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Fast priming in reading :: a new eye movement paradigm.

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FAST PRIMING IN READING:
A NEW EYE MOVEMENT PARADIGM

A Thesis Presented

by

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TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

During reading, proficient readers easily extract the meanings of individual words. Successful reading, of course, requires more than simple word recognition. In order for comprehension to occur, the reader must integrate the meanings of words into a developing text representation which may, in turn, affect the recognition of individual words. Over the past twenty years, numerous studies have investigated the components of visual word recognition from perceptual analysis to semantic interpretation. In order to isolate and identify factors affecting word recognition, psychologists have utilized a variety of presentation conditions such as rapid serial visual presentation, the cross-modal priming task, and single word presentation (with or without the use of primes, masks, or prior contexts). To complicate matters, a number of response time measures have been used, for example, lexical decision, naming, categorization, self-paced reading, and eye fixation duration. While much has been learned, a fine-grained analysis of *when* and *how* words are recognized remains elusive. The time course of lexical processing and the degree to which it is form- or content-driven are issues of concern for theories of word recognition and also for theories of language comprehension in general.

In this chapter, I will first give a brief overview of research that has dealt with lexical access and word recognition. Then I will discuss the priming paradigm in which the effects of context on word recognition are examined. My eventual goal is to investigate how lexically ambiguous words are processed with particular attention to the theoretical debate concerning modular versus interactive approaches to language processing. In this regard, evidence from the cross-modal priming technique as well as the limitations of the task are then described. Finally, I will turn to the central topic of this thesis, which is the development of a new paradigm for investigating the quick, automatic processing of words. The primary goal is to determine if fast semantic priming can be obtained during an eye fixation in reading. The successful demonstration of such an effect would validate the usefulness of "fast priming" as a technique to study automatic word processing and would enable the future application of the technique to the study of lexical ambiguity.

Lexical Access and Word Recognition

Recent developments in research on word recognition suggest that a paradigm shift may be in the making. With the emergence and proliferation of connectionist or parallel distributed processing models (e.g., Kawamoto, 1989; Seidenberg & McClelland, 1989), certain common assumptions held by traditional theories of lexical knowledge (in particular, the mediation of discrete lexical units) have been re-examined and challenged. In perspective, though, what has been termed the "standard model" of lexical access (Neuman, 1990) has resulted in substantial progress including the introduction of new experimental designs and an enriched understanding of lexical processing.

The standard model presumes the existence of internal units representing spoken or written words (e.g., logogens, nodes, lexical entries) that are located in one or several interconnected lexicons. Lexical structure, itself, is viewed as a memory network of nodes bound together by associative and semantic links wherein activation of one node spreads automatically to closely related nodes. The goal of the standard approach has been to explicate the structure and operation of the lexicon.

The use of reaction time tasks represents an important step in this direction. Hypotheses about the organization of the lexicon can be formulated, for example, if lexical decisions are influenced by word frequency (or if they are not). The priming technique, in conjunction with a reaction time task, has also proved to be effective. Differential priming effects on selected target words provide valuable information about the lexical relationship between prime and target. Recently, however, in the lexical decision task, the informativeness of response latency has been seriously challenged as an indicator of lexical access (e.g., Balota &

Chumbley, 1984). Different reaction time tasks introduce variables and biases that are not related in a simple manner to the time it takes to recognize a word. Similarly, priming effects are susceptible to later influences operating on decision processes as well as processes immediately involved in word recognition.

Given these doubts, it seems worthwhile to explore new methods for studying word recognition. Although eye movement recording has been associated with many other issues in reading, it also claims modest success in illuminating the time course of lexical access. The reasons are twofold: 1) reading is a natural, on-line task relatively free of response bias; 2) there is considerable evidence that fixation time on a word reflects lexical access time when contextual variables are controlled. Eye movements, as well as other techniques, have been used to study the effect of the context in which a word is seen. An important case is semantic priming, which will be discussed before the specific purposes of the thesis are introduced.

Priming

Semantic priming reflects the effects of context on word recognition using various experimental methods (for a recent review, see Neely, in press). One word, the **prime**, is presented and followed by another word, the **target**, with the subject's response time to the target as the dependent measure. Priming is functionally defined in terms of the speed of target recognition. Meyer and Schvanevelt (1971) demonstrated in a lexical decision task that a given word (e.g., *nurse*) could prime a semantically related or associated word (*doctor*) as compared to an unrelated word (*butter*). These results supported the notion of a mental lexicon that is semantically organized with related items stored close together.

Usually, the prime for a given target is a single word, but a sentence or discourse can also prime a word. Schuberth and Eimas (1977) used a sentence fragment prime followed by a string of letters for lexical decision (see also Fischler & Bloom, 1979). When the letter string constituted a word, subjects responded more quickly if the word followed a predictive context. In similar experiments, subjects were asked to name the target word (Stanovich & West, 1979, 1983). Response time was faster when the target word was related to the preceding context. Finally, experiments that have studied fixation durations during normal reading have shown that fixations are significantly shorter on words that are predictable from the preceding context (Balota, Pollatsek, & Rayner, 1985; Ehrlich & Rayner, 1981; Zola, 1984).

Priming is commonly explained by the mechanism of **spreading activation**, whereby activation from one node in a memory network spreads to neighboring nodes, lowering their recognition thresholds (Collins & Loftus, 1975; Collins & Quillian, 1969). Posner and Snyder (1975) accounted for spreading activation in terms of **automatic** processing, which they distinguished from **strategic** processing. Automatic processing is fast-acting, occurs without intention or awareness, and does not consume processing resources. Automatic processing, in effect, confers benefits without cost. In the example above, target recognition (*doctor*) is facilitated by the related prime (*nurse*) but is not inhibited by the unrelated prime (*butter*), when compared to a neutral prime condition. Strategic processing, on the other hand, is slower acting, intentional, is subject to conscious awareness, and requires attention. Expectancies are actively generated under strategic control and the violation of these expectancies results in inhibitory effects. Thus, unlike automatic processing, strategic processing involves costs. In the example above, if a prime is expected to be related to the target (*doctor*), then considerable cost is incurred with an unrelated prime (*butter*).

In priming paradigms, **stimulus onset asynchrony (SOA)**, the time from onset of the prime to onset of the target, is a critical variable. As SOA increases, so does the probability that strategic rather than automatic priming effects are being measured. SOAs on the order of 250 ms or less are often assumed to yield automatic priming effects, although the specific response measure used, the type of prime-target association, as well as the "neutrality" of the neutral prime condition may influence the extent to which this relationship is valid (Neely, 1977, in press). SOAs of 500 ms or longer, on the other hand, are generally assumed to yield strategic priming effects. Thus, the time available for processing prime and target plays a crucial role in determining the nature of priming effects.

Modularity and Interaction in Word Recognition

Within the domain of language comprehension, a long-running debate over the nature of the lexical processor has persisted. The **modular** position (e.g., Forster, 1979; Fodor, 1983) maintains that the operation of lexical access is autonomous with respect to concurrent non-lexical information. That is, the processing within the lexical module can not be influenced by non-lexical knowledge available to another processing subsystem or module. Thus, for example, a biasing sentential context will not prevent the lexical computation of *both* meanings of a subsequent ambiguous word because the lexical module is impervious to the output of the "message" processor. However, the presence of a prior word related to one sense of an ambiguous word could facilitate access of that meaning through the mechanism of spreading activation. Nevertheless, such a "contextual" effect would not be regarded as evidence against the modular view because the effect originates within the lexicon itself (Forster, 1979; Seidenberg, Tanenhaus, Leiman, & Bienkowski, 1982).

The **interactive** position places few restrictions on the interplay of various processing subsystems during sentence processing. Discourse information, in particular, is hypothesized to play an important role in lexical access. In the processing of an ambiguous word, contextual information is utilized to guide access of the appropriate meaning. It should be noted that this is not an absolute position. It is not denied that, at an early stage, access of both meanings is initiated. Nevertheless, the appropriate meaning is selected *before* the word is fully processed (McClelland, 1986).

Cross-modal Priming

From the previous discussion, it is clear that the *locus* of contextual priming effects is crucial particularly in regard to lexical ambiguity research. Where does it occur--intra-lexically or extra-lexically? When does it occur--pre-lexically or post-lexically? The **cross-modal priming paradigm** (Seidenberg, et al., 1982; Swinney, 1979; Tanenhaus, Leiman, & Seidenberg, 1979) illustrates the logic that has been employed in studying these questions. In the cross-modal priming task, subjects listen to a sentence and then respond to a visual target word by either making a lexical decision or naming the target. The target word is either related or unrelated to an auditory prime word. The **interstimulus interval (ISI)**, the time between offset of the prime and onset of the target, is a second important variable. In now classic experiments on lexical ambiguity (Swinney, 1979; Tanenhaus, et al., 1979), facilitation for target words related to both meanings of an ambiguous prime word was obtained with a zero ISI, while facilitation for the contextually appropriate meaning alone was obtained with longer ISIs (200 ms or more). These findings were interpreted as supportive of a modular, context-independent, multiple access account. Activation of *only* the contextually appropriate sense, however, does occur with a zero ISI under certain circumstances-- for example, when a word semantically related to the prime appears in the *immediately preceding* context (Seidenberg, et al., 1982; but see also Simpson, 1981; Tabossi, 1988). In this situation, the contextually appropriate sense of the ambiguous prime is presumed to have been activated *intra-lexically* by means of the spreading activation mechanism.

Although cross-modal priming has contributed valuable information about the time course of processing, there are some associated problems. In the cross-modal task, the SOA is not strictly controlled. With a zero ISI, for example, the visual target is presented immediately upon offset of the auditory prime. The associated SOA, therefore, depends on the duration of the auditory prime, which is typically 250 ms or more for a one-syllable word. Also, it has been suggested that the key result (priming of the target by the contextually inappropriate meaning of the ambiguous word) may be an artifact of **backward priming** (Glucksberg, Kreuz, & Rho, 1986; Van Petten & Kutas, 1987; but see Burgess, Seidenberg, & Tanenhaus, 1989; Peterson & Simpson, 1989). Backward priming could occur if the target word that is related to the contextually inappropriate sense of the ambiguous prime word backwardly primed that sense of the ambiguous word prime (held in auditory short-term memory), which in turn facilitated a response to the target word. Backward priming is compatible with an interactive, selective access account whereby context guides selection of the appropriate sense of an ambiguous word. Under this view, then, the finding that the contextually inappropriate sense of an ambiguous word does prime a target (at a zero ISI) could be interpreted as a *post-lexical* effect following upon the target-induced access of the inappropriate meaning by backward priming.

Given the limitations of the cross-modal priming task, an experimental priming procedure was developed to pinpoint the locus of priming effects while still providing an on-line measure of processing. The procedure involved eye movement recording with the presentation of a very brief prime word at the onset of an eye fixation. Because the durations of eye fixations are much shorter than the reaction times involved in lexical decision and naming, this experimental design will not be as susceptible to backward priming effects. It also allows finer control over the time course of lexical processing compared to the cross-modal procedure.

Fixation Times "Reflect" Lexical Processing

The effects of sentence context on word processing can be studied by recording eye movements during reading. Word fixation time is examined as a function of the prior sentence context (Balota et al., 1985; Inhoff, 1984; Schustack, Ehrlich, & Rayner, 1987; Zola, 1984). Eye movement data provide certain advantages in studying priming effects. First, eye movements are a normal part of reading unlike the more artificial tasks of lexical decision and naming. Second, subjects are not required to make decisions about isolated words. Third, eye movement recording does not involve presenting a target word that disrupts the normal course of reading. Finally, when compared to the cross-modal task, a unimodal (visual) presentation permits more experimental control over the temporal processing of a prime and target.

It is well-documented that fixation times reflect lexical and cognitive processes associated with understanding text (see Rayner, Sereno, Morris, Schmauder, & Clifton, 1989 for a recent review). In a series of experiments by Rayner and Duffy (1986), fixation time on a word was found to be strongly influenced by word frequency. Other studies have shown that fixation time decreases when a target word is predictable or semantically related to a preceding word. Parafoveal information (i.e., information about word *n* while fixating word *n-1*) also influences the fixation following an eye movement (Balota et al., 1985; Inhoff & Rayner, 1986; Rayner, 1975). Information about initial letter sequences, for example, can reduce subsequent lexical processing of the parafoveal word. Parafoveal preview effects, however, have not provided substantial evidence that lexical or semantic processing of parafoveal words is achieved during the preview interval.

While fixation times reflect processing ease or difficulty, fixation duration cannot be taken as a pure measure of the processing time associated with a word. Spillover effects increase fixation time on word *n+1* when the processing of word *n* is difficult (Rayner & Duffy, 1986; Rayner et al., 1989). Parafoveal preview effects indicate that word processing is initiated on the prior fixation. The present study attempts to control both of these factors.

Constraints of Eye Movements

As indicated above, a number of recent studies have demonstrated priming effects during reading using eye movement data. Readers, for example, tend to fixate approximately 30 to 90 ms longer on words that are not contextually predictable, and these words are skipped less frequently than predictable words during normal reading. Whether lexical access or post-lexical integration is implicated, however, has rarely been directly addressed (but see Schustack et al., 1987). Moreover, these data do not usually involve automatic, semantic priming because of long delays between contextual primes and their targets (but see Zola, 1984).

It is possible to investigate word recognition with fast, automatic priming during an eye fixation, but several factors constrain the presentation conditions of the foveal prime.

The first constraint is that prime duration must be brief. The deadline for programming a saccade to another location in the text is 100 to 150 ms before the end of the fixation (Rayner, Slowiaczek, Clifton, & Bertera, 1983). With an average fixation of about 250 ms, the decision to move the eyes may occur after only 100 or 150 ms of fixation. If the prime is presented for 100 ms before the onset of the target, the fixation duration on the target obviously would not be a reliable measure of processing difficulty because the decision to move the eyes may already have been made. A brief prime duration also should attenuate possible disruption effects due to a display change. The second constraint involves the parafoveal preview of the target region. The parafoveal field must be controlled so that preview information is uniform. Otherwise, fixation time on the target, itself, may be confounded as a measure of processing. A third constraint has to do with spillover effects resulting from textual integration. Spillover can be controlled by holding the prior context constant in all cases. The final constraint is that the prime (and hence the target) word be relatively short. Short words (four or five letters) are normally processed in a single fixtaion, whereas longer words often require two or more fixations. In general, these experimental constraints insure that fast, automatic priming effects are being measured.

"Fast Priming" Experiments

Fast priming during eye fixations has not previously been studied, although related work has examined the time course of priming for words in isolation. The standard (isolated words) priming paradigm has been used to demonstrate priming effects with short SOAs and a zero ISI. Warren (1977) presented a prime word for 75 ms above a fixation point. At the offset of the prime, a target word appeared below the fixation point and a mask simultaneously covered the prime. Subjects were instructed to fixate the point, ignore the prime, and name the target. There was a significant 14 ms advantage for "synonym" primes versus an unrelated control condition. Fischler and Goodman (1978) reported a lexical decision experiment in which they displayed a prime word for 40 ms which was immediately replaced by a word or nonword target in the same location (masking the prime). Prime words were equally divided between "associated" and "unrelated" types, with associated primes resulting in a 41 ms facilitation.

Two eye movement studies have examined the influence of a brief word presentation during a fixation. Blanchard, McConkie, Zola, and Wolverton (1984) replaced a target word with another word at various intervals during an eye fixation. At the onset of fixation, a target word was presented for either 50, 80, or 120 ms. The entire line of text was then masked (by a pattern mask) for 30 ms and the replacement word was presented for the remainder of the fixation. Although they found that longer viewing times, in general, increased the probability of subsequent recall, briefly presented targets were sometimes identified. In a related set of experiments, Rayner, Inhoff, Morrison, Slowiaczek, and Bertera (1981) masked the text after 10, 30, 50, 100, or 150 ms of a fixation. As with Blanchard et al. (1984), they were not interested in priming effects, but rather in the length of time required for readers to extract the needed information. They found that if the text was available for 50 ms, reading performance was almost as good as when there was no mask. They concluded that readers can obtain most of the information needed for reading in the first 50 ms of the fixation. Both of these studies are relevant to the present study because they suggest that a prime presented for a relatively brief period of time may still have a significant effect in reading.

The present study was designed to determine whether fast, automatic, semantic (foveal) priming during reading could be established. If it is shown that such priming is feasible, a valuable new tool for exploring lexical structure and lexical processing would become available. The near-instantaneous nature of the priming would ensure that purely lexical effects were being measured. Through the *mediation* of the brief prime, it would then become possible, for example, to investigate whether extra-lexical contextual information could directly affect the lexicon, thereby providing a new and strong test of the modularity hypothesis.

CHAPTER II

EXPERIMENT 1

This chapter describes an initial attempt to determine if fast priming effects could be obtained during eye fixations in reading. Thus, in Experiment 1, a prime word was presented at the onset of a subject's fixation on a target location. To insure foveal processing, primes (and hence targets) consisted of relatively short words (four or five letters long). The following series of sentences illustrates the sequence of events that occurred while a subject read an experimental sentence (the asterisks represent fixations and the horizontal dashed lines represent saccades):

```
      *-*-----*-------*---
1a) Tight quarters produce¦d gzsd and discord.

                           ----*
 b) Tight quarters produce¦d love and discord.

                               *
 c) Tight quarters produce¦d hate and discord.

                                --------*
 d) Tight quarters produce¦d hate and discord.
```

In sentence (1a), when the eyes were to the left of the invisible boundary (indicated by ¦), a preview of random letters (*gzsd*) occupied the target position. During the saccade that crossed the boundary, the preview was replaced with the prime (*love*) for a designated time (1b). The prime was either related (*love*, in this example), unrelated (e.g., *rule*), or identical (*hate*) to the target (*hate*). The prime was then replaced with the target word (1c) which remained in place while the subject finished reading the sentence (1d). The duration of the prime was varied to determine the optimal level of priming. Based on indications from prior studies (e.g., Fischler & Goodman, 1978; Rayner et al., 1981), prime durations of 60, 45, and 30 ms were chosen.

Method

Subjects

Eighteen members of the University of Massachusetts community were paid to participate in the experiment. They all had normal uncorrected vision and were naive concerning the purpose of the experiment.

Apparatus

The sentences used in the study were presented on a Hewlett-Packard 1300A cathode ray tube (CRT) which was interfaced with an Epson Equity III+ computer. The sentences were printed in lower case letters (except when capitals were appropriate) and were formed from a 5 X 7 matrix. The CRT was covered by a dark theater gel to enhance the clarity of the letters. Subjects were seated 61 cm from the CRT and three letters equaled one degree of visual angle. All sentences were displayed on a single line with a maximum length of 42 characters. Luminance of the display was adjusted to a comfortable level and held constant throughout the experiment. The CRT has a P-31 phosphor with the characteristic that display blanking results in a drop to 1% of maximum brightness in .25 ms.

Subjects' eye movements were monitored via a Stanford Research Institute Dual Purkinje Eyetracker which was also interfaced to the Equity computer. The eyetracker has a resolution of 10 minutes of arc (half a character) and the signal from the eyetracker was sampled every millisecond by the computer. All display changes that were made in the study (both during saccades and fixations) were accomplished within three to six milliseconds. Although viewing was binocular, eye movements were recorded from the right eye.

Materials

A critical target noun was embedded in each of 108 experimental sentences. Half of the target nouns were four letters long and half were five letters long. The mean log word frequency for the target nouns was 1.40 per million as computed from the Francis and Kucera (1982) norms.

For each target noun (e.g., *hate*), three prime words (equal in length to the target) were identified. One of the primes was semantically related (*love*) and one was unrelated (*rule*). Conditions in which these primes appear will be referred to as the Related (R) and Unrelated (U) conditions. In addition, there was an Identical (I) condition in which the prime and target noun were identical (i.e., *hate* was presented from the onset of fixation). For each target noun, a subject was presented with only one of the three possible primes. If there was letter overlap between a R prime, for example, and its target (*love*, *hate*), then the U prime (*rule*) would have the same letter overlap. Also, R and U primes were matched in frequency.

Related primes were selected intuitively. Some of them appear in published associative norms but some do not because it was not always possible to find a prime-target pair of equal length. Positive findings, however, would be enhanced by such a broad selection.

There were 27 filler sentences. In these sentences, a word other than a noun was identified as the "target" (e.g., an adjective or a verb). The length of these filler targets ranged from three to seven letters. Each filler target had associated R, U, and I primes. The R and U filler primes were matched in frequency and letter overlap.

All experimental sentences together with the R and U primes appear in the Appendix.

<u>Design</u>

Across the 108 experimental sentences, three prime durations of 60, 45, and 30 ms were used. The sentences were blocked by prime duration: a third of the subjects received the 60 ms prime duration first, followed by the 45 and 30 ms durations; another third received the order 45, 60, and 30 ms; and the remaining subjects had the order 30, 60, and 45 ms. The three types of primes (R, U, and I) were presented equally often within each block of 36 experimental sentences. Thus, there were nine conditions formed by crossing prime type (R, U, and I) with prime duration (60, 45, and 30 ms). Nine subjects were needed, then, to complete the design (i.e., each target presented in every prime condition at every prime duration). Each subject was presented with each target item in only one of the three prime conditions at only one of the three prime durations. This produced 12 possible data points per subject per condition.

Procedure

When a subject arrived for the experiment, a bite bar was prepared in order to eliminate head movements. The initial calibration of the eyetracking system generally required five to 10 minutes. Subjects were asked to read sentences on the CRT as their eye movements were recorded. They were told that there would be display changes (i.e., they "might see something flash") while they read, but that they should try to read as normally as possible. They were also told that they would be asked questions about the sentences and were instructed to read for comprehension.

Subjects read six practice sentences in order to become familiar with the procedure. Prior to reading each sentence, subjects looked at a fixation cross which marked the first character position of the sentence. The experimenter checked to insure that the subject was fixated on the cross, gave a ready signal, then pressed a button to present the sentence. After reading the sentence, the subject pressed a button to blank the screen. Then, either the sequence resumed without interruption or the subject was asked a yes-no comprehension question. After the practice sentences, subjects read the 108 experimental sentences randomly interspersed among the 27 filler sentences. Questions were asked on approximately 25% of the trials. Subjects had no difficulty answering the questions correctly.

When the sentence was initially presented on the CRT, a string of random letters occupied the target location. An invisible boundary located between the penultimate and final letter of the word preceding the target noun was identified in each sentence. When an eye movement crossed over this boundary, the computer replaced the random letters with a prime word. This display change was accomplished within three to six milliseconds. Since the change took place during the saccade, it was not seen by the subjects. The prime word remained in the target location for a specified duration (measured from onset of the fixation, *not* from when the eye crossed the boundary) and was then replaced by the target noun. The latter change also took three to six milliseconds, but since it occurred during a fixation rather than a saccade, a change was often, although not always, noticed by the subjects. The target noun remained in the target location until the subject finished reading the sentence.

At the end of the experiment, subjects were asked how frequently they saw a display change (from the prime to the target) and how frequently they thought they could identify the first word (i.e., the prime). Subjects estimated seeing display changes about one-third to tow-thirds of the time. They reported being aware of both words 10 to 20% of the time. Thus, although many were conscious of the change from the prime to the target (during the fixation), they were generally unable to identify the prime word.

Results

The data were analyzed in terms of the **first fixation duration** and **gaze duration** on the target. First fixation duration represents the initial fixation on a word either when it is the only fixation on the word or when it is the first of multiple fixations made on the word. Gaze duration represents the total amount of time that the reader looked at the word prior to an eye movement to another word; it is the sum of the fixations on a word excluding any that result from regressions to the word.

The mean first fixation duration and mean gaze duration on the target at the three levels of prime duration across the three prime conditions are displayed in Tables 1 and 2, respectively. In the R and U conditions, a prime initially occupied the target location (in the I condition, the prime was the target). Hence, a second measure has been constructed by subtracting the prime duration from the fixation time in the R and U conditions and these *modified* fixation times are listed in parentheses in the tables. For example, in

Table 2, gaze duration in the R prime condition is 419 ms at the 45 ms prime duration level and 374 ms (419 ms minus 45 ms) represents fixation time from the onset of the target. Modified R and U means are then comparable across level of prime duration as well as prime type to unmodified I means with respect to time spent on the target.

Data were excluded from the analyses if: 1) there was a track loss (e.g., caused by a blink); 2) the reader initially skipped over the target word; 3) the display change was triggered inappropriately because of drift or a hook overshoot of the eye; or 4) the subject's saccade landed on the final letter of the word preceding the target word. In the last case, the data were not included because it was uncertain whether the subject's attention was directed to the word to the left of the boundary or to the target region.

Because considerable data were excluded from the analyses for the reasons listed above, a criterion was established--a subject had to have at least 60% usable data to be included in the study. In addition to the 18 subjects whose data were analyzed, another three subjects were run in the experiment but were replaced because they did not meet the 60% criterion. Across the 18 subjects whose data were analyzed, 26% of the data were unusable for one of the four reasons listed above. Since there were 12 sentences per condition, this essentially meant that on average there were nine data points per condition.

A 3 (prime duration: 60, 45, or 30 ms) X 3 (prime type: I, R, or U) analysis of variance (ANOVA) was carried out on the first fixation and gaze duration means. As mentioned above, in order to make the means from the I condition comparable to the means in the other two conditions (where a different word initially occupied the target location), the duration of the prime was subtracted from the fixation times in the R and U conditions. Of course, when the prime durations were *not* subtracted, the ANOVAs yielded highly significant main effects and interactions of the variables. Thus, for first fixation duration there were highly significant effects of prime duration, $F(2,34) = 9.13$, $p < .001$, and prime type, $F(2,34) = 38.55$, $p < .001$, as well as an interaction of the two, $F(4,68) = 3.76$, $p < .01$. For gaze duration, the main effects of prime duration, $F(2,34) = 5.49$, $p < .01$, and prime type, $F(2,34) = 35.28$, $p < .001$, were likewise significant as was the interaction, $F(4,68) = 3.28$, $p < .05$. However, when the subtractive procedure was used, the only significant effect was a main effect of prime type, both for first fixation, $F(2,34) = 3.64$, $p < .05$, and for gaze duration, $F(2,34) = 6.29$, $p < .01$.

Three pairwise comparisons (U-R, I-R, I-U) at each level of prime duration (60, 45, 30 ms) were carried out and will be discussed in turn. Again, the subtractive procedure was used. Because the important patterns of results were most apparent in the gaze duration data, those data will be the primary focus of this section. Table 3 shows the gaze duration differences at each level of prime duration for these comparisons.

First, in the U-R comparison at the 30 ms prime duration, there was a significant +28 ms advantage for R versus U primes, $F(1,17) = 6.38$, $p < .05$. However, at the 45 and 60 ms prime durations, the difference between the R and U prime conditions was not significant, $Fs < 1$. For the I-R comparison, there was no difference between the I and R prime conditions at the 30 ms prime duration, $F < 1$. The difference was significant at the 45 ms prime duration (-36 ms), $F(1,17) = 6.82$, $p < .05$, and marginally significant at the 60 ms prime duration (-31 ms), $F(1,17) = 3.37$, $p < .08$. Finally, in the I-U comparison, the difference between I and U prime conditions at the 30 ms prime duration was marginally significant (-33 ms), $F(1,17) = 4.20$, $p < .054$. As in the I-R contrast, the difference was significant at the 45 ms prime duration (-37 ms), $F(1,17) = 14.29$, $p < .01$, and marginally so at the 60 ms prime duration (-39 ms), $F(1,17) = 3.82$, $p < .06$.

To determine if the order in which subjects were presented the different blocks of sentences (with duration blocked across sentences), a 3 (order of presentation: 60-45-30 ms, 45-30-60 ms, or 30-60-45 ms) X 3 (prime duration) X 3 (prime type) ANOVA was carried out with the first variable manipulated between subjects and the other two variables within subjects. There was no main effect of order in either the gaze duration or first fixation duration analysis, Fs < 1. In the gaze duration data, but not in the first fixation duration data, there was a significant order X prime duration interaction, $F(4,30) = 4.69$, $p < .05$. However, this interaction is largely uninteresting since it results from a deviant data point in the 45 ms prime duration condition (see Table 4). A separate 3 (order) X 3 (prime type) ANOVA for the 30 ms duration revealed no significant effect of order, $F < 1$. It seems reasonable to conclude that the specific order of prime duration in which the sentences were blocked did not influence the significant priming effect that was obtained.

Finally, it should be noted that in the I condition the gaze durations did not differ, $F(2,34) = 1.37$, $p > .25$, as a function of prime duration (60, 45, or 30 ms). Prime duration was, in effect, a "dummy" variable in this condition. Thus, as was expected, the gaze durations within the I condition were equal.

Discussion

The purpose of Experiment 1 was to determine whether fast, automatic priming could be obtained under the conditions of an eye movement paradigm. R, U, and I primes were presented for the first 60, 45, or 30 ms of fixation and were then replaced by a target word. Comparisons of gaze duration on the target word across the different prime conditions at the three levels of prime duration were made.

The most notable result was a significant +28 ms difference in gaze duration between the U and R prime types at the 30 ms prime duration (384 versus 356 ms). At both the 45 and 60 ms prime durations, no such advantage for R over U primes was evident (+1 and +8 ms, respectively). I-R and I-U contrasts at the 45 and 60 ms prime durations, as well as the I-U contrast at the 30 ms duration level, were all significant or marginally significant. There was in fact an average difference in these contrasts of -35 ms in the gaze duration means. The presence of a *non*-identical prime during the initial stage of fixation should presumably produce a disruptive effect. Only in the I-R contrast at the 30 ms duration was there a non-significant -5 ms difference between the means (351 ms in the I condition, 356 ms in the R condition). Thus, it seems here that the priming facilitation (+28 ms) may have offset the prevailing disruption effect (-35 ms).

Fixation times on the target in this experiment are inflated when compared to an average fixation time (of about 250 ms) in normal reading. There are two reasons for this. First, in all conditions (I, R, and U), parafoveal preview of the target region was not available to the reader. This was a necessary constraint of the experimental design. Random letters occupied the target location prior to a fixation there. Any preview information from the target location was actually *mis*-informative. Fixation time in the I condition thus represents the time needed for word processing in the absence of a valid parafoveal preview (Blanchard, Pollatsek, & Rayner, 1989). Second, in the R and U conditions, a word other than the target was present at the onset of fixation. Although prime duration was subtracted from gaze duration means (so that gaze duration reflects processing of the *target*, itself, preceded by a prime), fixation times were even more inflated than in the I condition (i.e., the disruption effect). The notable exception, as mentioned earlier, was in the R condition at the 30 ms duration, where the disruption effect was offset by priming facilitation.

The general pattern of results suggests that fast, automatic semantic priming did occur at the 30 ms prime duration. The question remains as to why the fast semantic priming effect occurred specifically at the 30 ms prime duration. This issue will be addressed in the General Discussion. The goal of Experiment 2 was to determine if the 30 ms priming effect was reliable.

CHAPTER III

EXPERIMENT 2

The purpose of Experiment 1 was to see whether automatic semantic priming effects could be obtained during reading under the constraints of an eye movement paradigm. The results showed a 28 ms priming advantage for R versus U primes at a 30 ms prime duration. Experiment 2 attempted to address several questions raised by the results of Experiment 1, namely: 1) Was the priming effect at the 30 ms duration reliable-- that is, could it be replicated?; 2) Was 30 ms the "right" duration or, for example, would there be stronger effects at an even lower prime duration?; and 3) Was the I condition an appropriate baseline?

Experiment 2, then, was designed with these questions in mind. The same experimental sentences with associated R and U primes were used. Prime durations of 39, 30, and 21 ms were chosen. The 30 ms duration served as a replication of the first experiment. The 39 and 21 ms durations were chosen to "bracket" the effect and see if priming effects would be obtained at durations somewhat higher and lower than the 30 ms duration. Finally, a Random Letter String (RLS) prime condition was used instead of an I condition.

The following series of sentences uses a RLS prime and illustrates the sequence of events while a subject read a sentence in this experiment (asterisks represent fixations and lines represent saccades):

------*--------*---
2a) Tight quarters produce¦d *gzsd* and discord.

----*
b) Tight quarters produce¦d *fxre* and discord.

*
c) Tight quarters produce¦d *hate* and discord.

---------*
d) Tight quarters produce¦d *hate* and discord.

In this example, the RLS prime (*fxre*) is presented from the time the boundary (indicated by ¦) is crossed (2b) until it is replaced by the target (*hate*) in (2c). The duration of the prime is measured from onset of the target region fixation. A RLS prime that is *different* from the parafoveal preview of random letters (*gzsd*) preserves the occurence of a display change while the eyes are in fixation (the event that accompanies presentation of a R or U prime). Within the RLS condition, a comparison of fixation times on the target across levels of prime duration should indicate the disruptive effects produced by a non-identical, non-lexical prime and serve as a baseline in this respect.

Method

Subjects

Fifteen members of the University of Massachusetts community were paid to participate in the experiment. They all had normal uncorrected vision and were naive concerning the purpose of the experiment. None of the subjects who participated in this experiment had been in Experiment 1.

Apparatus

The apparatus was the same as in Experiment 1.

Materials

The same six practice, 108 experimental, and 27 filler sentences used in Experiment 1 were used in this experiment. Once again, for each critical target noun (e.g., *hate*) in each experimental sentence, three prime words were identified. The same R (e.g., *love*) and U (*rule*) primes from Experiment 1 were used. There was no I (identical) condition (in which the prime was the target noun). Instead, there was a RLS prime condition (*frxe*). In Experiment 1, any letter overlap between a R prime and its target was controlled for in the U prime (i.e., it shared the same overlap). In this experiment, the RLS prime as well was controlled so that it had the same (if any) letter overlap as the R (and hence U) prime did with the target. Like R and U primes, RLS primes were the same length as their targets. Again, for each target noun, a subject was presented with only one of the three possible primes.

Design

The design was almost identical to that of Experiment 1 except that prime durations of 39, 30, and 21 ms were used. The sentences were blocked by prime duration, but since there was no main effect of order in Experiment 1, subject assignment was random.

Across the 108 experimental sentences, the three types of primes were presented at the beginning of a fixation equally often. The prime duration varied between 39, 30, and 21 ms. There were thus nine experimental conditions in the experiment formed by crossing the three relatedness conditions with the three prime durations. Once more, there were 12 possible data points per subject per condition.

Procedure

The procedure was identical to that in Experiment 1. At the end of the experiment, the subjects were asked how frequently they saw a display change and how frequently they thought they could identify both words (the prime word and the target word). Subjects estimated seeing display changes from about 10 to 50% of the time. They reported being aware of both words from zero to about 10% of the time.

Results

As in Experiment 1, when non-identical primes initially occupied the target location, prime durations were subtracted from fixation time. Thus, fixation time is measured from the onset of the target. In this experiment, *all* primes (RLS, R, and U) were non-identical to targets. Modified first fixation duration and gaze duration means on the target at the three levels of prime duration across the three prime conditions are presented in Tables 5 and 6, respectively. Means are then comparable across level of prime duration (as well as prime type).

Data were excluded from the analyses for the same four reasons listed in Experiment 1-- that is, basically, if the subject was not directly fixating the target region during presentation of the prime. An additional nine subjects were run in the study, but their data were excluded because they failed to satisfy the 60% data criterion established in the first experiment. Across the 15 subjects whose data were analyzed, 32% of the data were unusable for one of the four reasons. Since there were 12 sentences per condition, this essentially meant that on average there were eight data points per subject per condition.

As in the first experiment, 3 (prime duration: 39, 30, or 21 ms) X 3 (prime type: RLS, R, or U) ANOVAs were carried out on the first fixation and gaze duration means, both with and without subtracting the duration of the prime from fixation time. When prime durations were *not* subtracted, the ANOVAs yielded a significant main effect of prime duration for both first fixation duration, $F(2,28) = 6.38$, $p < .01$, and for gaze duration, $F(2,28) = 3.61$, $p < .05$. There was no main effect of prime type in either measure, $Fs < 1$. The interaction was not significant for first fixation, $F(4,56) = 1.59$, $p > .15$, but was marginally significant for gaze duration, $F(4,56) = 2.05$, $p < .1$. When the subtractive procedure was used, ANOVAs yielded only marginally significant effects: an effect of prime duration for first fixation,

$F(2,28) = 2.46$, $p < .1$; an interaction for gaze duration, $F(2,28) = 2.05$, $p < .1$.

Three pairwise comparisons (U-R, RLS-R, RLS-U) at each level of prime duration (39, 30, 21 ms) were made and will be discussed in turn. Because a non-identical prime was present in all conditions, it was not necessary to subtract prime durations in these comparisons. Differences between the gaze duration means in each comparison at every level of prime duration are shown in Table 7.

First, in the U-R comparison, at the 30 ms prime duration, there was a significant +31 ms advantage in gaze duration for R versus U prime type, $F(1,14) = 6.45$, $p <.05$. However, the difference between the U and R prime conditions was not significant at either the 39 ms prime duration, $F(1,14) = 1.49$, $p > .2$, or the 21 ms prime duration, $F(1,14) = 1.64$, $p > .2$. For the RLS-R comparison, there was no difference at any level of prime duration, $Fs < 1$. Finally, in the RLS-U comparison, the difference was not significant at any level of prime duration: at 39 ms, $F(1,14) = 2.68$, $p > .1$; at 30 ms, $F(1,14) = 1.54$, $p > .2$; and at 21 ms, $F < 1$.

In the RLS condition it was expected that, as prime duration was increased (from 21 to 39 ms), the disruption produced by a RLS prime would also increase (when the subtractive procedure was used). Although gaze duration increased by 26 ms from the 21 to the 30 ms level and by

19 ms from the 30 to the 39 ms level, these differences were not significant.

Discussion

The main goal of Experiment 2 to was to test the reliability of the priming results obtained in Experiment 1. The same experimental sentences and R and U primes were used. A RLS prime condition replaced the I condition of the first experiment. The primes were presented for 39, 30, or 21 ms measured from the onset of the target region fixation.

The results from Experiment 2, then, should clarify several points. If the U-R priming effect in Experiment 1 is replicable, then significant differences should again be found at the 30 ms duration in this experiment. The 39 and 21 ms durations were chosen to bracket the effect. Results at these durations should give clues about the size of the window of priming. Finally, the RLS prime condition should serve as a baseline to gauge possible disruptive effects. Fixation times are expected to increase (after prime duration is subtracted) as the prime duration is increased.

The results at the critical 30 ms prime duration confirmed the priming effect of Experiment 1. There was a significant +31 ms advantage in gaze duration for R versus U primes. No such advantage was found at either the 39 or 21 ms prime duration conditions. Finally, although fixation time did increase in the RLS condition as prime duration increased (from 21 to 30 ms and from 30 to 39 ms), the increases were not significant.

The question remains why there was priming *only* at the 30 ms duration. When the prime duration was either raised or lowered by as little as nine milliseconds, the priming effects disappeared. At the lowest prime duration (21 ms), fixation times in all prime conditions were the fastest (but not significantly so). A 21 ms masked prime may simply be too brief to have any effect. At higher prime durations (39 ms in this experiment; 45 and 60 ms in Experiment 1), there was similarly no effect of priming. The finding that priming seems to be limited to a such a narrow range is quite intriguing. The present experiment was not designed to determine why the priming effect occurs within such a narrow window. However, some possible speculations concerning the mechanisms underlying the effect will be addressed in the General Discussion.

CHAPTER IV

GENERAL DISCUSSION

The preceding experiments indicate that fast priming during an eye fixation in reading can produce positive, reliable results when the prime duration (and SOA) is 30 ms. In the following discussion, it should be noted that the prime duration and SOA are always identical because the ISI between the prime and target is zero. Decreasing the prime duration by as little as nine milliseconds (Experiment 2) eliminated the priming effect. At the lowest prime level of 21 ms, no significant differences were found between the RLS prime and word primes (R or U). It seems safe to think that a 21 ms masked prime in this experimental procedure is too brief to provide adequate sensory information. What is surprising is the significant priming effect at the still low 30 ms prime level and its abrupt disappearance at 39 ms.

A recent study of near-threshold masked priming (Dagenbach, Carr, & Wilhelmsen, 1989) provides an instructive account of the priming function in the threshold region. Using various threshold-setting procedures and a lexical decision task, Dagenbach et al. found that priming decreased to nonsignificance as the threshold SOA was approached from above. However, as the SOA was decreased further, significant priming effects reappeared. They speculated that there exists a narrow window of SOAs in the threshold region within which priming effects can be obtained.

The results of the experiments in the present study are compatible with such an account. While there was no strict control of subjects' awareness of primes, it was evident that the primes were generally below a *subjective* threshold. Across both experiments, subjects estimated on average that they were conscious of a "flash" in the target area on less than half of the trials. Only very occasionally did they think the flash preceding the target consisted of another word and virtually no primes were accurately recalled. Subjects participating in Experiment 2, in which prime durations were shorter, generally reported little or no distraction in reading sentences.

"Forward" and "Backward" Effects

Masked priming experiments that include short SOAs between prime and target are difficult to interpret because several covarying *forward* and *backward* effects operate simultaneously. Forward effects are those resulting from the prime which influence the perception of the target. Priming and disruption (e.g., forward masking) are two such effects which have been previously described. The source of backward effects is the target, itself, which masks the prime. The effectiveness or strength of backward masking depends upon the timing of prime and target presentation as well as the nature of the mask (the target).

Some patterns observed in the present experiments can be attributed to forward effects. Consider target fixation times in Experiment 2 (Table 6). As the prime duration increases from 21 to 30 ms, gaze duration on the target increases by 26 ms (n.s.) in the RLS condition and by 47 ms in the U condition. These results can be explained as a forward, disruption effect. In the U condition, a deeper level of processing is triggered by a *word* prime (compared to the RLS condition) which consequently extends fixation time on the target. A word prime is also present in the R condition. But here, a forward, facilitating priming effect offsets the co-occurring disruptive effect resulting in only a 1 ms increase from the 21 to 30 ms levels. The results of Experiment 1 (Table 2) also support this reasoning. At the 30 ms level, there is no disruption in the I condition because the prime and target are the same. There is evidence of disruption, however, in the U condition. Compared to the I condition, gaze duration in the U condition is elevated 33 ms. If, as has been postulated, the R condition incorporates offsetting priming and disruption effects, then gaze durations should be approximately equal in the I and R conditions, and such is the case (351 ms in the I condition, 356 ms in the R condition).

Other patterns in the data may require consideration of backward effects. A comparison of results at the 30 ms prime level with the next higher level (45 ms in Experiment 1;

39 ms in Experiment 2), suggests that the priming benefit has disappeared at the higher prime level. At the 30 ms level, the U-R difference is significant (+28 ms in Experiment 1; +31 ms in Experiment 2). At the higher levels, the U-R difference is not significant (+1 ms in Experiment 1; -13 ms in Experiment 2). A 2 (prime type: R or U) X 2 (prime duration: 30 ms or 45 and 39 ms) ANOVA which pooled the data from the two experiments yielded a significant interaction between relatedness and SOA, $F(1,32) = 6.6$, $p < .05$. Gaze durations on R targets were *longer* at the higher prime duration than at the lower prime duration (+18 ms in Experiment 1; +22 ms in Experiment 2) but gaze durations on U targets were *shorter* (-9 ms in Experiment 1; -22 ms in Experiment 2). The difference was significant for R primes but not for U primes.

These differences may be attributable to backward effects. Backward masking is dependent upon the relationship between the mask (the target) and the prime. Masks (targets) that are similar to their primes, for example, visually (Jacobson, 1974) or phonetically (Perfetti, Bell, & Delaney, 1988), are less effective. It is suggested here that masks (targets) which are *semantically* similar to their primes may, as well, prove to be less effective. Thus, in the present experiments, R primes may be more "visible" than U primes. As prime duration is increased, then, disruption effects from R primes should show a greater rate of increase than from U primes. This is supported by the significant interaction. However, U primes do not produce an increase in disruption effects as prime duration is increased. It could be, though, that even at the higher prime duration, U primes are still below a "visible" threshold.

Another explanation for why fixation time in the R prime condition is elevated at the higher prime duration compared to the 30 ms duration, may simply be due to less effective priming at the higher level. In terms of the results of the Dagenbach et al. (1989) experiments, a 30 ms prime duration represents a sub-threshold duration in which priming effects are obtained. As the SOA (prime duration) increases to threshold levels (the higher prime durations), priming disappears. By this account, priming should reappear at even higher SOAs. At the 60 ms prime duration, however, no priming effects were observed, which could provide evidence against this account if the 60 ms presentation were clearly supra-threshold.

<u>Lexical Ambiguity Resolution</u>

Regardless of the theoretical resolution to the overall pattern of results, there *was* significant priming at the 30 ms level (+28 ms in Experiment 1) and this effect was replicated (+31 ms in Experiment 2). A goal of this thesis was to determine if the technique of fast priming during eye fixations in reading was a viable one. As mentioned in the Introduction, the eventual goal was to apply this technique to the study of lexical ambiguity resolution. The results reported here seem to warrant such an application.

In investigating lexical ambiguity, an eye movement priming paradigm offers several advantages as an alternative to the cross-modal task. Fixation time in these experiments (about 375 ms on average) is shorter than the response time obtained in the cross-modal task (about 500 to 900 ms). The possible confounding effects of backward priming and post-lexical integration, consequently, are greatly reduced. In addition, the response time measure of fixation duration, compared to naming or lexical decision used in the cross-modal task, is not as susceptible to response bias or task demands.

An eye movement paradigm can be used to investigate lexical ambiguity in much the same manner as the cross-modal paradigm. An ambiguous word can be presented as a prime to a target in a sentence. The results of Experiments 1 and 2 show that reliable priming effects are obtained at a 30 ms prime duration. Thus, fixation time on the target should reveal effects of priming from either one or both senses of an ambiguous word prime presented at this duration. In such an experiment, a context is first established which biases the interpretation of the ambiguous prime toward one its senses. If *only* the contextually appropriate sense of the ambiguous prime is activated (measured by its effect on the target), a selective access account would be supported. On the other hand, if *both* the appropriate and inappropriate senses of the ambiguous prime are activated (again measured by their effect on the target), then a multiple or exhaustive access account would be upheld. Because of the speed, naturalness, and automaticity of eye movement responses, a test of these two accounts using this paradigm could provide important converging evidence.

Table 1

Mean First Fixation Duration (ms)
on the Target Word in Experiment 1

Prime Duration (ms)	Prime Type I	R	U
60	309	383 (323)	387 (327)
45	300	365 (320)	374 (329)
30	305	341 (311)	354 (324)

Note: Means in parentheses represent first fixation duration minus the duration of the prime.

Table 2

Mean Gaze Duration (ms)
on the Target Word in Experiment 1

Prime Duration (ms)	Prime Type I	R	U
60	345	436 (376)	444 (384)
45	338	419 (374)	420 (375)
30	351	386 (356)	414 (384)

Note: Means in parentheses represent gaze duration minus the duration of the prime.

Table 3

Differences in Gaze Duration
Means (ms) in Experiment 1

Prime Duration (ms)	Differences U - R	I - R	I - U
60	8	-31	-39
45	1	-36	-37
30	28	-5	-33

Table 4

Mean Gaze Duration (ms) on the Target
as a Function of Presentation Order

Block Order	Prime Duration (ms) 60	45	30
60-45-30	371	375	352
45-30-60	367	377	368
30-60-45	367	334	370

Table 5

Mean First Fixation Duration (ms) on the Target Word in Experiment 2

Prime Duration (ms)	Prime Type RLS	R	U
39	320	329	315
30	333	303	319
21	293	300	293

Note: Prime duration is subtracted from all means.

Table 6

Mean Gaze Duration (ms) on the Target Word in Experiment 2

Prime Duration (ms)	Prime Type RLS	R	U
39	408	399	386
30	389	377	408
21	363	376	361

Note: Prime duration is subtracted from all means.

Table 7

Differences in Gaze Duration Means (ms) in Experiment 2

Prime Duration	Differences U - R	RLS - R	RLS - U
39	-13	9	22
30	31	12	-19
21	-15	-13	2

APPENDIX

EXPERIMENTAL MATERIALS

Experimental Sentences (targets underlined)	Primes R	Primes U
Mary recalled the scent of a rose bouquet.	aroma	clown
Margaret enjoyed her flute lessons a lot.	piano	pupil
I had my first camel ride in Tunisia.	horse	heart
The bum's flask was empty tonight.	booze	vinyl
The finest linen would be her dowry.	cloth	noise
An honest crook is hard to find.	thief	fever
Matt added some cream to his coffee.	dairy	onion
I trusted that the blade was sharp.	knife	dance
The old steel was still salvageable.	metal	wagon
I think my ankle is sore from tennis.	elbow	logic
She needed the proper drill for the job.	tools	souls
He cleaned his pipes once a month.	cigar	witch
We needed another chair for the meeting.	table	piece
We should've brought more water along.	juice	dough
Bill provided for the birds every year.	robin	valet
The story of the gypsy queen was stirring.	kings	deals
Sometimes the music irritated me.	radio	claim
I was intrigued by the story of her exile.	novel	trend
It seemed the flea took advantage of Fido.	gnat	grit
Ed insisted the verb was used improperly.	noun	moth
Jane has painful memories of cots at camp.	beds	guns
Her choice has more lace than I care for.	silk	bulk
Tight quarters produced hate and discord.	love	rule
I wanted a setting for the ruby I bought.	gems	lard
We collected the pots from the cupboard.	pans	pins
Al can't separate beer from gin drinkers.	wine	clay
My first visit introduced cows to me.	barn	tank
Cheryl said several bees attacked her.	wasp	crab
The cold had made Tom's toes red and numb.	feet	idea
For us kids, the pond was a great hangout.	lake	meat
Some say real nice boys don't swear.	girl	mind
We love our town because it's part of us.	city	work
I hung the coat in the vestibule.	hats	keys
It seemed like an hour was a day at Bob's.	time	ways
Doug sensed the loss was really serious.	gain	seat
Her sad song captured their hearts.	tune	hint
We got stalled by the goats on the road.	sheep	brick
Greasy ovens really depress me.	stove	liver
The puppy mouthed the thorn then yelped.	spike	lilac
Grandpa's cough was getting better.	smoke	reply
Mike was cleared of arson in his trial.	theft	cheer
The large steer lazily flicked its tail.	ranch	organ
I said a decent mayor isn't easily bought.	judge	youth
Sally likes the lions best in the circus.	tiger	niece

Keith cleansed his wound with iodine.	blood	child
We visited Mark's grave this morning.	death	class
George served us some fruit for dessert.	apple	ivory
The oblong candy was extremely tart.	sugar	storm
Ducks gather at the river now and then.	creek	vowel
They found their shoes behind the door.	socks	sails
On holidays our uncle usually visits.	aunts	lunch
As usual, the plane was delayed.	pilot	pupil
Marty said that the waves were good today.	beach	visit
Memories of past years kept intruding.	month	field
John played the tuba in grade school.	drum	myth
We all rushed to the cave for shelter.	womb	lint
Paul is a hopeless pear juice freak.	plum	polo
Becky harassed the frog all afternoon.	toad	clam
My purple comb fell in the toilet.	hair	list
The news said the hail damage was immense.	snow	tube
He found the beef to be quite rare.	pork	wart
Jeff claims that the navy is a hassle.	army	lady
Grandma got attached to the cats quickly.	dogs	beds
Judy brought several pies to the reunion.	cake	rose
Sammy hid the lids from his mother.	jars	gaps
The rooster's tail was tattered.	head	form
He noticed that her lips were chapped.	kiss	ribs
Diane forgot which page she was on.	book	jobs
My hideout is in the tree by the bayou.	leaf	belt
Harry sold the acre to his brother.	land	road
I noticed a bleached bone beside the path.	skin	salt
I'd love a leisurely meal for a change.	food	game
It was the swamp that we feared most.	marsh	curse
A good waltz always gets Charlie excited.	dance	saint
The melancholy dwarf stumbled home.	giant	coach
We saw the groom go into the bathroom.	bride	prize
Phil lost his pants at the pool party.	shirt	screw
Greg had never seen the cobra in action.	snake	brain
Burt bent all the forks on the table.	spoon	grape
Gail felt little shame for her actions.	guilt	fluid
Al likes white bread with margarine.	toast	towel
The face of the watch was speckled.	clock	check
Dr. Beck's elaborate graph was impressive.	chart	flame
The irregular stair was a hazard.	porch	crime
My cousin's teeth were very crooked.	mouth	faith
Anne had to find a dress for the party.	skirt	slope
I was flying in my dream last night.	sleep	shell
Mom froze a half pound of caviar.	ounce	scrap
They said that the movie was worth seeing.	films	items
Aunt Rose lost some money at the races.	purse	stain
Jack saw a wolf when he was camping.	howl	moth
The dirty mugs were a real eyesore.	cups	guys
Sandy said a Vietnamese chef was hired.	cook	cure
Jim waited for the carp to bite all day.	fish	beam
Gary took the exam four days late.	test	hair
About twenty rats escaped from the lab.	mice	flag

We counted the eggs that we had collected.	hens	ties
This region has enormous coal deposits.	iron	gift
Surprisingly, our ship survived the storm.	boat	play
It was fate that ever we met.	luck	milk
It was almost dawn when we finally left.	dusk	deer
Linda cleaned the dirt from her toenails.	soil	roof
Brenda liked the face on the large doll.	eyes	area
The sudden wind spoiled our outing.	gust	pact
The rug is one foot too long for the room.	inch	cell
I was sorry that so few days remained.	week	room
Roy noticed Sue's legs for the first time.	arms	sons
Far from city lights, my star sparkles.	moon	lake

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