic relations within a person's lexicon do. Suppose, for example, that a subject reads the word "iron" as part of a discourse text on metallurgy. At this point, the two lexical nodes corresponding to the two meanings of "iron" will be equally activated, and activation from either node will spread to a few neighboring, strongly associated nodes in the lexicon.[1] That is, both "steel" and "clothes" become activated. If either of these words is presented simultaneously or shortly after "iron," priming effects will be observed in lexical decision and naming tasks.

After approximately 350-500 msec, the discourse context begins to select the appropriate meaning, or to suppress the inappropriate one. Priming is observed only for the context-appropriate associate "steel," but no longer for "clothes." This is the sense selection phase of word identification.

The final stage is sense elaboration. The word meaning that has been selected from the lexicon, which is no more than a semantic sketch, is elaborated contextually to the extent that resources, task demands, and the reader's knowledge permit. In normal comprehension, the needed elaboration is probably achieved by the end of the sentence or phrase in which the word is embedded, but in extreme cases this elaboration process may require extended problem-solving activities. Discourse context, and context in general, have their effects in these last two stages of word identification, but are irrelevant in the sense activation phase.

How strongly is this model supported by the existing data? Although there are numerous demonstrations of context effects in word identification, they seem generally irrelevant to the present argument. The experiments in question either do not deal specifically with the sense activation process only, or they fail to distinguish between the effects of "fixed" word associations and the effects of the discourse context per se. In support of the model, the equal priming of context-relevant and context-irrelevant associates of homophones and homographs appears to be established beyond reasonable doubt (Swinney, 1979; Onifer & Swinney, 1981; Seidenberg et al., 1982; Kintsch & Mross, 1985). On the other hand, the claim that context-appropriate words without any associative relations to the words in the text are not primed may be less well established. The problem is this: how does one determine what is context-appropriate? Kintsch and Mross (1985) constructed little stories from the scriptal norms of Galambos (1982), omitting one important step in each story. For example, in a story about an executive catching a plane, one sentence described how he raced down the hallway and the next described how he got on the plane. The step "comes to the gate," which people expect between these two actions (according to the norms), was omitted from the story. Hence, it could be argued that "gate" was a contextually appropriate word, at that point, and a good candidate for contextual priming. Although this seems a reasonable argument, Kintsch and Mross have not actually shown that at this particular point in their story, readers make an inference like "he passes the gate."

In the present experiments, we used texts for which it was known that readers, at the critical point, actually make a particular inference with high probability. Thus, a stronger argument can be made that the target words used here, as compared with those of Kintsch and Mross (1985), really were highly appropriate inferences. Indeed, if subjects were given enough time, the targets were the inference words the subjects themselves would have produced.

Another reason for conducting the present pair of experiments was to investigate more closely the time course of semantic priming in discourse. After all, our claim is not that context plays no role in word identification, but that its role changes: it is ineffective during the first 300 msec or so, but then becomes the dominant factor in the sense selection and elaboration phases of the process. Thus, the present experiments were designed to track this changing role of the discourse context. No context effects were expected when the target word followed the priming word right away. With a 1-sec interval, however, there should be enough time for sense selection and sense elaboration to occur so that semantically appropriate words should be primed in a lexical decision task, even though they bear no associative relations to the immediately preceding prime word. Indeed, as part of the elaboration process, subjects may generate the very words that we provide as inference target words.

## Experiment 1

In Experiment 1, subjects read brief texts, presented one word at a time. Each contained a homograph whose meaning was unambiguously specified by the context. Text presentation was interrupted, immediately following the homograph, with a lexical decision trial. There were five kinds of target items: nonword targets, contextually-appropriate associates of the prime, contextually-inappropriate associates, appropriate inference words (high-probability inferences from the text), and inference control words (words that were actually appropriate inferences for <u>other</u> texts). Stimulus onset asynchrony (SOA), between the onset of the prime and the onset of the target, was 333 msec or 1000 msec. Targets presented at the short SOA presumably came at the end of the sense activation phase or perhaps the beginning of the sense selection phase. Thus, we expected little or no effect of discourse context. Response latencies for both associates should be short relative to latencies for the inference words and inference control words. At the long SOA, in contrast, we expected context effects for both associate and inference words. That is, appropriate associates should be primed relative to inappropriate associates and appropriate inference words should also be primed relative to the (inappropriate) inference control words. In sum, for both associate and inference targets, we expected an interaction between SOA interval and contextual appropriateness, with appropriateness only having an effect at the longer SOA interval.

## Method

<u>Subjects</u>. The subjects were 48 undergraduates from the University of Colorado who participated to fulfill a psychology

course requirement. Subjects were randomly assigned to the two SOA conditions, with 24 in each group.

Design. The between-subjects variable was SOA, with subjects in either the 333 msec or the 1000 msec condition. Two within-subject variables resulted from the crossing of context-appropriateness and target type. Of 56 critical target words requiring a positive lexical decision, 14 were appropriate associates, 14 were inappropriate associates, 14 were appropriate inferences, and 14 were inference control words (i.e., "inappropriate inferences," since in this last case there was no obvious relation between primes and target words). Although not analyzed, list was treated as a design variable and was counterbalanced across subjects. Half saw the texts of List A first, followed by List B, while half saw the lists in the other order.

Materials. Two lists were constructed, each with 28 critical paragraphs and 21 filler paragraphs. Critical paragraphs were those in which a priming word was followed by a test item that was an English word, rather than a nonword. Only one such test item was presented in each paragraph, and rarely did it produce a syntactically or semantically well-formed continuation of the sentence being comprehended (e.g., sage... brush).

The two lists were constructed in parallel. Specifically, a pair of paragraphs was written around an ambiguous noun that appeared in both. This ambiguous item was used as the priming word for the lexical decision test item (that interrupted the story). Paragraph pairs were constructed so that only one meaning of the ambiguous word was appropriate for each paragraph in a pair. Each paragraph consisted of two sentences and was about 22 words in length. For approximately half of the paragraphs, in either list, the ambiguous word appeared in the first sentence, and for the other half, it appeared in the second sentence.

The ambiguous nouns were selected from Cramer's (1970) association norms for homographs. As much as possible, the homographs (which were also homophones) were chosen such that among their top associates there was a pair of approximately equally strong associations to both senses of the word. For example, "iron" was selected because its two strongest associates are "steel," with a response probability of .128, and "clothes," with a response probability of .119. The ambiguous noun always appeared at the end of a sentence, but we constructed sentences so that endings were not predictable (i.e., 80% of the sentences would have been grammatical if they had ended at some point before the ambiguous word).

For each ambiguous word used in the critical paragraphs, the two paragraphs containing it were assigned to List A or List B so as to keep the average prime/test word associative strength approximately equal for the two lists. Critical paragraphs were also constructed so that certain probable inferences might be drawn during comprehension. Thus, the paragraphs in a pair were worded to suggest not only different associates to the prime word, but also different inferences, of approximately equal response strength. The initial assignment of paragraphs in each pair to Lists A and B, equating the lists for associative strength of associate test words, was modified to insure that the "inference strength" of inference test words was also approximately equal for Lists A and B.

The inference words chosen to be test words rarely or never appeared in Cramer's (1970) association norms. Typically, they were modal responses of moderate strength made by 62 subjects asked, in a pilot study, to read each paragraph up to the point of the prime word, and to write down a word reflecting their understanding of what the paragraph was about. An examination of the inference word responses showed that our previously selected associate test words rarely appeared as inference responses.

---

Insert Table 1 about here

---

Characteristics of the test words used in critical paragraphs are summarized in Table 1. The data are collapsed over Lists A and B, which were constructed to be quite similar on these values. It can be seen that associative priming and inferential priming are relatively independent in this study. In response to an associate priming word, our associates were often given (.159) while our inference words rarely occurred (.001). In response to our story contexts, the (appropriate) inference words were frequently given (.242) while the (appropriate) associates rarely appeared (.025). It is also apparent in Table 1 that associates were generally shorter than inference words, $\underline{t}(55) = 3.87$, $\underline{p} < .001$, but were not significantly higher in mean word frequency, $\underline{t}(55) = 1.42$ (though a simple sign test, insensitive to the skewness, suggested associates were of higher word frequency: for 38 of 56 pairs, $p < .05$).

The 28 critical paragraph pairs were divided into four subgroups as similar as possible on the characteristics noted above. These subgroups were assigned to the four test-word conditions (e.g., appropriate associate, etc.) according to a Latin-square arrangement. Thus, each subgroup of paragraphs was tested equally often in each test-word condition. Specifically, there were six subjects in each of four subgroup-assignment conditions.

Since all subjects saw List A and List B, they necessarily encountered each prime word twice. Therefore, assignment of test words to subgroups of paragraphs was constrained such that test words during the second list were different in type and appropriateness. For example, if a paragraph from the first list was tested with an appropriate associate, then the corresponding paragraph in the second list was tested with an inappropriate inference. Similarly, when the first list used an inappropriate associate, the corresponding item in the second list used an appropriate inference.

The 21 filler paragraph pairs, containing the negative (i.e., non-word) lexical decision trials, were of similar style and word length. They were written around an ambiguous noun, from Cramer's (1970) norms, not used in preparing the critical paragraphs. Each paragraph consisted of two sentences, with the ambiguous noun placed at the end of the first or second, and was written to suggest some kind of thematic inference. The nonword targets were taken from Taft (1982). Since filler paragraphs were used only for negative trials, we made no attempt to quantify associative or inference strength. One filler paragraph from each pair was arbitrarily assigned to List A and List B.

Within each list, the 28 critical paragraphs were combined with the 21 filler paragraphs such that every block of 7 paragraphs contained a random ordering of the following trials: one appropriate associate, one inappropriate associate, one appropriate inference, one inference control word, and three nonword test items. The random orderings for List A and List B were unrelated. An example of a block of seven paragraphs from List A is shown in Table 2; all possible test words are shown along with the (underlined) test words for one subject.

Insert Table 2 about here

For each list, we constructed 14 comprehension items. Each was a single sentence requiring a "Yes" response if it was a true (though perhaps abbreviated) statement from an earlier paragraph or a "No" response if it was a scrambling of earlier paragraphs (topics and predicates from different paragraphs). After every block of seven paragraphs, two comprehension items (based on that block) were presented. Comprehension items were presented one at a time. Half of the items called for a "Yes" response while half called for a "No."

Finally, we prepared a single set of seven paragraphs and two comprehension items for use as practice material. These items were similar in style and length to the experimental materials.

Procedure. Upon arrival, a subject was randomly assigned to one of two SOA conditions (333 or 1000) and then to one of the 8 combinations of 2 list orders x 4 subgroup-assignment orders.

Subjects worked individually on IBM personal computers equipped for real-time experiments, with up to two in the same experimental room. They were instructed to read the stories that would be presented in the center of the screen, by means of a rapid serial visual procedure (RSVP), and to be prepared to answer questions about the stories later. A 2-sec fixation-point (asterisk) occurred first, followed by a 1-sec pause, and then the first word of a story. During the text presentation, the words followed each other on the same central screen location, each word being presented for 333 msec (with negligible off-time between words).

In addition to reading for comprehension, subjects were asked to perform a second task as fast as possible and without errors: Once in each story paragraph, a target string would appear in the center of the screen, and their task was to indicate whether the letters formed an English word or not by pressing a key identified as "Yes" or one identified as "No." Index fingers were to be kept on these keys all the time. These lexical decision trials clearly interrupted the reading of the paragraph since the target string appeared in the same location as previous words, but was flanked by four asterisks (e.g., **** clothes ****).

In the SOA 333 condition, these target strings occurred immediately after the ambiguous prime word (i.e., with the same latency as all other words in the text). In the SOA 1000 condition, target strings appeared 667 msec after the offset of the prime word. Presentation of a target string started a timer that recorded response latency; actual response (yes/no) was also recorded. Text presentation resumed when the subject made the response, or when 2000 msec had elapsed (in which case the trial was counted as an error). Finally, there was a 2-sec pause between texts.

After the instructions, subjects read a series of seven practice stories, each containing a lexical decision trial, followed by two comprehension items requiring a Yes/No (untimed) response. Each comprehension item remained on the screen until a "Yes" or "No" response was made.

All subjects appeared to understand the comprehension and lexical decision tasks by the end of the practice session. The first list of paragraphs and comprehension items were then presented just as in the practice trials except that, after every block of seven texts and two comprehension items, subjects controlled the initiation of the next block with a key press. After the first list, subjects had a brief, self-paced rest pause. Without further instruction, subjects then worked through the materials of the second list just as they had the first.

<u>Results</u>

Comprehension scores were high ($\underline{M}$ = 88%) and lexical decision errors were few, suggesting that subjects had complied with the instructions emphasizing the importance of both tasks. The overall error rate for positive lexical decision trials was 3.8%, with 0.6%

due to response latencies exceeding 2000 msec. The specific error rate associated with each type of target word varied from 0.6% to 3.6%, but there was no significant difference between the two SOA conditions, $t(46) = 0$, and no evidence of a speed-accuracy trade-off. Similarly, there was no significant difference between SOA conditions in comprehension scores, $t(46) = 1.12$.

---

Insert Figure 1 about here

---

The major analyses were based on response latencies for positive (correct) lexical decision trials. In the analyses by subjects, the median response latency for each SOA x appropriateness condition was based on up to 14 items. In the analyses by items, the corresponding median response latencies were based on the data of up to six subjects. Mean of median latency was analyzed, by subjects and by items, in separate analyses of variance for associate words and inference words. The points plotted in Figure 1, however, show the average of corresponding values from the subject and item analyses. All reported effects were significant at the .05 level or beyond, unless otherwise noted.

At SOA 333, response latencies for appropriate inference words were about the same as for inference control words. There was no evidence that appropriate context facilitated priming. In contrast, after 1 sec, response latencies for the contextually appropriate inference words were 45 msec faster than latencies for the inference control words. The data are shown in Figure 1.

The interaction between SOA and contextual appropriateness was statistically significant in the analysis by subjects, $F(1,46) = 4.73$, as well as by items, $F(1,110) = 4.18$. The main effect of SOA was significant in the item analysis, $F(1,110) = 11.3$, but not in the subject analysis, $F(1,46) = 2.30$, $p > .05$. The generally faster response times at the 1000 msec SOA reflect a preparation effect: at the longer SOA, subjects have more time to prepare themselves for the lexical decision response and are therefore able to react faster. The main effect of context appropriateness (inference vs. control) failed to reach significance in either analysis.

As also seen in Figure 1, responses to contextually appropriate and inappropriate associates were almost identical at SOA 333. However, after 1 sec, appropriate associates were identified as words 38 msec faster than were inappropriate associates.

The analyses on associate word latencies revealed a significant main effect of SOA in the item analysis, $F(1,110) = 25.7$, as well as in the subject analysis, $F(1,46) = 5.55$. The main effect of context appropriateness was not significant in either analysis. The interaction between appropriateness and SOA, however, was significant in the analysis by subjects, $F(1,46) = 3.95$, but not in the analysis by items, $F(1,110) = 2.45$, $p > .05$.

## Experiment 2

A second experiment was performed in an attempt to replicate our findings and to explore in more detail the time course of priming for associate and inference words. Three SOA intervals of 300, 500, and 1000 msec were included. Most details of the method and procedure were identical to those of the first experiment, except where noted. The data analysis was different, however, in that we performed separate analyses of variance on the data of each SOA condition. This was motivated, in part, by the decreased power to detect statistically significant SOA x context appropriateness interactions across <u>three</u> levels of SOA (rather than two, as in the first experiment).

<u>Method</u>

<u>Subjects</u>. The subjects were 52 undergraduates from the University of North Dakota who participated for course credit. The data from four subjects were discarded because of failure to understand the task (1 case), lexical decision error rate more than three standard deviations above the group mean (1 case), or comprehension scores more than three standard deviations below the group mean (2 cases). The subjects were randomly assigned to three groups, with 16 in each.

<u>Design and Materials</u>. The design and materials were the same as in Experiment 1, except that there were three SOA conditions (300, 500, and 1000 msec). In addition to list order, paragraph order was treated as a design variable and counterbalanced across subjects. Thus, in contrast to the first experiment, half of the subjects seeing a given list saw the paragraphs in one order ("forward" order) while the other half of the subjects saw them in the opposite order ("reverse" order).

<u>Procedure</u>. Upon arrival, a subject was randomly assigned to one of three SOA conditions, and then further assigned to one of 16 combinations of 2 list orders x 2 paragraph orders x 4

subgroup-assignment orders.

Subjects were tested individually as they sat in front of an Apple IIe computer; only one subject was tested at a time. Text presentation was the same as in Experiment 1 except that all words appeared on the screen for 300 msec. Thus, in the SOA 300 condition, target strings occurred immediately after the prime word. In the SOA 500 condition, target strings appeared 200 msec after the offset of the prime word. And, in the SOA 1000 condition, target strings occurred 700 msec after the offset of the prime word. In contrast to Experiment 1, response latencies were recorded even if they exceeded 2000 msec.

Results

Comprehension scores were high ($M$ = 90%) and the overall error rate for positive lexical decision trials was 2.5%. The specific error rate associated with each type of target word varied from 0.9% to 6.1%, but the three SOA groups were not significantly different on error rates (or on comprehension scores). As in Experiment 1, the major analyses were based on response latencies for positive (correct) lexical decision trials. Latencies above 2000 msec were quite rare (less than .3% of all cases), and in no case did they affect the magnitude of computed median latencies.

In the analyses by subjects, the median response latency for each target type x appropriateness condition was based on up to 14 items. In the analyses by items, the corresponding median latencies were based on the data of up to four subjects. Mean of median latency was analyzed, by subjects and by items, in separate analyses of variance for the SOA 300, SOA 500, and SOA 1000 conditions. All reported effects were significant at the .05 level or beyond, unless otherwise noted. Results are shown in Figure 2 with means averaged from the subject and item analyses.

Insert Figure 2 about here

For the SOA 300 condition, latencies were shorter for associate test words than for inference test words. The effect was clearly significant, $F(1,15) = 39.7$, in the analysis by subjects, and was marginally significant, $F(1,110) = 3.71$, $p < .06$, in the analysis by items. There was no effect of appropriateness and no target type x appropriateness interaction. These results confirm our expectations that, on the average, contextual effects have not yet begun to influence lexical decision at this short (300 msec) SOA. Latencies are generally shorter for associates than for inferences. While this could be attributed to the fact that associates are shorter in word length and of higher word frequency than inference words, other studies showing priming of appropriate and inappropriate associates relative to matched control words (e.g., Kintsch & Mross, 1985) lead us to see the present data as evidence for activation of both associates prior to postlexical processes driven by context.[2]

For the SOA 500 condition, response latencies again appeared to be shorter for associate test words than for inference test words, though the effect seemed due in part to an interaction pattern in which latencies for appropriate associates were particularly short. In the analysis by subjects, in which the pattern appears as a crossover interaction, there was a main effect of target type, $F(1,15) = 10.6$, but no main effect of appropriateness. The interaction approached significance, $F(1,15) = 4.12$, $p < .06$. As suggested in Figure 2, context appears to be facilitating response to appropriate associates by 500 msec and inhibiting the earlier facilitation of inappropriate associates, but not yet influencing response to inference words. In the analysis by items, there was no significant effect of target type, $F(1,110) = 2.41$, $p < .13$. The main effect of appropriateness approached significance, $F(1,110) = 3.62$, $p < .06$, though the interaction was not reliable, $F(1,110) = 1.95$, $p < .17$. Since context effects were ultimately seen (at still longer SOA) for both associates and inferences, this discrepancy between the analysis by subjects and the analysis by items leaves us uncertain as to whether the time course for contextual effects is different for associates and inferences. Nevertheless, the data do hint at earlier facilitation (and/or inhibition) for associates than for inferences.

In the SOA 1000 condition, there appeared to be two main effects with no trace of an interaction. The main effect of target type was reliable in the analysis by subjects, $F(1,15) = 7.19$, and marginally significant in the analysis by items, $F(1,110) = 3.34$, $p < .07$. Even at 1000 msec after the onset of the prime, lexical decisions were faster for associates than for inference words. The main effect of context appropriateness was also significant in the analysis by subjects, $F(1,15) = 15.9$, as well as in the analysis by items, $F(1,110) = 11.4$. Thus, for both kinds of test word, a sentence context appropriate to the meaning of the test word facilitated lexical decision.

## General Discussion

Word meanings are not fully developed at the moment a word is perceived. Instead, they are constructed from the subject's lexical and world knowledge, and the discourse context. This process of meaning construction takes an appreciable amount of time and proceeds in three phases. At first, all lexical information that might be relevant to a particular visual (or auditory) input is activated, irrespective of the discourse context. This sense activation phase is followed by a sense selection phase in which the context-irrelevant portions of the initially activated lexical information are suppressed. Finally, the very sketchy word meaning, now limited to a context-appropriate sense, is enriched to the degree required by the task demands or allowed by the subject's resources. This is the sense elaboration phase of the process. It can be very extensive, involving considerable world knowledge and problem solving activity, though it is probably very perfunctory in many cases.

The experimental results reported in our two experiments provide strong support for such a model of word identification. In particular, the results suggest three conclusions with regard to the role of context in lexical decision.

First, the present data resolve some of the ambiguity in the Kintsch and Mross (1985) study regarding thematic context effects. Specifically, the present study constrained thematic context to suggest probable inferences about instruments, reasons, or consequences of events (cf., Till, 1977, 1985), and in so doing was able to select test words for which associative and inferential relationships would be relatively independent. Nevertheless, all test words were known to have reasonably high response probabilities (based on norms). For both experiments, there was no evidence whatever that context-appropriate inferences were primed in a lexical decision task, relative to "inappropriate," inference control words, unless the reader was given sufficient time to elaborate the sentence meaning. With such time, however, the reader very likely generated the inference in question which, in turn, facilitated the identification of the inference word. Thus, in Figures 1 and 2, inference words and inference control words are reacted to in the same way up to the 500 msec SOA. Only at SOA 1000 are context effects observed, with inference words being identified faster than control words. In contradiction to fully interactive models of word identification, context effects in the present study were clearly postlexical, confirming the results of Seidenberg et al. (1982) and Kintsch and Mross (1985).[3] This claim is consistent with other recent results. For example, Sharkey and Mitchell (1985) found strong context effects for script-related words in a lexical decision task after subjects read, at their own rate, a two-sentence script-based text. Presumably, by the time these subjects came to a lexical decision trial, they had sufficiently elaborated the text they had read and had made scriptal inferences, thereby facilitating the identification of scriptal target words (as did our subjects in the SOA 1000 condition).

Second, while the initial stage of word identification appears to be unaffected by the discourse context, it is affected by the associative and/or semantic network in which a lexical concept is embedded. At SOAs of 300 and 333 msec, response latencies to context-appropriate and context-inappropriate associates of homographs were identified equally easily, as in Swinney (1979), Onifer and Swinney (1981), and Kintsch and Mross (1985). Presumably, all associates whether appropriate or inappropriate were primed to some extent whereas no inference words were. Admittedly, there is no comparison here with suitable control words (nonassociates, matched for length and frequency) with which to claim that associates are primed at all. However, the studies cited above clearly indicate that priming effects are normally obtained under these conditions. Furthermore, the set of associate words used by Kintsch and Mross overlapped considerably with the present set and since their study included matched control words, our present findings are consistent with their earlier finding of priming for all associates at short SOAs. By the 500 msec SOA, there was as yet no facilitory effect for inference words, yet the sense selection phase had begun to show inhibition of the inappropriate meanings of associates.

Third, the present data provide some of the strongest evidence yet that context does not facilitate priming of appropriate but nonassociated words, and the data also help to clarify the time course of contextual priming in discourse.[4] For associate prime words, there appears to be early facilitation (by 300 msec) of both context-appropriate and context-inappropriate associates. By 500 msec, the sense selection phase has led to the loss of facilitation for context-inappropriate associates. Sense elaboration apparently requires more than 500 msec, but is evident by 1000 msec. Thus, the prime words (actually the implicational texts ending with the prime words) show no early priming at all for inference test words; i.e., appropriate inferences and "inappropriate" control words show similar response latencies. By 1000 msec, however, the appropriate inferences are clearly primed relative to the inference controls.

According to our present model of word identification in discourse, the lexical node that is first activated by a word contains less than its "full meaning." The latter must be constructed contextually from the text discourse and the subject's world knowledge, leading to different and varied results in different contexts. This process of construction may begin very conservatively with a context-free, "bottom-up" semantic interpretation of the word, dependent on a relatively "fixed" module of information (e.g., Fodor, 1983). Although the time course of context-free and context-dependent phases of word identification may be relatively short (thematic effects here within 1 sec), and may be difficult to tease apart (due to great subject and item variability), it holds the answer to arguments over "top-down" vs. "bottom-up" processing. Effects in both directions may be seen at different points in the time course of word identification.

References

Cramer, P. (1970). A study of homographs. In L. Postman & G. Keppel (Eds.), Norms of word association. New York: Academic Press.

Fischler, I. & Goodman, G. O. (1978). Latency of associative activation in memory. Journal of Experimental Psychology: Human Perception and Performance, 4, 455-470.

Fodor, J. A. (1983). The modularity of mind. Cambridge, Mass.: MIT Press.

Galambos, J. A. (1982). Normative studies of six characteristics of our knowledge of common activities. Cognitive Science Tech. Rep. 14, Yale University.

Glucksberg, S., Kreuz, R. J., & Rho, S. (in press). Context can constrain lexical access: Implications for models of language comprehension. Journal of Experimental Psychology: Learning, Memory, and Cognition.

Kintsch, W. & Mross, E. F. (1985). Context effects in word identification. Journal of Memory and Language, 24, 336-349.

Kučera, H. & Francis, W. N. (1967). Computational analysis of present-day American English. Providence, R. I.: Brown University Press.

Onifer, W. & Swinney, D. A. (1981). Accessing lexical ambiguities during sentence comprehension: Effects of frequency of meaning and contextual bias. Memory and Cognition, 9, 225-236.

Seidenberg, M. S., Tanenhaus, M. K., Leiman, J. M., & Bienkowski, M. (1982). Automatic access of the meaning of ambiguous words in context: Some limitations of knowledge-based processing. *Cognitive Psychology*, *14*, 489-537.

Sharkey, N. E. & Mitchell, D. C. (1985). Word recognition in a functional context. *Journal of Memory and Language*, *24*, 253-270.

Simpson, G. B. (1984). Lexical ambiguity and its role in models of word recognition. *Psychological Bulletin*, *96*, 316-340.

Swinney, D. A. (1979). Lexical access during sentence comprehension: (Re)consideration of context effects. *Journal of Verbal Learning and Verbal Behavior*, *18*, 645-659.

Taft, M. (1982). An alternative to grapheme-phoneme conversion rules? *Memory and Cognition*, *10*, 465-474.

Tanenhaus, M. K., Leiman, J. M., & Seidenberg, M. S. (1979). Evidence for multiple stages in the processing of ambiguous words in syntactic contexts. *Journal of Verbal Learning and Verbal Behavior*, *18*, 427-440.

Till, R. E. (1977). Sentence memory prompted with inferential recall cues. *Journal of Experimental Psychology: Human Learning and Memory*, *3*, 129-141.

Till, R. E. (1985). Verbatim and inferential memory in young and elderly adults. *Journal of Gerontology*, *40*, 316-323.

## Author Notes

Experiment 1 was conducted at the University of Colorado, Boulder, while Robert E. Till was on sabbatical leave for 1984-85. The research was supported in part by grant MH-15872-18 from the National Institute of Mental Health to Walter Kintsch. Experiment 2 was conducted at the University of North Dakota. We wish to thank Steve Rambur for help with data collection in Experiment 2 and Mark Grabe for comments on an earlier draft of the manuscript.
Requests for reprints should be sent to Robert E. Till, Department of Psychology, University of North Dakota, Grand Forks, ND 58202.

Footnotes

[1] We have chosen an example in which the two meanings of the homograph are known to be about equally dominant (e.g., Cramer, 1970); Simpson (1984) discusses the asymmetric case in depth.

[2] A group of 16 additional subjects, similar to the experimental groups in comprehension ($M$ = 86%) and positive lexical decision error rate ($M$ = 2.6%), was tested in the SOA 300 condition with modified materials. Specifically, the 28 inference test words were replaced with the 28 associate words not already used in the other lexical decision trials. These additional associates served as control words since they were assigned at random to paragraphs (with some check to insure they were unrelated to prime words). Thus, these controls were perfectly matched in length and frequency to the appropriate and inappropriate associate words. As expected, response latencies for appropriate and inappropriate associates did not differ. More importantly, responses were faster when test words appeared as associates ($M$ = 703), whether appropriate or inappropriate, than when these same words appeared as unrelated control words ($M$ = 721), $t(15) = 2.271$, $p < .05$.

[3] Glucksberg, Kreuz, and Rho (in press) have tried recently to salvage fully interactive theories of word identification by arguing that the priming of context-irrelevant associates is an instance of backward priming, rather than a lack of context effects. But if context effects are at work at our short SOAs, and contribute to priming of the appropriate associates, why do they

not also facilitate the priming of appropriate inference words, or Kintsch and Mross' (1985) script-related words?

4 The time course may differ for cross-modal lexical decision. Kintsch and Mross (1985) did find evidence of sense selection at about 300-400 msec with a cross-modal priming procedure. However, subjects used a self-paced procedure and the SOA was an average of the reading times for all words. Quite possibly the time of viewing the prime words was longer than this average (while the time of viewing articles and/or short words was generally shorter). Indeed, subjects' viewing time for prime words may have coincided very closely with sense selection.

Table 1

Characteristics of Test Words

| Test Word & Measure | Number Syllables | Word Freq | Response Probability in Context | | |
|---|---|---|---|---|---|
| | | | Associative Prime Only | Sentence Context | |
| | | | | Appropriate | Inappropriate |
| Associates | | | | | |
| Mean | 1.28 | 158.6 | .159 | .025 | .001[a] |
| SD | .56 | 217.1 | .102 | .046 | .002 |
| Inferences | | | | | |
| Mean | 1.71 | 89.6 | .001[a] | .242 | 0 |
| SD | .73 | 280.1 | .002 | .165 | 0 |

Note. All means were based on 56 observations. Word length for associates and inferences differed as did word frequency (from Kučera & Francis 1967 norms) once the effect of skewness was removed. Median word frequency for associates was 89.5 and for inferences was 30.5. Response probabilities for associations to prime words were taken from Cramer's (1970) norms. Response probabilities for inferences to story contexts were based on normative pilot data of the present study.

[a] Actual probability was less than .001.

Table 2

Sample of Paragraphs, Target Items, and Comprehension Items Taken from List A

| Paragraphs | Non-Word | Possible Target Items: Associate Approp | Associate Inapp | Inference Approp | Inference Inapp |
|---|---|---|---|---|---|
| The stewardess was really looking forward to going on a vacation in the spring *** That's when the skiing is best. | <u>duve</u> | | | | |
| The old man sat with his head down and did not hear a word of the sermon during mass *** Nevertheless, he felt better after the service. | | church | <u>weight</u> | sleep | test |
| The millionaire jumped from the window when he heard about the new rate of interest *** His entire fortune was at stake. | | money | hobby | <u>suicide</u> | affair |
| The jogger had been running at a quick pace but did not feel winded. Then all of a sudden, he felt a muscle tighten in his calf *** | <u>flud</u> | | | | |

Table 2 (cont.)

| | | | | | |
|---|---|---|---|---|---|
| The townspeople were amazed to find that all the buildings had collapsed except the mint *** Obviously, it had been built to withstand natural disasters. | | money | candy | earthquake | breath |
| The audience stood and continued to clap loudly after the last refrain *** The performance was easily the best of the concert season. | | song | stop | encore | gamble |
| The two brothers decided to go fishing for bass on the lake. Unfortunately, all they caught was perch *** | sware | | | | |

| Comprehension Items | Correct Response |
|---|---|
| The townspeople had been running at a quick pace. | N |
| The millionaire heard that all the buildings had collapsed except the mint. | N |

Note. Underlined items were targets for one subgroup of subjects. Other subjects saw different combinations of target items. For critical paragraphs of List A (in which targets were words), there were companion paragraphs shown in List B, each including a test word different in kind and

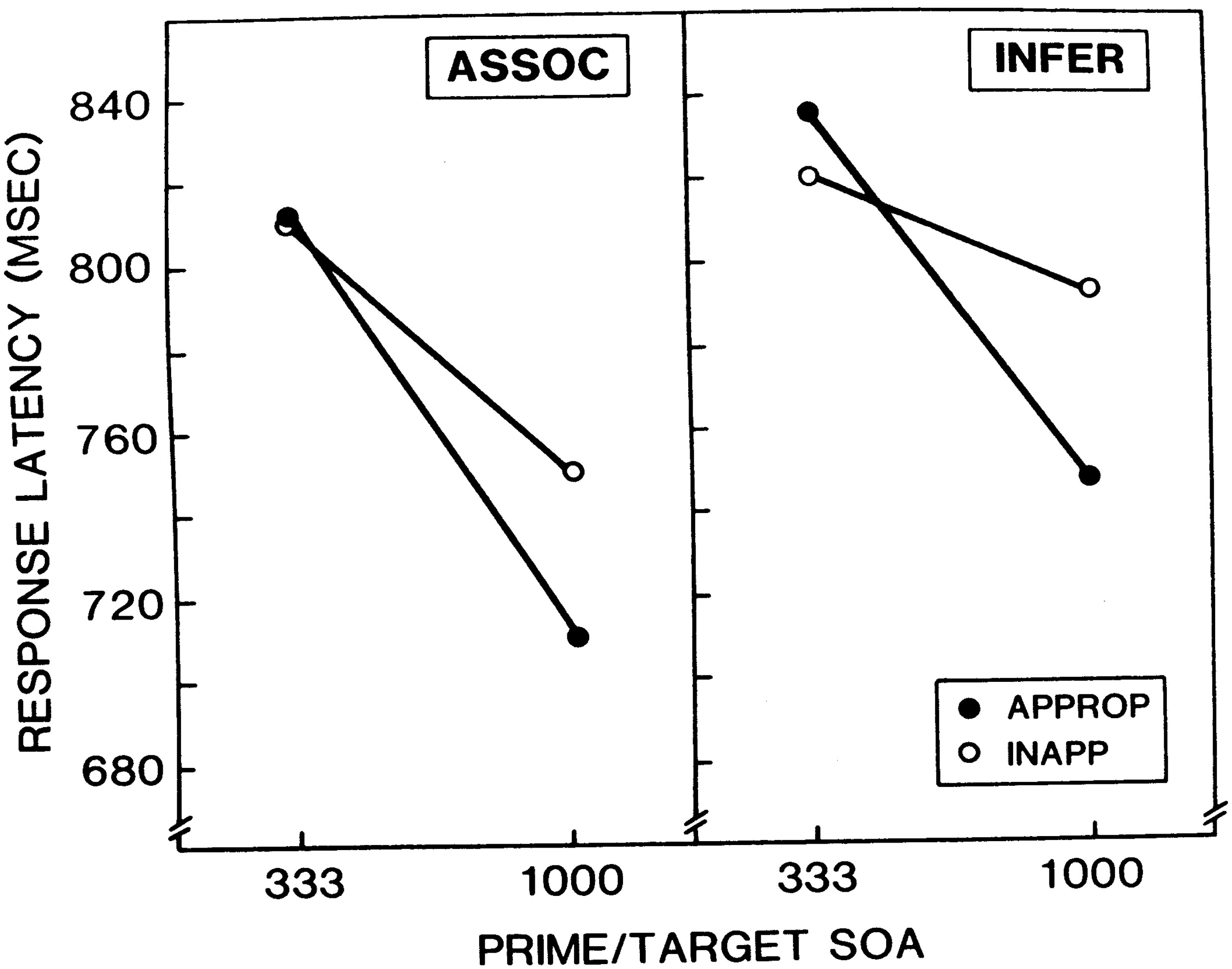
Table 2 (cont.)

appropriateness. For example, List B would contain "Thinking of the amount of garlic in his dinner, the guest asked for a mint *** He soon felt more comfortable socializing with the others" with the lexical decision item being "money." Asterisks indicate point of lexical decision task. Approp = Appropriate, Inapp = Inappropriate.

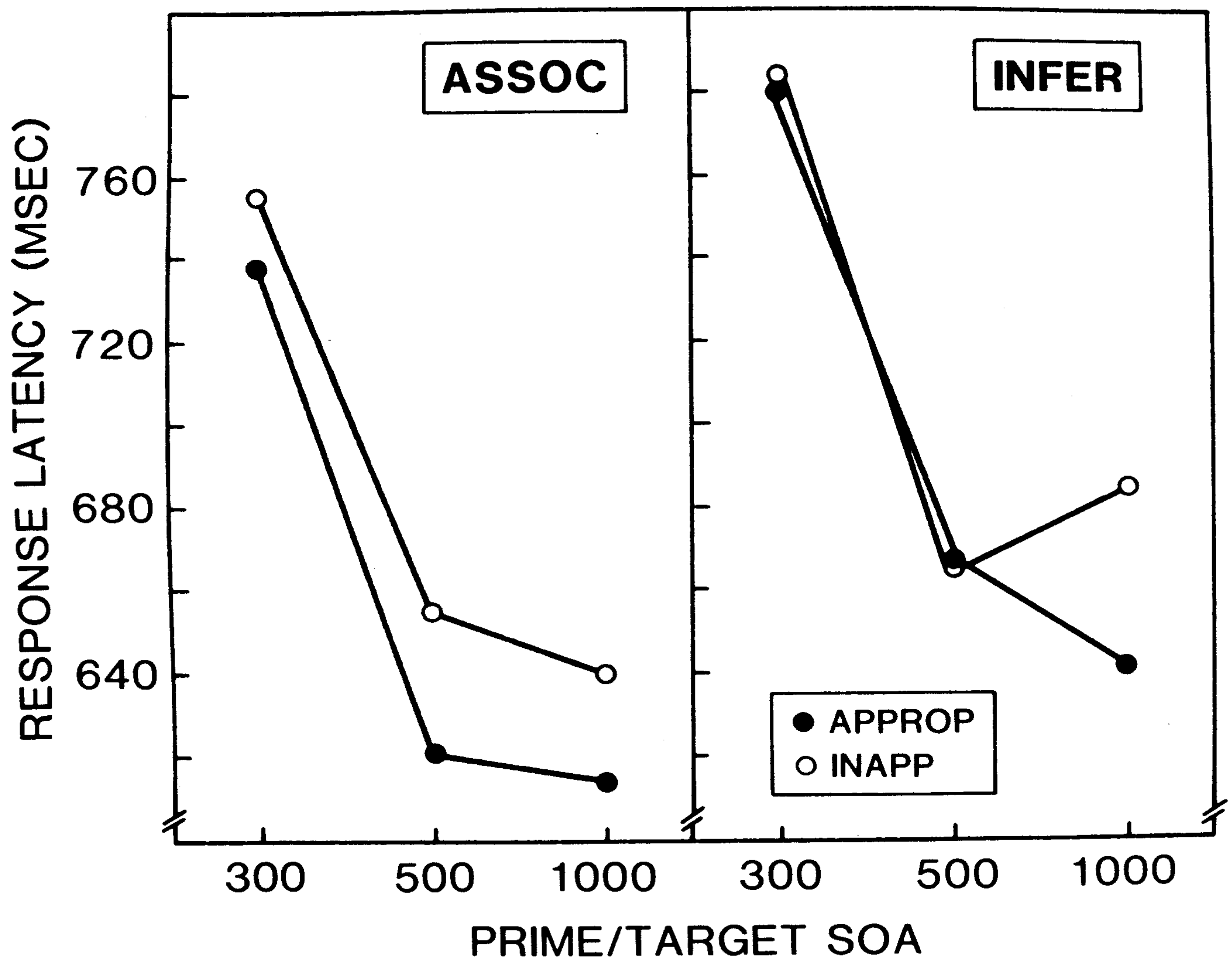
## Figure Captions

*Figure 1*. Response latency in milliseconds on positive lexical decision trials for associate (Assoc) and inference (Infer) test words in Experiment 1. Data are shown for prime-to-target onset asynchrony (SOA) of 333 msec and 1000 msec and as appropriate (Approp) or inappropriate (Inapp) to the discourse context.

*Figure 2*. Response latency in milliseconds on positive lexical decision trials for associate (Assoc) and inference (Infer) test words in Experiment 2. Data are shown for prime-to-target onset asynchrony (SOA) of 300, 500, and 1000 msec, and as appropriate (Approp) or inappropriate (Inapp) to the discourse context.



ASSOC
INFER
840
800
760
720
680
RESPONSE LATENCY (MSEC)
333
1000
333
1000
PRIME/TARGET SOA
APPROP
INAPP


ASSOC
INFER
RESPONSE LATENCY (MSEC)
760
720
680
640
300
500
1000
300
500
1000
PRIME/TARGET SOA
APPROP
INAPP