Applied Psycholinguistics **22** (2001), 191–215
Printed in the United States of America

Lexical and sentential priming in competition: Implications for two-stage theories of lexical access

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ABSTRACT
This article presents a new method that can compare lexical priming (word–word) and sentential priming (sentence–word) directly within a single paradigm. We show that it can be used to address modular theories of word comprehension, which propose that the effects of sentence context occur after lexical access has taken place. Although lexical priming and sentential priming each occur very quickly in time, there should be a brief time window in which the former is present but the latter is absent. Lexical and sentential priming of unambiguous words were evaluated together, in competing and converging combinations, using time windows designed to detect an early stage where lexical priming is observed but sentential priming is not. Related and unrelated word pairs were presented visually, in rapid succession, within auditory sentence contexts that were either compatible or incompatible with the target (the second word in each pair). In lexical decision, the additive effects of lexical priming and sentential priming were present under all temporal conditions, although the latter was always substantially larger. In cross-modal naming, sentential priming was present in all temporal conditions; lexical priming was more fragile, interacting with timing and sentential congruence. No evidence was found for a stage in which lexical priming is present but sentential priming is absent – a finding that is difficult to reconcile with two-stage models of lexical versus sentential priming. We conclude that sentential context operates very early in the process of word recognition, and that it can interact with lexical priming at the earliest time window.

Language comprehension appears, for the most part, to be an effortless process. When we are reading or listening to a sentence, the meaning of what is read or heard seems to emerge naturally. Despite the clear outcome of language comprehension, the stages leading up to this outcome are not clear. That is, not only are the intermediate stages in the language comprehension process not apparent to readers or listeners, but their existence and nature are also unclear to psycholinguists who study it. One intermediate stage that has been investigated extensively is lexical access, defined as the point in time at which a word's orthographic or phonological form is retrieved. The study of lexical access has taken a number of methodological approaches. One approach uses different tasks such as lexical decision and naming to look at lexical access. A second approach examines the effects of lexical and sentential context on lexical access. A third approach is to study the effects of time on the interaction of context effects and lexical access. The current study employs all three methods in a single paradigm to examine when and how lexical and sentential contexts combine to influence lexical access.

Lexical versus post-lexical effects

Traditionally, lexical access has been defined as the moment at which a perceptual input makes contact with a corresponding store in lexical memory. Several models have been proposed in the literature to explain lexical access. These include Becker's (1980) verification model, Morton's (1969) logogen model, and Forster's (1990) bin model. In each of these classic models, there is a moment in time at which sufficient stimulus information has been accumulated so that a lexical representation may be activated. Anything that occurs before this moment is defined as "pre-lexical," whereas events that occur after this moment are said to be "post-lexical" (for a review, see Balota, 1990).

The primary tasks that have been used are lexical decision and naming. Initially, it was thought that both of these tasks looked directly at lexical access. However, on closer inspection, each seems to involve some aspect of post-lexical processing that goes beyond lexical access. Lexical decision includes the processes used in the discrimination of words and nonwords. Naming includes the processes used in the motor program to produce words. Because a number of variables (e.g., frequency effects or lexical priming effects) are larger in lexical decision, it has been proposed that these variables influence the discrimination process in lexical decision more than they affect motor programming and implementation in pronunciation (Balota, 1990; Balota, Boland, & Shields, 1989). The conclusion reached by some is that naming may be a "purer" measure of lexical access than lexical decision, providing a more direct assessment of this critical moment.

So far, we have reviewed accounts of how lexical access occurs. It is important to remember that these accounts were designed to explain access of isolated words. However, it is less clear how lexical access occurs in a larger context, such as sentences or discourse passages. To grapple with this, researchers have adopted some of the same concepts that have been used to consider lexical access in isolation. Specifically, the distinction between lexical and post-lexical processing has been taken up to explain how lexical and sentential contexts affect lexical access.

On the nature of priming

Traditionally, lexical contexts and sentential contexts were thought to play very different roles in word recognition, each applying at a separate stage. Lexical contexts were thought to affect access pre-lexically via a form of automatic activation that spreads across the semantic network (Collins & Loftus, 1975). Sentential contexts, in contrast, were attributed to a post-lexical stage in which the accessed word is integrated into a larger conceptual structure. This two-stage model has received strong support from studies examining the activation of multiple meanings of an ambiguous word. In cross-modal paradigms, all meanings of an ambiguous word appeared to be immediately accessed, regardless of contextual bias (Onifer & Swinney, 1981; Seidenberg, Tanenhaus, Leiman, & Bienkowski, 1982). After a short delay (200–500 ms after the offset of the ambiguity), selective activation of the contextually appropriate meaning was observed. The conclusion was that sentential integration is a post-lexical process that follows pre-lexical activation and lexical access itself. These studies concluded that lexical access occurs independently of the sentential context (i.e., exhaustive access).

A number of studies have questioned this view. Accounts of lexical priming have gone beyond the idea of a pre-lexical spreading activation mechanism (Collins & Loftus, 1975). According to spreading activation, words are represented in a semantic network; a prime leads to activation of a related target because the two are close together in a semantic network. Neely, Keefe, and Ross (1989) suggested that semantic priming must involve additional mechanisms beyond spreading activation, including expectancy priming (Becker, 1980) and plausibility checking (Norris, 1986). According to both Becker and Norris, word recognition involves establishing a set of words that is visually similar to the target (i.e., a visually defined set). Becker argued that, when a target is primed by a word, an expectancy set of semantically related words is generated. The expectancy set overrides the visually defined set. On the other hand, Norris argued that priming occurs after a word is recognized, using a plausibility check to ensure that prime and target are related. These models account for certain findings in the priming literature (for a review, see Neely, 1991). According to Neely et al. (1989), all three mechanisms are needed to account for all of the findings in the literature. Hence, lexical priming is most likely due to multiple mechanisms, which may operate pre-lexically and/or post-lexically.

Studies on the nature of sentential priming have questioned whether activation of lexical access proceeds independently of sentential contexts. Some studies have found evidence for contextually dependent access (i.e., selective access), even early in processing (for a review, see Simpson, 1994). Other studies have suggested that it is not solely the product of post-lexical processing. For instance, Stanovich and West (1983) found that sentential priming shows patterns of facilitation dominance and effects of visual degradation that are similar to those found in the single-word priming literature. In addition, Hernandez, Bates, and Avila (1996) found that sentential priming shows automatic and controlled effects with Spanish–English bilinguals. According to these findings, sentential priming and lexical priming show some of the same “automatic” effects in processing. This view has received additional support from studies using event-related potentials (ERPs): the amplitude and onset of the N400 (an index of semantic incongruity) is the same for semantic violations whether they involve a lexical or a sentential context (Van Petten & Kutas, 1987). Finally, a host of behavioral studies have found that sentences can override or alter the nature of lexical priming (Foss & Ross, 1983; Moss & Marslen-Wilson, 1993; Peterson & Simpson, 1989). The conclusion from these studies is that sentential priming can affect the magnitude and nature of lexical priming. This would suggest that, for unambiguous words, lexical priming and sentential priming are based on the same processing mechanisms, which overlap in time.

Work by Peterson and Simpson (1989) has shed light on the effects of sentential contexts on lexical priming. Of particular relevance is their Experiment 2, in which an auditory word was presented and participants were asked to name or make a lexical decision with regard to words presented visually. The auditory word was presented in isolation or was the final word of a sentence. The auditory primes and the visual targets were either bidirectionally related (BABY–CRY) or only related through backward priming (STORK–BABY: BABY primes STORK but not vice versa). The targets were presented either 0 or 200 ms after the prime. Priming for bidirectionally related prime–target pairs was found for single-word and sentence primes, both for naming and lexical decision across all time courses. Backward priming was found for single-word primes at both time courses (0 and 200 ms) for lexical decision, but it was seen only at the shorter time course for naming. There was no backward priming for lexical targets primed by sentences either in lexical decision or naming. The results from Peterson and Simpson's experiment reveal two important points. First, the role of timing may be different in naming and lexical decision. Backward priming decayed very quickly for naming in isolation but not for lexical decision. Second, a sentential context can alter the effects of lexical priming. Backward priming was not found at all within a sentence context. It would seem, then, that timing and type of response are crucial for understanding how sentential contexts interact with lexical contexts.

To disentangle these effects more precisely, Hernandez and Bates (1994) proposed a method called "competitive priming." This method enables a direct comparison of lexical (word–word) and sentential (sentence–word) priming effects for unambiguous words by examining the time course and the (potential) interaction between these two sources of information in very early time windows. Participants were asked to listen to short paragraphs taken from elementary school texts and comparable sources. At various points in the auditory paragraphs, a word was omitted (e.g., " . . . the man was walking down the____ . . . "), and a visual prime was presented for 200 ms, followed immediately by a visual target. Participants were instructed to read aloud the second word of the pair; reaction times were measured using a voice key. Each prime–target pair appeared in one of five conditions: (1) both words fit the sentence (STREET–ROAD); (2) the target fit the sentence but the prime did not (APPLE–ROAD); (3) neither prime nor target fit the sentence but the two were lexically related (APPLE–ORANGE); (4) the prime fit the sentence but the target did not (STREET–ORANGE); (5) (the neutral baseline) neither prime nor target fit the sentence and the two were not lexically related (APPLE–CLOCK). The results revealed a significant interaction between lexical and sentential priming. Reaction times were fastest when the target fit the sentence but the prime did not (APPLE–ROAD), slower (by about 20 ms) when the pair was lexically related (STREET–ROAD; APPLE–ORANGE), and slowest when the prime fit the sentence but the target did not (STREET–ORANGE). Reaction times in the neutral baseline proved to be significantly slower than those in conditions (1), (2), and (3), suggesting that both sentential and lexical priming may involve some form of facilitation. However, reaction times in condition (4) were even slower than those in the neutral baseline, suggesting that some kind of competition, inhibition, or masking may take place if the prime can be integrated immediately into the sentence. Most important for our purposes here, lexical priming only reached significance when the target did not fit the sentence.

In line with the ERP and reaction time studies cited here, Hernandez and Bates (1994) concluded that sentence contexts can alter the existence, magnitude, and direction of lexical priming. However, their study had a number of limitations. First, they used naturalistic paragraphs, which made it difficult to control for the cumulative effects of context, including the presence of lexical associates. Second, most of the word pairs they used were very weakly associated. Although both words might have been good completions, the lack of an associative relationship might have weakened lexical priming. Given such limitations, it was important to replicate the findings of that study using a new set of materials in which these potential confounds were strictly controlled.

In the present study, participants were presented with short auditory contexts that consisted of three sentences: e.g., "Joey had always wanted a pet of his own. He worked hard to show his parents that he was responsible enough to feed and care for any animal. His diligence paid off when he received a fluffy____for his birthday." For each paragraph, a word pair was visually presented during the pause in the auditory context. Four different temporal conditions were employed, differing by the duration of the prime (100 or 200 ms) and by the interval between the prime and the target (0 or 100 ms ISI). Each word pair was from the same semantic category (Battig & Montague, 1969; Hunt & Hodge, 1971) and was associatively related (Postman & Keppel, 1970). During the middle of the second or third sentence, participants were shown a word pair that appeared in one of four conditions (see Table 1). These conditions were treated as independent variables in a 2 (presence/absence of lexical priming) × 2 (presence/absence of sentential priming) design within each task and temporal condition. The fifth condition – no semantic relationship between the sentences and the word–word pairs – was treated as a neutral baseline for post-hoc analyses evaluating the direction of lexical and sentential priming effects. Note that some of the paragraphs contained lexical associates of the target word, whereas others did not.

Experiment 1 used a lexical decision paradigm. Experiment 1A examined the robustness of lexical decision priming effects across temporal conditions for word pairs presented visually in isolation (i.e., without any contextual information). A significant level of priming for associatively and categorically related stimuli had to be demonstrated under all temporal conditions as a precondition

Table 1. *Sample stimuli for the competitive priming technique*

Block A		Block B	
Joey had always wanted a pet of his own. He worked hard to show his parents that he was responsible enough to feed and care for any animal. His diligence paid off when he received a fluffy ____ for his birthday.		In the old fairy tales, the knight would be called upon to rescue the princess from an evil villain. When the knight came to the castle, he would approach the throne. On his knee he would proclaim that he would be victorious and return the daughter to the ____ before asking for her hand in marriage.	
Condition	Word pair	Condition	Word pair
Lexically related / Fits sentence	dog–cat	Lexically related / Fits sentence	king–queen
Lexically unrelated / Fits sentence	king–cat	Lexically unrelated / Fits sentence	dog–queen
Lexically related / Does not fit sentence	king–queen	Lexically related / Does not fit sentence	dog–cat
Lexically unrelated / Does not fit sentence	dog–queen	Lexically unrelated / Does not fit sentence	king–cat

for their use in Experiment 1B. These stimuli were then employed in a new competitive priming task (Experiment 1B) in order to observe how and when lexical and sentential priming would affect lexical access.

A number of studies have suggested that lexical decision and naming tap different aspects of post-lexical processing. Lexical decision involves a decision between words and nonwords (Balota, 1990; Balota et al., 1989). This decision process most likely contributes to a number of strategic effects that could conceivably cloud the word recognition process. Experiment 2 employed a cross-modal naming paradigm (i.e., pronunciation priming) using the same stimuli and design as Experiment 1. Experiment 2A examined the robustness of pronunciation priming effects for word pairs presented visually in isolation (a precondition for their use in Experiment 2B). In Experiment 2B, these word pairs were presented in a congruent or incongruent sentence context. Experiment 2B served as a replication of Hernandez and Bates (1994).

Our aim was to examine the effects of lexical and sentential priming on lexical access using two different tasks. We explored the effects of each task and temporal condition with planned comparisons, in addition to omnibus analyses of word congruence, sentence congruence, duration, and ISI. Post-hoc comparisons were conducted for Experiments 1B and 2B, comparing performance under each priming condition with performance in the neutral baseline condition, to learn about the nature and direction of any priming effects that were found. Finally, our method employed strong sentential contexts; the idea was to test how lexical priming appears under conditions that encourage integration of the target into the sentence.

EXPERIMENT 1A: ISOLATED PRIMING IN A LEXICAL DECISION TASK

Participants

There were 120 participants (mean age = 20.47 years; *SD* = 1.23) in this experiment. Of these, 72 were female and 48 were male; all were students enrolled at the University of California, San Diego. Any participant who routinely had heard or spoken a language other than English in the household or who had lived for more than three months in a non–English-speaking country was excluded from the experiment. The participants were divided into four groups of 30, randomly assigned to a ISI × Prime Duration condition.

Apparatus and materials

The visual stimuli were presented with a Macintosh IIsi using the PsyScope experimental shell from Carnegie Mellon University (Cohen, MacWhinney, Flatt, & Provost, 1993). All word pairs appeared in uppercase letters (12-point Geneva) on a 12-inch black-and-white Macintosh monitor. The stimuli varied in length from three to nine characters.

We created 148 word pairs. The word pairs we selected were good exemplars from the same category (e.g., *cat* and *dog* within the category *animal*) (Battig & Montague, 1969; Hunt & Hodge, 1971) and were highly associated with each other (e.g., *dog* is elicited when *cat* is presented) (Postman & Keppel, 1970). In addition, prime and target items were chosen that would be equally good continuations of the sentences used in Experiment 1B. The within-pair association was consistently in the strongest direction to increase the likelihood of significant priming effects. The 148 word pairs were divided into 74 sets of two-word combinations to create counterbalanced congruent and incongruent word pairs. For example, the set of word pairs that included DOG–CAT and KING–QUEEN was used to produce four different priming conditions: two related (DOG–CAT or KING–QUEEN) and two unrelated (KING–CAT or DOG–QUEEN).

Two blocks of 74 word pairs were created. To ensure that all word pairs had an equal probability of occurring in each condition, five different versions of each block were created such that each block had only one rotation of a particular word pair. Thus, if version 1/block A had DOG–CAT, then version 1/block B had KING–QUEEN; if version 2/block A had KING–CAT, then version 2/block B had DOG–QUEEN. None of the words that appeared in block A also appeared in block B (i.e., participants saw each word pair only once). For this lexical decision experiment, another set of 74 word–nonword pairs was created using stimuli developed by Smith, Besner, and Miyoshi (1994). None of the words that appeared in these pairs overlapped with previously selected words.

Design and procedure

Each trial began with a row of nine Xs presented in the middle of the computer screen for 750 ms to cue the beginning of the trial, followed by a blank screen for 500 ms. Then a pair of words appeared on the screen, one right after another; the duration of the prime presentation and the ISI were varied. The prime appeared for either 100 ms or 200 ms. For each temporal condition, the target appeared either immediately after the prime (0 ms ISI) or after a 50 ms mask (another row of Xs) and 50 ms of blank screen (100 ms ISI).

Participants were told that they would see a row of Xs on the computer screen in front of them and that two stimuli would immediately follow the Xs, one at a time. They were asked to respond to the targets by pressing the left button for stimuli that were real words and the right button for stimuli that were not real words. Once a participant pressed the key, the target disappeared and the intertrial interval (1000 ms) was initiated. If no response was registered within 1000 ms, the stimulus disappeared and the intertrial interval was automatically initiated. Participants were given a short practice session of 20 trials before each experiment, using stimuli that did not appear in the experiment itself.

Results and discussion

Lexical priming was examined by assessing the effect of prime–target relatedness on lexical decision response time. Both analyses over subjects (*F1*) and analyses over items (*F2*) are reported here. All reaction time responses falling below 200 ms (1.58% of all trials) were excluded. Error rates (e.g., incorrect classification of nonwords as real words) were below 2% for all experiments and thus were not subjected to further analyses. Overall reaction times for lexical decisions on the target averaged 897.3 ms, when presented out of context.

A 2 (Prime Duration) × 2 (Prime–Target ISI) × 2 (Lexical Priming) ANOVA, with prime duration and ISI as between-subjects factors and lexical priming as a within-subject factor, revealed significant main effects of duration, $F1(1, 116) = 7.50$, $p < .007$, $MSE = 10806.51$; $F2(1, 148) = 186.51$, $p < .001$, $MSE = 8320.53$, and lexical priming, $F1(1, 116) = 30.81$, $p < .001$, $MSE = 212.18$; $F2(1, 148) = 14.52$, $p < .001$, $MSE = 20873.06$. Longer prime durations decreased reaction times overall, but ISI manipulation had no significant influence on reaction times. Lexical priming effects were in the predicted direction (faster reaction times for related pairs), with an average difference score of 25 ms between related and unrelated pairs. However, there were no significant interactions between lexical priming and the temporal variables. In other words, lexical priming was of equal magnitude across all conditions. The results from this study can be seen in Table 2.

Experiment 1A demonstrated that these word pairs did yield significant priming effects under all four temporal conditions. There were no significant interactions between priming and temporal conditions when the word pairs were presented in isolation. We then proceeded to examine the relationship between lexical priming and sentential priming when the two prime types were combined across the same four temporal conditions.

Table 2. *Mean reaction times and error rates for Experiment 1A*

Lexical relationship	Lexical decision
Related	884 (1.74%)
Unrelated	909 (1.88%)
Lexical priming	25***

***$p < .001$.

EXPERIMENT 1B: CROSS-MODAL LEXICAL AND SENTENTIAL PRIMING OF LEXICAL DECISION

Participants

A total of 120 undergraduates at the University of California, San Diego (mean age = 20.41 years; *SD* = 1.17) participated in this experiment. Of the individuals tested (30 per experiment), 69 were female and 51 were male. Any participant who routinely had heard or spoken a language other than English in the household or who had lived for more than three months in a non–English-speaking country was excluded from the experiment.

Apparatus and materials

The visual stimuli were presented on a Macintosh IIsi using the PsyScope experimental shell from Carnegie Mellon University (Cohen et al., 1993). The auditory sentence contexts were recorded into a Sony digital audiotape recorder in a soundproof booth. They were then digitized at 16-bit, 22k sampling rate using the SoundEdit16 software package.

The word pairs that yielded significant priming effects in Experiment 1A were employed in this experiment. For each of the 148 word pairs, a three-sentence context was designed to bias the congruent target word (see Table 1). Thus, each word pair had a corresponding sentence context. The 148 sentence contexts were divided in two blocks of 74 contexts. For example, a sentence that primed DOG–CAT (block A) was placed in one block, and a sentence that primed KING–QUEEN (block B) was placed in the other (see Table 1). Congruent and incongruent word pairs were formed by pairing DOG with QUEEN and KING with CAT, as in Experiment 1A. Thus, one group would see a given word pair in the congruent sentence (e.g, "when he received a fluffy DOG–CAT/KING–CAT"), while another group would see this word pair in an incongruent sentence ("return the daughter to the DOG–CAT/KING–CAT"). Note that each of the four conditions involved the same target word. A fifth condition (neutral baseline) was set up in which a word that did not fit the sentence was paired with a different word (matched on length and frequency) that also did not fit the sentence (DOG–CUP). For both blocks, five different versions of the experiment were prepared. In every version, each sentence and each word pair appeared only once. The sentences were randomly assigned to a condition in the first version. For each subsequent version, the word pair was presented in the next condition. Thus, each condition was rotated systematically across participants. In addition, for each participant, either block A or block B had words replaced with nonwords. Thus, participants saw 74 words and 74 nonwords. The sentence contexts were presented in random order so that participants would not be able to predict which condition the stimulus would appear in next.

Design and procedure

The experiment employed a 2 (Prime Duration) × 2 (ISI) × 2 (Lexical Relatedness) × 2 (Sentential Relatedness) mixed factorial design, with two between-subjects factors (prime duration and ISI) and two within-subject factors (lexical and sentential relatedness). (Evaluations of the priming conditions against the neutral baseline condition are presented later.) This lexical decision task required that participants respond to a visually presented target word by pressing either the left button for real words or the right button for nonwords.

Each session consisted of three sequential parts. First, a baseline measure was administered: participants were shown 20 isolated word pairs on the screen and were asked to make simple lexical decisions. Second, a practice block of trials was administered: participants were given five texts similar to those used in the experiment; they were told to listen to each text and to respond with a button press to the target word when it appeared on the screen. Third, participants completed the 74 experimental trials. (The baseline and practice items were not used in the experimental trials.)

Participants were told that they would hear a set of texts presented over two speakers. First, they would see the words "Get Ready" on the computer screen (750 ms), which served as a cue for the auditory text; immediately after, the text would begin. Participants were instructed to pay attention to the content of the passage because they would be asked questions about the text. They were also told that, at a predetermined point during the text, the sound would stop and two words would appear on the computer screen, one right after the other. Participants were informed that some words would fit the text and others would not, and that some of the stimuli would not be real words at all. Half of the word pairs appeared during the second sentence and half appeared during the third sentence of the texts. None of the targets appeared in sentence-initial or sentence-final position. The conditions of the visual presentation were identical to those in Experiment 1A. A response window of 1000 ms was provided. Once a participant pressed a button, the target disappeared and the text continued. If there was no response, the sentence would continue. Finally, a multiple-choice question was randomly presented at the end of some trials (approximately one out of every five) to ensure that participants had attended to the auditory texts. Participants were permitted as much time as they needed to answer the question. Once the question was answered, the next passage would begin.

Table 3. *Mean reaction times and error rates for Experiment 1B*

	Lexical relationship	Fits sentence	Does not fit sentence	Mean	Sentential priming
0 ISI	Related	701 (1.49%)	766 (1.64%)	733 (1.62%)	65**
	Unrelated	714 (1.49%)	791 (1.78%)	753 (1.53%)	77**
	Mean	708 (1.58%)	779 (1.73%)	743 (1.54%)	28**
	Lexical priming	13*	25**	14**	
100 ISI	Related	734 (1.41%)	799 (1.52%)	767 (1.43%)	65**
	Unrelated	743 (1.54%)	816 (1.44%)	779 (1.53%)	73**
	Mean	738 (1.48%)	808 (1.72%)	772 (1.56%)	33*
	Lexical priming	9*	15*	12*	

***$p < .001$; **$p < .01$; *$p < .05$.

Results and discussion

Both analyses over subjects (*F1*) and analyses over items (*F2*) are reported here. All reaction times below 200 ms were excluded from the analyses (1.8% of all trials). Error rates (those in which participants identified a nonword as a word or vice versa) were below 2% and were not subjected to further analyses. In addition, error rates on the comprehension questions were very low (below 4%) and were not subjected to further analyses.

Response latencies for Experiment 1B were placed in a 2 (Prime Duration) × 2 (ISI) × 2 (Lexical Priming) × 2 (Sentential Priming) ANOVA. This analysis revealed a significant main effect of lexical priming: related targets were responded to faster than unrelated targets within the word pairs, $F1\ (1,\ 116) = 16.98$, $p < .001$, $MSE = 1813.79$; $F2(1, 292) = 9.04$, $p < .001$, $MSE = 9532.49$. There was also a significant main effect of sentential priming: targets that fit the sentence context were responded to faster than targets that did not, $F1(1, 116) = 354.41$, $p < .001$, $MSE = 1663.89$; $F2(1, 292) = 163.17$, $p < .001$, $MSE = 9532.49$. There was a significant Duration × ISI interaction, $F1(1, 116) = 6.104$, $p < .015$, $MSE = 675.39$; $F2(1, 292) = 99.5$, $p < .075$, $MSE = 4807.00$, indicating substantially faster reaction times in the 200/0 condition. However, sentential priming and lexical priming did not interact with each other or with ISI (see Table 3).

Post-hoc comparisons. If the two-stage model is correct, it ought to be possible to find a time window in which lexical priming is present but sentential priming is absent. Results of the analysis of variance indicated that this was probably

Table 4. *Magnitude of priming effects for Experiment 1B*

	100 Prime/ 0 ISI	100 Prime/ 100 ISI	200 Prime/ 0 ISI	200 Prime/ 100 ISI
Lexical priming overall	16 ms*	11 ms (*ns*)	22 ms**	6 ms (*ns*)
Sentential priming overall	63 ms***	75 ms***	78 ms***	64 ms***
Neutral / +Word + Sentence	66 ms***	62 ms***	79 ms***	66 ms***
Neutral / +Word − Sentence	2 ms (*ns*)	−6 ms (*ns*)	14 ms (*ns*)	5 ms (*ns*)
Neutral / −Word + Sentence	49 ms***	55 ms***	70 ms***	55 ms***
Neutral / −Word − Sentence	−16 ms (*ns*)	−28 ms (*ns*)	−22 ms (*ns*)	−12 ms (*ns*)

***$p < .001$; **$p < .01$; *$p < .05$; $p > .05$, *ns*.

not the case; we found no significant interaction involving lexical priming, sentential priming, and temporal conditions. Nevertheless, a series of planned comparisons was carried out within each temporal condition to test this prediction of the two-stage model. In addition, we conducted post-hoc comparisons within each temporal condition to investigate the magnitude and direction of priming effects, comparing each of the four Lexical Priming × Sentential Priming conditions against the neutral baseline (i.e., no relation between prime, target, or sentence context). Results of the planned comparisons are summarized in Table 4. Results for each priming condition against the neutral baseline are illustrated in Figure 1.

As Table 4 indicates, sentential priming effects were significant in all four temporal conditions ($p < .001$ in every case). In fact, they were relatively large, with difference scores between sententially congruent (+ Sentence) and sententially incongruent (− Sentence) targets ranging from 63 ms in the 100/0 window to 78 ms in the 200/0 window. By contrast, lexical priming effects were relatively small, with difference scores between related (+ Word) and unrelated (− Word) word pairs ranging from 6 to 22 ms; they were also fragile, failing to reach significance in the 100/100 and 200/100 conditions. Recall that lexical priming effects averaged 25 ms when the same word pairs were presented out of context (Experiment 1A), and that the magnitude of priming did not change as a function of temporal condition. Thus, it would seem that lexical priming effects were reduced when placed within a sentence context. One might argue that lexical priming was reduced because listeners had to divide their attention between the auditory sentence context and the visual word presentation. If this were the only explanation, we would expect to find an increase in lexical priming with longer prime durations and/or longer intervals between prime and target (giving participants more time to process the visual stimuli). However, this did not seem to be the case; indeed, if anything, lexical priming effects were smaller when the interval between the words was larger.

Figure 1 shows that, across temporal conditions, the fastest reaction times occurred when the two forms of priming converged (+ Word and + Sentence). Whether or not the word pair was related, reaction times for sententially congruent targets were significantly faster than reaction times in the neutral baseline

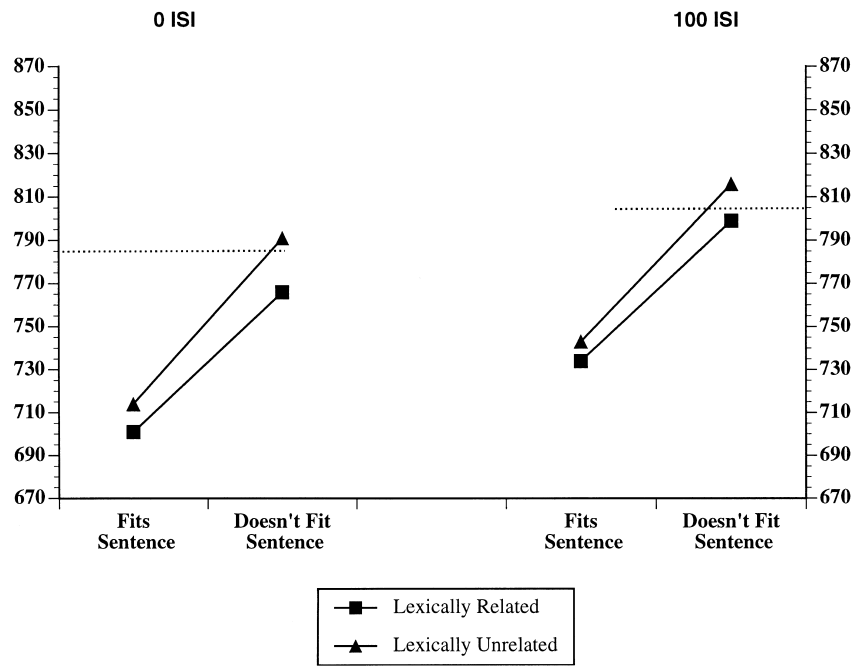

Figure 1. Sentential and lexical priming across temporal conditions for lexical decision cross-modal priming paradigm (Experiment 1B).

condition (i.e., no semantic relationships of any kind), suggesting that sentential priming effects were facilitative in nature in all four temporal conditions. By contrast, even though there was a small main effect of lexical priming in the overall analysis (related vs. unrelated pairs), reaction times to related word pairs in the sententially incongruent condition (e.g., "The man was walking down the [APPLE–ORANGE]") were not significantly faster than reaction times in the neutral baseline condition (e.g., "The man was walking down the [APPLE–CLOCK]").

Associative versus sentential priming. The sentential priming effects observed in Experiment 1B appear to be substantially larger and more reliable than the lexical priming effects. However, it has been suggested that sentential priming could be an artifact of cumulative lexical priming, due to the presence of words associated with the target (Fodor, 1983; Foss & Ross, 1983; Gough, Alford, & Holley-Wilcox, 1981). To control for this possibility, all sentences were coded by strength of associates in the sentence. This was done using a combination of distance and strength of associates. Strong associate sentences (coded as 2) had one or more strong associates or more than two weak associates of the prime and target in the same sentence. Weak associate sentences (coded as 1) had one or more weak associates of the prime and target in one of the sentences preceding the sentence with probe. Finally, sentences that had no associates were coded as 0. In addition, strength of association between prime and target was also analyzed. These factors were correlated with four difference scores: (1) the magnitude of lexical priming for targets that fit the sentence; (2) the magnitude of lexical priming for targets that did not fit the sentence; (3) the magnitude of sentential priming for word pairs that were lexically related; (4) the magnitude of sentential priming for word pairs that were not lexically related. The results did not reveal any significant correlations between any of the four difference scores and strength of associates in the sentence or strength of association between prime and target. Based on these analyses, we concluded that the sentential priming effects observed in this lexical decision study were not simply the product of strength of association between prime and target or strength of the associates in the sentence itself.

The results of the lexical decision experiment suggested that sentential priming effects were larger and more reliable than lexical priming effects assessed within the same paradigm, using the temporal conditions of previous studies to isolate automatic priming effects. Sentential priming was present in every time window. Lexical priming, however, varied according to temporal condition and to both lexical and sentential relatedness. Earlier studies have suggested that some effects may influence lexical decision. In general, it has been found that effects using word pronunciation may differ in key respects. For this reason, we used a pronunciation task in Experiment 2.

EXPERIMENT 2A: ISOLATED PRIMING IN A PRONUNCIATION TASK

Participants

There were 120 participants (mean age = 19.83 years; *SD* = 1.16) in this experiment. Of these, 66 were female and 54 were male; all were students enrolled at the University of California, Santa Barbara. Any participant who routinely had heard or spoken a language other than English in the household or who had lived for more than three months in a non–English-speaking country was excluded from the experiment. The 120 participants were divided into four groups of 30, randomly assigned to a ISI × Prime Duration condition.

Apparatus and materials

The creation and presentation of the stimuli were the same as for Experiment 1A. Here, however, no nonword stimuli were used.

Design and procedure

As in Experiment 1A, each trial began with a row of nine Xs presented in the middle of the computer screen for 750 ms to cue the beginning of the trial, followed by a blank screen for 500 ms. Then a pair of words appeared on the screen, one right after another; the durations of the prime presentation and the ISI were varied. The prime appeared for either 100 ms or 200 ms. For each temporal condition, the target appeared either immediately after the prime (0 ms ISI) or after a 50 ms mask (another row of Xs) and 50 ms of blank screen (100 ms ISI).

Participants were told that they would see a row of Xs on a computer screen and that two stimuli would immediately follow the Xs, one at a time. They were asked to read aloud the second item as quickly as possible into the microphone. Once a participant verbally responded, the target disappeared and the intertrial interval (1000 ms) was initiated. If no response was registered within 1000 ms, the stimulus disappeared and the intertrial interval was automatically initiated. Participants were given a short practice session of 20 trials before each experiment using stimuli that did not appear in the experiment itself.

Results and discussion

All reaction time responses falling below 200 ms (1.58% of all trials) were excluded. Error rates (e.g., incorrect classification of nonwords as real words) were below 2% for all experiments and were not subjected to further analyses. Overall reaction times averaged 568.5 ms for cross-modal naming out of context – more than 300 ms faster than the average (897.3 ms) for lexical decisions on the same word pairs out of context (Experiment 1A).

Lexical priming effects out of context were examined by assessing the effect of prime–target relatedness on naming times. Analyses over subjects (*F1*) and analyses over items (*F2*) are reported here. A 2 (Prime Duration) × 2 (Prime–Target ISI) × 2 (Lexical Priming) ANOVA, with prime duration and ISI as between-subjects factors and lexical priming as a within-subject factor, revealed significant main effects of duration, $F1(1, 116) = 7.43$, $p < .007$, $MSE = 37548.53$; $F2(1, 148) = 347.29$, $p < .001$, $MSE = 1138.78$, and lexical priming, $F1(1, 116) = 29.82$, $p < .000$, $MSE = 1223.70$; $F2(1, 148) = 14.52$, $p < .001$, $MSE = 2690.39$. In most respects, the results were similar to those for lexical decision out of context in Experiment 1A. First, as prime durations increased, reaction times for cross-modal naming decreased. Second, ISI manipulation had no significant influence on reaction time. Third, prime duration and ISI had no effect on the magnitude of lexical priming. In other words, lexical priming scores were similar in magnitude across temporal conditions. Aside from the large difference in mean reaction times on these tasks, the only difference in the analysis of variance between Experiments 1A and 2A was the absence of a two-way interaction between prime duration and ISI in the naming task. The mean reaction times for related and unrelated word pairs can be seen in Table 5.

EXPERIMENT 2B: CROSS-MODAL LEXICAL AND SENTENTIAL PRIMING OF WORD PRONUNCIATION

Participants

There were 120 participants (mean age = 20.34 years; $SD = 1.26$) in this experiment. Of the individuals tested (30 per condition), 71 were female and 49 were male. Any participant who routinely had heard or spoken a language other than English in the household or who had lived for more than three months in a non–English-speaking country was excluded from the experiment.

Table 5. *Mean reaction times and error rates for Experiment 2A*

Lexical relationship	Naming
Related	563 (1.59%)
Unrelated	574 (1.51%)
Lexical priming	10***

***$p < .001$.

Apparatus and materials

The stimuli were presented and designed in the same manner as in Experiment 1B. The word pairs that yielded significant priming effects in Experiment 2A were used in this experiment.

Design and procedure

The design and procedure were almost identical to Experiment 1B. However, nonwords were not included in this task, and participants responded to the targets by reading them aloud as quickly as possible rather than by pressing a button.

Results and discussion

All reaction times below 200 ms or above 1000 ms were excluded from the analyses (5.96% of all trials). Error rates (trials in which participants said the wrong word, hesitated, or produced a sound before saying the word) were below 2% and were not subjected to further analyses. In addition, error rates on the comprehension questions were below 4% and were not subjected to further analyses.

Mean reaction times for this cross-modal task were 530 ms. This mean was substantially faster than the mean (758 ms) obtained in the lexical decision task in context (Experiment 1B) and somewhat faster than the mean (568.5 ms) obtained for the pronunciation task out of context.

In order to assess the interaction of lexical priming and sentential priming across time, response latencies were placed in a 2 (Prime Duration) × 2 (ISI) × 2 (Lexical Priming) × 2 (Sentential Priming) ANOVA. The results revealed significant main effects of duration, $F1(1, 116) = 4.71$, $p < .032$, $MSE = 23509.16$; $F2(1, 292) = 131.96$, $p < .001$, $MSE = 2687.02$; lexical priming, $F1(1, 116) = 27.86$, $p < .001$, $MSE = 628.36$; $F2(1, 292) = 12.93$, $p < .001$, $MSE = 4157.39$; and sentential priming, $F1(1, 116) = 107.84$, $p < .001$, $MSE = 675.39$; $F2(1,292) = 43.20$, $p < .001$, $MSE = 4157.39$. There were also significant interactions of Duration × Sentential Priming, $F1(1, 116) = 6.104$, $p < .015$, $MSE = 675.39$; $F2(1, 292) = 3.19$, $p < .075$, $MSE = 2687.02$, and Lexical Priming × Sentential Priming, $F1(1, 116) = 4.58$, $p < .034$, $MSE = 664.78$; $F2(1, 292) = 3.15$, $p <$

Table 6. *Mean reaction times and error rates for Experiment 2B: Prime Duration × Sentential Priming interaction*

Prime duration	Fits sentence	Does not fit sentence	Mean	Sentential priming
100 ms	530	560	512	30**
	(1.48%)	(1.76%)	(1.62%)	
200 ms	506	524	525	19**
	(1.41%)	(1.64%)	(1.53%)	

****p* < .001; ***p* < .01; **p* < .05; *p* > .05, *ns*.

Table 7. *Mean reaction times and error rates for Experiment 2B: Lexical Priming × Sentential Priming interaction*

Lexical relationship	Fits sentence	Does not fit sentence	Mean	Sentential priming
Related	505	519	512	14**
	(1.43%)	(1.62%)	(1.53%)	
Unrelated	509	541	525	32**
	(1.49%)	(1.76%)	(1.63%)	
Mean	507	530	519	23**
	(1.46%)	(1.69%)	(1.58%)	
Lexical priming	4 (*ns*)	22**	13**	

****p* < .001; ***p* < .01; **p* < .05; *p* > .05, *ns*.

.077, *MSE* = 4157.39. There was also a marginal interaction of ISI × Sentential Priming × Lexical Priming, *F1*(1, 116) = 3.71, *p* < .056, *MSE* = 664.78; *F2*(1, 292) = 6.74, *p* < .010, *MSE* = 1498.12. Main effects were all in the predicted direction: there were faster reaction times with longer prime durations, faster responses for semantically related word pairs, and faster responses for targets that fit the sentence context. The two-way interactions are summarized in Table 6 (Duration × Sentential Priming) and Table 7 (Lexical Priming × Sentential Priming), and the three-way interaction is summarized in Table 8.

The interaction of Duration × Sentential Priming reflected larger sentential priming (Δrt = 30 ms) with a shorter (100 ms) prime duration and smaller sentential priming (Δrt = 19 ms) with a longer (200 ms) prime duration (Table 6). If lexical and sentential priming were independent in these early time windows, we would expect the opposite result: longer prime words should give sentential context more time to build up, thus increasing the ultimate impact of sentence congruence or incongruence when the target is heard. Instead, it would appear that sentential priming and lexical priming interacted and perhaps even competed for resources.

This brings us to the significant two-way interaction between lexical priming

Table 8. *Mean reaction times and error rates for Experiment 2B: ISI × Lexical Priming × Sentential Priming interaction*

	Lexical relationship	Fits sentence	Does not fit sentence	Mean	Sentential priming
0 ISI	Related	505 (1.41%)	519 (1.74%)	512 (1.68%)	19**
	Unrelated	509 (1.47%)	541 (1.88%)	525 (1.69%)	37**
	Mean	507 (1.55%)	530 (1.76%)	519 (1.58%)	28**
	Lexical priming	4 (*ns*)	24**	14**	
100 ISI	Related	512 (1.44%)	525 (1.49%)	536 (1.47%)	33**
	Unrelated	536 (1.50%)	547 (1.64%)	547 (1.57%)	34**
	Mean	529 (1.40%)	555 (1.76%)	542 (1.52%)	33*
	Lexical priming	24**	22**	8 (*ns*)	

****p* < .001; ***p* < .01; **p* < .05; *p* > .05, *ns*.

and sentential priming and the marginally significant interaction between ISI, sentential priming, and lexical priming. The two-way interaction (Table 7) can be summarized from two different points of view: (1) sentential priming was larger (Δrt = 32 ms) when word pairs were unrelated and smaller (Δrt = 14 ms) when they were related; (2) lexical priming was larger (Δrt = 22 ms) when sentences were incongruent with the target and smaller (Δrt = 4 ms) when they were congruent. Clearly, the two forms of priming were not additive, and they may have participated in some kind of competitive relationship.

The three-way interaction (Table 8) reflected the interactive effect of lexical and sentential priming in the 0 ms ISI condition compared to the additive effect of lexical and sentential priming in the 100 ms ISI condition. When the ISI between word pairs was set at 0, post-hoc comparisons revealed no significant lexical priming for sententially congruent targets (collapsed over prime duration), $F(1, 116) = 0.4$, $p > 1.0$, $MSE = 664.78$l; however, there was significant lexical priming for sententially incongruent targets (also collapsed over prime duration), $F(1, 116) = 244.98$, $p < .001$, $MSE = 664.78$. This finding constituted a replication of Hernandez and Bates (1994), who used a word prime duration of 200 ms and 0 ms ISI between word pairs in the cross-modal priming task. By contrast, the 100 ms ISI condition yielded significant lexical priming, regardless of sentence context: when targets fit the sentence, $F(1, 116) = 56.03$, $p <$ .001, $MSE = 664.78$; when targets did not fit the sentence, $F(1, 116) = 46.31$, $p < .001$, $MSE = 664.78$. The 100 ms ISI condition brought our cross-modal

Table 9. *Magnitude of priming effects for Experiment 2B*

	100 Prime/ 0 ISI	100 Prime/ 100 ISI	200 Prime/ 0 ISI	200 Prime/ 100 ISI
Lexical priming overall	14 ms***	8 ms (*ns*)	12 ms***	13 ms***
Sentential priming overall	28 ms***	34 ms***	18 ms***	19 ms***
Neutral / +Word + Sentence	37 ms***	39 ms***	32 ms***	30 ms***
Neutral / +Word – Sentence	18 ms*	5 ms (*ns*)	24 ms**	21 ms***
Neutral / –Word + Sentence	31 ms***	31 ms***	30 ms***	28 ms***
Neutral / –Word – Sentence	–5 ms (*ns*)	–3 ms (*ns*)	2 ms (*ns*)	8 ms (*ns*)

***$p < .001$; **$p < .01$; *$p < .05$; $p > .05$, *ns*.

naming results closer to the additive patterns obtained with lexical decision – a much slower task (Experiment 1B).

Planned comparisons. If a strong version of the two-stage theory is correct, we should find a time window in cross-modal naming in which lexical priming is present but sentential priming is absent. Although the results of these analyses suggested that this was probably not the case, eight planned comparisons, parallel to those reported for Experiment 1B, were carried out to test the effectiveness of each prime type in each temporal condition (Table 9). The results were very clear: significant sentential priming was present in every temporal condition, although it was larger when the word pair ISI was 100 ms (Δrt = 34 ms for 100/100; Δrt = 19 ms for 200/100) and smaller when the word pair ISI was 0 ms (Δrt = 28 ms for 100/0; Δrt = 18 ms for 200/0). Lexical priming was very small in all temporal conditions: it reached significance when the word pair ISI was 0 (Δrt = 14 ms for 100/0; Δrt = 12 ms for 200/0), but it was less robust when the word pair ISI was 100 ms (Δrt = 8 ms for 100/100; Δrt = 13 ms for 200/100). Of course, because the differences in priming scores are small, they should be interpreted with caution. Nonetheless, they were in the same direction revealed by the planned comparisons in Experiment 1B (constituting a partial replication), and they were compatible with the significant interactions reported there.

Table 9 also includes the statistical results for post-hoc analyses comparing each priming condition against the neutral baseline for each temporal condition. The overall pattern of results is illustrated in Figure 2. When the target fit the sentence context (+ Sentence), reaction times were significantly faster than reaction times in the neutral baseline – not unlike the findings reported for lexical decision. Our results revealed that sentential priming effects were facilitative in nature. However, the results for lexical priming (+ Word) were slightly different from those reported for lexical decision. In the lexical decision task, reaction times to related word pairs (e.g., APPLE–ORANGE) in the sententially incongruent condition were no faster than reaction times in the neutral baseline (e.g., APPLE–CLOCK). But in the cross-modal naming task, reaction times to related word pairs in the sententially incongruent condition were significantly faster in three of the four temporal conditions. Hence, even though the lexical priming effects

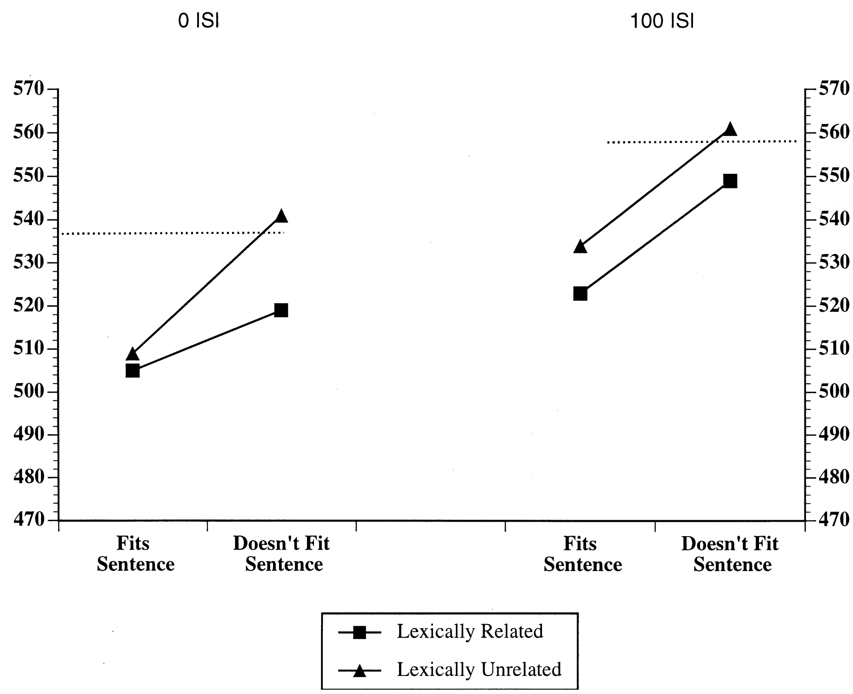

Figure 2. Sentential and lexical priming across temporal conditions for pronunciation cross-modal priming paradigm (Experiment 2B).

were small and fragile in the cross-modal naming task, they seemed to reflect an automatic spreading activation that could not be overridden by violations of the sentence context.

Associative versus sentential priming. As in Experiment 1B, the results of the cross-modal lexical and sentential priming task were analyzed to determine whether they were affected by the presence of lexical associates. Analyses parallel to those reported in Experiment 1B revealed no significant correlations between any of the priming difference scores and strength of associates in the sentence or strength of association between prime and target. From these analyses it was clear that sentential effects were not simply the product of strength of association between prime and target or strength of the associates in the sentence itself.

SUMMARY AND DISCUSSION

In the present study, lexical (word–word) and sentential (sentence–word) priming were studied, in competing and converging combinations, using temporal parameters designed to investigate early processing. A word pair was visually presented immediately after the offset of an auditory sentence context; the duration of the prime was set at either 100 or 200 ms; the interval between the words in the pairs was either 0 or 100 ms; the target was available for only 200 ms before it disappeared and the auditory sentence context continued. These materials were employed with two different tasks: cross-modal lexical decision and cross-modal naming.

Preliminary experiments (1A and 2A) showed that significant lexical priming was obtained on both tasks, under all temporal conditions, when semantically related and highly associated word pairs were presented out of context. The magnitude of lexical priming in isolation did not vary as a function of the four temporal conditions in either experiment, although lexical priming effects were larger overall in lexical decision, which elicited reaction times more than 300 ms slower than in cross-modal naming on the same word pairs. None of these findings were surprising; they were, however, a necessary precondition to the study of lexical priming when the word pairs were nested in competing or converging sentence contexts.

The factorial design of Experiments 1B and 2B permitted us to evaluate separate lexical and sentential priming effects, along with any interactions that might emerge between the two forms of priming, both within and across temporal conditions. In lexical decision, both sentential and lexical priming were present in every temporal condition. Although sentential priming effects were substantially larger than lexical priming effects, the two were additive.

In cross-modal naming, which produced much faster reaction times overall, sentential priming was significant in every temporal condition; lexical priming proved to be relatively fragile, interacting with sentential priming and temporal conditions. For example, there was no significant main effect of lexical priming when the interval between the word pair was longer (100 ms ISI). At the shorter interval (0 ms ISI), lexical priming reached significance only when sentential integration failed: that is, when the target did not fit the sentence context (see Figure 2). This finding constituted a replication of Hernandez and Bates (1994), who used similar temporal parameters (200/0), but very different materials.

We considered the possibility that our robust sentential effects might actually be lexical effects, due to the presence of lexical associates in the sentence (Fodor, 1983). In both Experiments 1 and 2, we conducted a series of post-hoc analyses to determine whether sentences with 0, 1, or 2 lexical associates differed in the magnitude of the priming effects observed (lexical or sentential). No effect of lexical associates was found, which led us to conclude that the sentential priming effects observed here were due to the global meaning of the discourse as a whole; they were not an artifact of cumulative (but structure-independent) lexical priming.

Within each temporal condition, we included a neutral baseline in which there was no semantic relation between the sentence context, the prime, and the target (e.g., "The man was walking down the [APPLE–CLOCK]"); this was done to determine whether the sentential and lexical priming effects were facilitative or inhibitory in nature. The search for a valid neutral baseline for this evaluation has been a frustrating problem in the priming literature. The problem is present in research examining lexical priming (where many investigators have abandoned the use of baselines altogether), but it is even more prevalent in research uncovering the effects of single-sentence or multi-sentence discourse. What, after all, is a neutral paragraph? For this reason, we handled all comparisons to the neutral baseline in post-hoc analyses and presented the results with a degree of skepticism. However, to the extent that these comparisons are useful, our results suggested that sentential priming may involve some kind of facilitation: that is, a semantic relation may facilitate processing, compared to a situation in which no element is related.

In both tasks, post-hoc comparisons showed that sentential priming effects produced reaction times that were significantly faster than those in the neutral baseline condition. Results for lexical priming were less straightforward. In lexical decision, we obtained a small, but reliable, main effect of lexical priming that was independent of sentence congruence in the analysis of variance. Nevertheless, comparisons with the neutral baseline showed that lexical priming produced reaction times that were no faster than those in the neutral baseline when the two related words did not fit the sentence context (e.g., "The man was walking down the [APPLE–ORANGE]" vs. "The man was walking down the [APPLE–CLOCK]"). Hence, it would appear that the lexical priming effect may have been truncated or overridden by incongruent sentence contexts in the (relatively slow) lexical decision task. By contrast, the corresponding condition in Experiment 2B produced reaction times that were significantly faster than those for the neutral baseline in three of the four temporal conditions. Following this logic, we may speculate that lexical priming did not have time to decay and/or was not completely overridden by sentence context in the (relatively fast) cross-modal naming task.

If this interpretation is correct, what happens to lexical priming when a related word pair does fit the context (e.g., "The man was walking down the [STREET–ROAD]")? The pattern of results in Figure 2 suggests that lexical and sentential priming are facilitative in nature, but they are not always additive – at least not within a cross-modal naming task. In the 0 ms ISI conditions, no lexical priming was observed in congruent sentences (e.g., no difference was found between [STREET–ROAD] and [APPLE–ROAD]), although both produced reaction times that were faster than those in the neutral baseline condition. There are several possible interpretations of this finding.

The least interesting interpretation would be that these cells reflect a floor effect: reaction times simply cannot get any faster. This interpretation could be used to salvage the multimechanism view, explaining why additive effects are not always observed. However, in view of the fact that the same pattern held with 100 ms and 200 ms prime durations, which varied significantly in overall timing (i.e., reaction times were faster with a longer prime duration), an interpretation in terms of absolute (motor) floor effects seems unlikely.

A more interesting interpretation would be that these cells reflect a kind of semantic floor effect: the sentence has already predicted the identity of the word so well that the related words (e.g., ROAD–STREET) cannot make things any clearer. The only effect that an intervening prime word could have in this semantic condition would be to distract or interfere with the identification (confirmation or selection) of the predicted target word, thus increasing reaction times for incompatible word pairs (e.g., APPLE–STREET). In the cross-modal naming task, with 0 ms ISI between prime and target, there may not have been time for this kind of interfering effect to build up, so that ROAD–STREET and APPLE–STREET yielded comparable reaction times. This finding is compatible with the view that lexical priming and sentential priming are not the product of two separate stages of processing. If this were the case, sentence priming would not be able to override lexical priming. This interpretation could also explain why sentential priming effects were substantially larger than lexical priming effects, both within and across tasks and temporal conditions.

There is a third possible interpretation. Our findings constitute a partial replication of Hernandez and Bates (1994), but there is one aspect of their results that we failed to replicate here. In the earlier study, reaction times to lexically related word pairs (ROAD–STREET) presented in a congruent sentence were significantly slower than reaction times in the neutral baseline condition. Hernandez and Bates suggested that this may occur because the listener tries to integrate the congruent word prime into the sentence context, leading to a momentary competition between the first (e.g., ROAD) and second (e.g., STREET) word, both of which could fill the same slot. This kind of lexical competition has been observed in production tasks such as picture-naming at very short windows (for a review, see Glaser, 1992). For example, if a prime (CAT) is presented within 150 ms of a semantically related target (DOG), speakers respond significantly slower than they would if the prime had not been related (CUP). In short, the retrieval of a word may be slowed down by the presence of a semantically related competitor. We did not replicate this interference effect in the present study; the materials used here were less naturalistic, but better controlled, than those employed by Hernandez and Bates. However, we must be open to the possibility that our design evoked a combination of lexical priming (e.g., priming from ROAD to STREET) and lexical interference, created by the very early integration of the prime into a congruent sentence context (i.e., interference from ROAD to STREET). In some of the early time windows in cross-modal naming, these two forms of priming may have cancelled each other out. Note, however, that this effect was not present in lexical decision. Hence, it is possible that this effect appears only when participants have to retrieve the correct word. We are currently conducting studies designed to examine these possibilities.

What model might account for how sentential and lexical contexts influence word recognition? One possibility is that sentence context may influence one (or more) of the processes that are thought to account for lexical priming. Earlier, we presented Neely's three-process model, which proposes that spreading activation, semantic expectancy, and plausibility checking affect the speed with which a prime influences the recognition of a target. One could envision that sentential priming of a target occurs in much the same manner. Sentential context could influence the semantic expectancy set and influence the plausibility of the word. When word pairs are presented in isolation, the expectancy set of the prime accelerates processing of the target. In addition, plausibility checking of the target, given the prime, leads to faster responses to a related target. Hence, sentential contexts can alter the influence of lexical contexts because two of the underlying processes are shared by both. What should we conclude about spreading activation? This mechanism appears to be immune to sentence contexts. We found that lexical priming occurred, but only when the word did not fit the sentence context. In this condition, both words were unrelated to the sentence but were semantically related to each other. According to Neely's model, spreading activation would predict exactly what we found. We propose that spreading activation provides a backup for when sentence integration fails. Although our results fit very well with current views on how lexical and sentential contexts affect word recognition, they do not support the view that lexical and sentential priming occur at discrete stages.

Finally, we would like to point out that the competitive priming technique illustrated here may have broader applications in psycholinguistic research. For example, we are completing a series of studies with bilingual listeners in which lexical and sentential priming are examined in a within-language context (Spanish only; English only) and in between-language contexts (Spanish words nested in English; English words nested in Spanish; word–word combinations that are or are not translation equivalents). The technique could also be used to assess the relative strength and contribution of sentential versus lexical contexts at different points in language development to determine which form of priming has developmental priority.

ACKNOWLEDGEMENTS

Support for this research was provided by a minority graduate supplement to Arturo Hernandez in association with the grant "Cross-linguistic Studies in Aphasia" (NIH/NIDCD Grant #2-ROI-DC00216-10), the grant "Aging and Bilingualism" (NIA Grant #5-R01-AG13474-02), National Science Foundation and McDonnell-Pew Center for Cognitive Neuroscience Graduate Fellowships to Christine Fennema-Notestine, and a McDonnell-Pew Center for Cognitive Neuroscience Post-Doctoral Fellowship to Arturo Hernandez. We would like to thank David Ramirez, Patricia Eshagian, and Crystal Sevilla for their assistance in data collection and Ronald Figueroa, Lorena Huerta, Luis Avila, Robert Buffington, and Larry Juarez for technical support. Finally, we would like to thank Roberto Heredia and Greg B. Simpson for comments on earlier drafts of this manuscript. Portions of this article were presented at the eighth annual CUNY conference on Human Sentence Processing, Tucson, AZ.

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