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Repetition Blindness: Levels of Processing

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Repetition blindness (RB) is the failure to detect or recall repetitions of words in rapid serial visual presentation. Experiment 1 showed that synonym pairs are not susceptible to RB. In Experiments 2 and 3, RB was still found when one occurrence of the word was part of a compound noun phrase. In Experiment 4, homonyms produced RB if they were spelled identically (even if pronounced differently) but not if spelled differently and pronounced the same. Similarly spelled but otherwise unrelated word pairs appeared to generate RB (Experiment 5), but Experiment 6 produced an alternative account. Experiments 7 and 8 demonstrated that repeated letters are susceptible to RB only when displayed individually, not as part of two otherwise different words. It is concluded that RB can occur at either an orthographic (possibly morphemic) level or a case-independent letter level, depending on which unit (words or single letters) is the focus of processing.

Repetition blindness (Kanwisher, 1986, 1987) is the failure to detect second occurrences of repeated words presented in rapid serial visual presentation (RSVP). This phenomenon occurs at rapid presentation rates even when as many as three words intervene between the two instances of the repeated word and even when the two differ in appearance (upper- vs. lowercase). Repetition blindness (RB) was demonstrated most clearly when repeated words were embedded in sentences and presented in RSVP (at about 8 words/s) for immediate verbatim recall (Kanwisher, 1987). Although overall recall for unrepeated words was high, subjects selectively omitted second occurrences of repeated words, sacrificing sentence meaning and grammaticality. For example, after viewing the sentence "When she spilled the ink there was ink all over," most subjects responded with something like "When she spilled the ink there was all over," whereas with the control sentence "When she spilled the liquid there was ink all over," the word *ink* was rarely left out.

Repetition blindness has been interpreted in terms of a distinction between type recognition and token individuation. In recognition, a word is identified as a type (e.g., the word *chair*); in individuation, an item is characterized as a particular token of a given type (e.g., as the second instance of the word *chair*). Kanwisher (1986, 1987) offered the following account of repetition blindness: Even though the second instance of a repeated word is recognized as a type, it is not individuated as a distinct token when it occurs too soon after the first instance. Instead, the second instance is assimilated to the first instance, and only one token of that word type is registered consciously. One piece of evidence that recognition (type activation) of the second occurrence is not blocked is that threshold recognition of the last word in an RSVP list is helped, not hindered, by a prior occurrence of that word in the same list (Kanwisher, 1986, 1987).

In a further study, Kanwisher and Potter (1989) showed that repetition blindness is a specifically visual phenomenon; it does not occur when sentences containing repeated words are presented auditorily in rapid (compressed) speech. Further, they showed that the effect is not diminished when the two occurrences are presented in different spatial locations. Thus, repetition blindness cannot be explained simply in terms of the visual system's requirement of spatial information to distinguish between like tokens.

Repetition Blindness and Other Repetition Phenomena

In previous studies of repetition effects on perception and memory, both positive and negative effects have been reported. A discussion of positive effects is postponed until the General Discussion; here, we consider some of the negative effects previously reported. Humphreys, Besner, and Quinlan (1988) found that when an unmasked priming word immediately precedes a masked target word, identification of the target is more difficult when mask and target are identical (except for case). This finding can be seen as a special case of RB in which there are no items intervening between the two occurrences of the repeated word. The effect reverses sign, however, when the prime itself is masked so that it cannot be reported. This observation is consistent with the claim (Kanwisher, 1986, 1989) that it is token individuation (rather than type recognition) of the first occurrence that causes RB for the second occurrence. (It also helps resolve the apparent conflict between RB and the vast literature on positive priming effects; see General Discussion.)

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Marohn and Hochhaus (1988) reported on a similar case of zero-lag repetition blindness (which they call "perceptual blindness"), characterized by poorer identification accuracy and shorter perceived duration for repeated items. It is worth noting that in their study prime and target appeared in two different locations. This accords with findings of Kanwisher and Potter (1989), who showed that RB occurs even when the two instances of the repeated word appear in different locations. It also agrees with Kaufman's (1977) finding that visual detection of repeated digits in rapid sequences was not affected by a change of location or font between the two occurrences when there was at least one intervening item. (Although Kaufman's repetition detection rates are comparable to those of Kanwisher, 1987, Kaufman was not in a position to assess repetition blindness because she had no baseline of performance on unrepeated items.)

Mozer (1989) reported that subjects more severely underestimate the number of letters in a simultaneously presented string of letters if the string contains repeated letters. He further showed that this "homogeneity effect" (named by Frick, 1987), has both an abstract letter-level component and a lower level configural component and that it occurs only under attention-limited conditions. MacKay's (1969, 1987) studies of misspelling of words with repeated letters and related phenomena and Morotomi's (1981) demonstration of masking with repeated Japanese characters may also be cases of RB.

Another phenomenon that may also be a case of RB is the repeated-letter inferiority effect (Santee & Egeth, 1980; see also Bjork & Murray, 1977), in which responses to a target letter are less accurate when the nontarget flanking letters are identical to the target than when they are different. Although these investigators have interpreted their findings in terms of "feature-specific inhibition" or a higher level equivalent (Egeth & Santee, 1981), others (e.g., Keren & Boer, 1985) have argued that the effect is more a function of positional uncertainty—an account that is compatible with the type/token view offered here.

Although the findings just reviewed may well be related to RB, several well-known findings superficially resemble RB but are probably *not* related in any deep way. One is the "spacing" or "lag" effect (Melton, 1967) in which the benefit of repetition on recall of items from lists increases with the number of intervening items between the two occurrences. Like RB, the lag effect has been explained as "the second occurrence [being] short changed at conditions of massed repetition" (Crowder, 1976, p. 284). But, unlike RB, the lag effect occurs only when repetitions have been successfully detected (Crowder, 1976, p. 289). Thus, the lag effect is a contextual effect on how already-individuated items are stored, whereas the diminution and eventual disappearance of RB as lag increases up to 500 ms (Kanwisher, 1987) consists of an improved chance that a repeated word will be individuated in the first place.

Another phenomenon that superficially resembles RB is the Ranschburg effect (see Jahnke, 1969)—a difficulty in reporting strings containing repeated items. Kanwisher (1987) described several important differences between the Ranschburg effect and repetition blindness and argued that none of the proposed explanations of the Ranschburg effect can account for repetition blindness.

Finally, Allport, Tipper, and Chmiel (1985) described the "negative priming" effect of an ignored distractor letter on a subsequent identical target letter. They proposed that this effect occurs because it is hard to bind one letter identity to two different physical features (i.e., the distractor color, which was green, and the target color, which was red). Though this account bears some relation to the RB model (Kanwisher, 1987), it was disconfirmed by Tipper and Cranston (1985) in favor of a response inhibition model.

Levels of Processing in Repetition Blindness

This study addresses which levels of processing are involved in RB. Letters and words are used because the levels of language processing have been characterized in detail. It should be noted, however, that RB also occurs for other types of visual stimuli such as colors (Kanwisher, 1989) and probably pictures (Potter, 1986).

Because RB occurs over changes in letter case (Kanwisher, 1987), it must occur at a level more abstract than one encoding pure visual form. On the other hand, the absence of "repetition deafness" for rapidly spoken sentences suggests a level before auditory and visual inputs converge (Kanwisher & Potter, 1989). A natural guess, then, is that RB takes place at the visual lexical level. The available evidence, however, is inadequate to decide the issue. The fact that whole words are lost in RB does not necessarily imply a lexical basis for the phenomenon; RB could in theory result from repetitions of abstract letter identities, letter clusters, words, or even meanings. The following experiments investigate these possibilities.

Experiment 1

Do meanings suffer repetition suppression, even when those meanings are represented by different words (i.e., synonyms)? If so, one would have to conclude that RB occurs (at least in part) at a level of processing beyond the lexical level, presumably a conceptual level. The failure to find "repetition deafness" for rapid auditorily presented sentences would seem to contradict the possibility, because visual and auditory inputs presumably converge before conceptual representations are reached. There remains a possibility that RB occurs at a conceptual level but that auditory information is sufficient to overcome it (see, e.g., Kanwisher & Potter, 1989). If RB is restricted to early levels of processing, such as those involved in visual recognition, then pairs of words with equivalent meanings but different lexical identities would not be subject to RB.

In order to investigate this question, synonym pairs were embedded in sentences. Earlier research had shown that it is primarily the second occurrence of a repeated word that is affected, not the first, so this study was designed to compare recall performance in three conditions in which the second word (R2) was held constant but the first work (R1) was varied. In the repeated condition R1 was the same word as

R2. In the synonym condition, R1 was a synonym of R2. In the unrepeated (control) condition, R1 was a new word different from R2 in form and meaning. There was also a second control condition, the blank condition, in which R2 was omitted.

If RB happens at the level of words, not meanings, then R2 recall should be equivalent in the synonym condition and the unrepeated condition. However, if the phenomenon occurs also (or entirely) at the conceptual level, then the synonym condition should produce some RB, although perhaps not as much as the repeated condition in which the two meanings are identical.

Method

Subjects. Twenty-four subjects from the subject pool at the Massachusetts Institute of Technology participated in this experiment. They were native speakers of American English and were under 30 years of age. They were paid for their participation.

Materials. Twenty pairs of noun synonyms were chosen. An attempt was made to choose pairs that were very close in meaning. One of the pair was randomly selected to occur second in the sentence (R2). R1 and R2 were embedded in sentences such that there were one to three words intervening between them; R2 was never the last word in the sentence. The sentences were written so that removal of R2 always left an ungrammatical or highly anomalous sentence. The sentences are shown in Appendix A.

In the repeated condition, R1 was the same word as R2. In the synonym condition, R1 was the other member of the synonym pair. In the unrepeated condition, R1 was exchanged for a word unrelated to R2. In all cases the resulting sentence was acceptable.

The blank condition was like the repeated condition except that R2 was omitted, leaving an ungrammatical sentence. This condition was included to see how often subjects would intrude the critical word when they did not see it. The blank condition might be expected to aid R2 detection in the repeated condition by providing a contrast between repeated and omitted R2s. At the same time, the inclusion of the ungrammatical blank sentences—if subjects saw them accurately—would encourage subjects to report what they actually saw regardless of grammaticality. In this and the other experiments in the present article, the accuracy of reporting R1 was in the same range for the blank condition as for the other conditions. Intrusions of R2 in the blank condition were uncommon in most of the experiments. Therefore, the results for the blank condition are not ordinarily reported except when there were more than 10% intrusions of R1 in place of the missing R2.

Design and procedure. The four conditions of each sentence (synonym, repeated, unrepeated, and blank) appeared in four versions of the experiment, counterbalanced so that a given subject saw 5 sentences in each condition for a total of 20 test sentences per subject. Five filler sentences without repetitions were added to provide more variety in sentence structure.

Each trial began when the subject pressed the space bar on the computer keyboard. A row of asterisks appeared for 750 ms at the same location as the subsequent words. Then the sentence appeared one word at a time in the same place, for 117 ms per word. Except for an initial capitalized word, all words were in lowercase.

Subjects were instructed to read the sentence as carefully as possible and to recall it aloud as soon as it ended. Subjects were warned that some sentences would be strange or ungrammatical but that they were to repeat them "as is," without "fixing them up." Two practice sentences preceded the experimental sentences.

Apparatus. In this and all experiments reported here, the stimuli were presented on a CRT (cathode ray tube) screen with a rapid fade phosphor, controlled by either a Terak microcomputer or an IBM AT. Each word subtended about 2° of visual angle. The experiment was carried out in normal room illumination.

Results and Discussion

Overall, recall accuracy for the sentences was high. The percentages of correct recalls of R1 and R2 were scored separately for the synonym, repeated, and unrepeated conditions and are given in Table 1. Recall of R1 averaged 93%, which was representative of recall of the other words of the sentence (other than R2) in the present experiments. The primary focus of Experiment 1 was on recall of the critical word (R2), which was recalled on 40% of repeated trials, 85% of synonym trials, and 92% of unrepeated trials. Analyses of variance on the percentage of correct recalls of R2 showed a significant main effect of condition, $F'_{min}(2, 74) = 23.8$, $p < .001$. A Newman-Keuls test showed that recall of R2 was significantly lower in the repeated condition than either the synonym, $q(2, 46) = 13.5$, $< .01$, or unrepeated, $q(3, 46) = 15.3$, $p < .01$, condition but that the latter conditions did not differ, $q(2, 46) = 1.7$.

Although this experiment was not designed to look at the effect of repetition on R1 because R1 was a different word in each condition, the data nevertheless provide an approximate measure of the effect of a subsequent repetition on recall of R1: There was no main effect of condition in either subject or item analysis (both $Fs = 1.7$, $p = .10$).

One concern about the present results is that R2 could usually be paraphrased by a simple referring pronoun (such as "it" or "they") in the repeated condition, but not in the other conditions. Subjects might have simply included R2 less often in the repeated condition than the unrepeated or synonym condition because they were paraphrasing R2. Such pronoun intrusions were made on 4 synonym trials (3%), 10 repeated trials (8%), 5 unrepeated trials (4%), and 16 blank trials (13%; note that R1 itself was never intruded). The blank condition provides a baseline for the probability of intruding a pronoun when R2 was not seen. Thus if the trials in which subjects omitted R2 in the repeated condition (60%) were equivalent to blank trials, we would expect $16 \times 0.6 = 9.6$ pronoun intrusions in the repeated condition; 10 such intrusions were observed. We can therefore reject the hypothesis that the observed low report of R2 in the repeated condition was due to paraphrasing of a perceived R2 rather than to RB.

To sum up, Experiment 1 showed that under conditions in which repetition of a word produces repetition blindness, repetition of a concept (by means of a synonym) does not.

Table 1
Percentage of Correct Recalls of R1 and R2, Experiment 1

Critical word	Condition		
	Synonym	Repeated	Unrepeated
R1	94	90	97
R2	85	40	92

Experiment 2

Although Experiment 1 showed that sameness of meaning is not sufficient to cause repetition blindness, it was not yet clear whether RB occurred at the level of words, morphemes, or letters. In Experiment 2 the effect on RB of presenting a word as part of a compound expression was examined. Compound expressions that have become petrified and have taken on special shades of meaning (such as *heart attack* or *hot dog*) are considered to constitute single lexical items (Lyons, 1977), even when they are written as two separate words. Thus, if RB is a strictly lexical phenomenon, it should happen less often when one of the occurrences is part of such a compound expression and the other is not. Compounds can be contrasted with other noun phrases (e.g., *epilepsy attack* or *wet dog*). RB for words that were parts of compounds was compared with RB for words in ordinary noun phrases. In Experiment 2 the two words in a compound or noun phrase were presented successively in RSVP; in Experiment 3 the two words composing a compound were presented simultaneously as a single word.

A second question was also addressed in Experiment 2: Does the syntactic category of a word affect the word's sensitivity to RB? In the experiments already reported, the critical words were always open class words. Much recent work (Bradley, Garrett, & Zurif, 1980; Rosenberg, Zurif, Garrett, & Saffran, 1982) suggests that closed class words (such as prepositions and modals) are processed differently from open class words. Although this work has come under attack (Gordon & Caramazza, 1982; Segui, Mehler, Frauenfelder, & Morton, 1982), if it is valid it indicates that open class items, but not closed class items, are accessed via frequency-sensitive routes. Thus, if RB reflects phenomena involved in lexical access, it is possible that RB would not affect closed class items to the same extent as the open class words used in our previous studies. In order to explore this question, Experiment 2 included a set of sentences in which closed class words were repeated.

Method

Subjects. Twenty subjects from the pool described earlier participated in this experiment.

Materials. Compounds and their noun-phrase controls: Sixteen compound expressions were selected to meet several criteria. First, compounds were acceptable only if the first word of the compound was necessary to preserve the general meaning of the phrase, as in *sand bar* (but not *log cabin*). Second, the compound had to be acceptable when written as two separate words (e.g., not *butter fly*).

For each compound, a sentence was written that contained that compound as well as a repetition of one of the component words of the compound (e.g., "Sailors in *bars* discuss *sand bars* which are dangerous"). The sentences never had more than three words intervening between the repeated words. For half of the items, the compound preceded its repeated component, and for the other half the compound came second. For nine of the items, it was the head noun of the compound that was repeated in the same sentence (e.g., *bars . . . city bars*); for seven of the items, it was the first word in the compound (*saw horse . . . saw*).

For each compound a corresponding noncompound noun phrase was composed (e.g., *city bars* for *sand bars*, *dry sticks* for *fish sticks*). The sentences were written such that the noncompound control noun phrase could be substituted for the compound (e.g., "Sailors in *bars* discuss *city bars* which are dangerous"). The sentence was occasionally slightly altered to accommodate the new phrase. The materials are shown in Appendix B.

Each version of the sentence appeared in four different conditions. The first two, compound and (noncompound) noun phrase, both contained (the same) repeated words (R1 and R2). The unrepeated condition was created from the compound sentence by changing R1 to a new word (e.g., "Sailors in *pubs* discuss *sand bars* which are dangerous"). Last, in the blank condition R2 was removed from the compound sentence (e.g., "Sailors in *bars* discuss *sand* which are dangerous").

Closed class words: Sixteen sentences were constructed in which the repeated word was a closed class word. These sentences, given in Appendix B, all contained a compound or noun phrase (this served the auxiliary purpose of reducing the subject's expectation that words in compounds would be repeated). Half of the trials (eight per subject) were repeated; one fourth (four per subject) were unrepeated, with R1 exchanged for a different closed class word; and one fourth (four per subject) were blank, with R2 removed, which left an ungrammatical sentence.

Design and procedure. The conditions and sentences were counterbalanced over the four versions of the experiment. The design, procedure, and apparatus were like those of Experiment 1.

Results

The compound and closed class trials were analyzed separately; the percentages of correct recalls are shown in Table 2. For the compound materials there was little effect of repetition condition on R1, which was recalled more than 90% of the time in all three main conditions. However, there was an effect of repetition condition on recall of R2, $F'_{min}(2, 64) = 6.6$, $p < .005$. Newman-Keuls tests showed that the unrepeated condition differed from both the compound, $q(3, 38) = 8.1$, $p < .01$, and noun-phrase, $q(2, 38) = 7.8$, $p < .01$, conditions but that these did not differ from each other, $q(2, 38) = 0.29$. A post hoc examination of sentences in which the compound came first or second (and the critical word was the first or second word in the compound) did not reveal any consistent pattern of differences in RB.

For the closed class materials, R1 was recalled equally often in repeated and unrepeated conditions. For R2, repeated and unrepeated conditions were significantly different, $F'_{min}(1, 30) = 3.5$, $p < .05$. R2 was intruded on 21% of the blank trials. This high intrusion rate is discussed below.

Table 2
Percentage of Correct Recalls of R1 and R2 for Compound and Closed Class Materials, Experiment 2

Critical word	Condition		
	Compound	Noun phrase	Unrepeated
Compound			
R1	94	92	99
R2	34	35	68

	Condition	
	Repeated	Unrepeated
Closed class		
R1	86	88
R2	36	72

Discussion

Closed class words. The analysis of closed class items shows that recall was much lower on repeated than unrepeated trials, so closed class words are evidently susceptible to RB. Hence, whatever the mechanism of repetition blindness is, it does not seem to discriminate among these different syntactic categories of words. What does seem to distinguish open and closed class words is the propensity to intrude an omitted word; the rate of R2 intrusions on blank trials was higher than in any experiment we have carried out. This propensity to supply missing (and often predictable) closed class items has been noted in previous RSVP work (Potter & Kroll, 1984). What the 21% intrusion rate does suggest is that the true RB rate may be even greater for closed class words than Table 2 indicates.

Compounds. Overall, it made no difference whether a repeated word occurred once as part of a compound or as part of a noncompound noun phrase; RB was equivalent in the two cases. The repeatedness effect was significant and similar in magnitude to that seen in earlier experiments in which critical words were not components of multiple-word noun phrases. Evidently being encoded as part of a compound does not individuate a word sufficiently to prevent RB. Whatever the units may be that are suppressed in RB, they do not differentiate between a word in a compound and a word in a noun phrase, and both of these seem to be equivalent to a noun standing alone.

This result casts some doubt on the idea that it is lexical units as linguistically defined that are suppressed in RB, because components of compound noun phrases do not function as whole lexical items in these sentences. On the other hand, one could argue that because the compounds were broken up in the display, their components were treated (at least initially) as distinct lexical items. This hypothesis would predict that if the compound components were run together and displayed simultaneously as one word (e.g., *sandbars*), one might not find RB for compound components. This question was pursued in the next experiment.

Experiment 3

In Experiment 3, compounds were presented in RSVP sentence contexts, either run together as single words in the "glued" condition (e.g., *hotdogs*) or one component at a time as in Experiment 2 (*hot dogs*). It was predicted that having a word appear as part of a glued compound (as compared with a split compound) might reduce or eliminate repetition blindness when that word also appeared by itself elsewhere in the same sentence.

Method

Subjects. Twenty subjects from the pool previously described participated in the experiment.

Materials. Compounds were chosen that were acceptable in both split and glued forms. Sixteen sentences (much like those in Experiment 2) were written, each including the compound and one of its component words, with no more than three intervening words. For half of the sentences, the compound appeared earlier in the sentence than its constituent word ("compound-first"), and for the other half the compound came afterward ("compound-last"). Each sentence appeared in four different conditions, created by crossing format (split/glued) by repetition (repeated/unrepeated). For compound-first sentences, unrepeated R1s were created by exchanging R1 (the repeated component of the compound) for another word that could form a new compound with the nonrepeated component. For example, one sentence in the repeated condition was "She could see the lovely flowerbed from her bed every morning;" in the unrepeated condition it was "She could see the lovely flowerbox from her bed every morning."

Design and procedure. Each of the 16 test items appeared in each of the four conditions, counterbalanced across four versions of the experiment. In each version there were 4 items in each condition. For each of these conditions, half of the items were compound-first and half were compound-last. In addition, there were eight filler blank trials with sentences similar to the experimental sentences but with different compounds; R2 was omitted on these trials. In all other respects Experiment 3 was identical to Experiment 2.

Results and Discussion

Table 3 shows the percentage of recalls of R1 and R2. A subject analysis of the R1 responses showed no significant effects of repetition or format (glued vs. split); overall, R1 was reported correctly 86% of the time. For R2 recalls there was a significant main effect of repetition, $F'_{min}(1, 31) = 10.7$, $p < .005$, but no main effect of format, $F_1(1, 19) = 1.6$ and $F_2(1, 14) = 1.2$, both $ps > .20$, or compound-first/last ($F_1 < 2$ and $F_2 < 1$). The interaction of repetition by format reached significance in the subject analysis, $F(1, 19) = 4.9$, $p < .05$, but not in the item analysis, $F(1, 14) = 3.7$, $p = .075$. No other main effects or interactions reached significance.

Separate analyses of the split and glued conditions showed that the repetition effect was independently significant for each: $F_1(1, 19) = 35.9$, $p < .001$ and $F_2(1, 14) = 14.9$, $p < .005$ for the split condition; $F_1(1, 19) = 7.1$, $p < .02$ and $F_2(1, 14) = 5.0$, $p < .05$ for the glued condition. Although the split condition showed a compound-first/last effect, $F_1(1, 19) = 10.5$, $p < .005$ and $F_2(1, 14) = 3.0$, $p = .1$, the glued condition did not, $F_1(1, 19) = 1.3$, $p = .3$; $F_2(1, 14) = 0.5$, $p = .5$. However, the interactions of repetition by compound-first/last were not significant for either the split or glued condition analyses (all $Fs < 1.5$, all $ps > .2$), so the apparent loss of RB in the glued compound-first condition was not reliable.

These results indicate that although gluing the components of a compound together into one word reduces the extent of RB when one of the components appears elsewhere in the same sentence, such gluing does not eliminate the effect altogether. Thus, RB is robust enough to remove a repeated piece of a compound even when the compound is displayed as one contiguous word. It is of interest that when this happened, subjects reported the other part of the compound on 76% of split trials and 64% of glued trials. Several subjects even expressed surprise or outrage after viewing the sentence "Unless they are hot enough, hotdogs don't taste very good." This experiment lends further support to the claim that the units involved in RB are not strictly lexical, because a compound is a different word from either of its components. On the other hand, these results do not speak to the issue of whether RB requires morphemic—as opposed to merely orthographic—overlap of R1 and R2.

Table 3
Percentage of Correct Recalls of R1 and R2, Experiment 3

	Condition					
	Split		Glued		Mean	
Critical word	Rep.	Unrep.	Rep.	Unrep.	Rep.	Unrep.
			R1			
Compound-first	80	85	92	92	86	89
Compound-last	90	80	90	80	90	80
M	85	82	91	86	88	84
			R2			
Compound-first	28	68	65	72	46	70
Compound-last	52	82	48	72	50	78
M	40	75	56	72	48	74

Note. Rep. = repeated; Unrep. = unrepeated.

Experiment 4A

A more direct test of the role of lexicality in repetition blindness is possible with the use of homograph pairs, pairs of identically spelled but distinct lexical items such as (money) *bank* and (river) *bank*. If RB respects only orthographic form and not lexical identity, then we might expect it to be as severe for homographs as for repetitions of identical words. This question can be refined further: homographs can be either homophonic, as in (she) *rose* and (the) *rose*, or heterophonic, as in (the) *wound* and (he) *wound*. If RB is only a function of orthography, independent of either lexical identity or phonological form, then both homophonic and heterophonic homograph pairs should manifest RB. Finally, one can test the role of phonology without orthographic identity with heterographic homophones such as *thyme* and *time*. If RB is solely a function of phonological identity then these pairs should be as susceptible as homographic homophones. In Experiment 4A we tested these predictions by embedding the different types of word pairs in sentences and presenting them in RSVP for immediate recall.

Method

Subjects. Twenty-four subjects from the pool previously described participated in the experiment.

Materials. There were four types of R1–R2 pairs in this experiment: (a) identical controls, for example, *cat-cat*; (b) homophonic homographs, for example, (she) *rose*–(the) *rose*, hereafter called *homonyms*; (c) heterophonic homographs, for example, (he) *wound*–(the) *wound*), hereafter called *homographs*; and (d) heterographic homophones, for example, *thyme–time*), hereafter called *homophones*. Nine word pairs of each type were selected. They were embedded in disambiguating sentences such that there were never more than three words intervening between R1 and R2. The resulting sentences were somewhat strained, but in all cases they were grammatical and clear in meaning. The materials are shown in Appendix C.

Design and procedure. Each item appeared in three conditions (repeated, unrepeated, and blank), although the precise nature of the repeated condition depended on the item type (e.g., for homophones in the repeated condition, R1 might be *thyme* and R2 *time*). Items were counterbalanced across three versions of the experiment, with three items of each type in each condition in each version of the experiment. As in earlier experiments, subjects were instructed to read the sentence as carefully as possible and to repeat it verbatim as soon as it ended. In all other respects this experiment was identical to Experiment 1 in design and procedure.

Results and Discussion

The percentage of correct recalls of R1 and R2 for the different pair types is shown in Table 4 (top portion). For R1 no main effects were significant, although the Repeatedness × Type interaction did reach significance in the subject analysis, $F_1(3, 66) = 4.3$, $p = < .01$; $F_2 = 2.0$, *ns*. Analysis of the R2 responses showed significant main effects of repeatedness, $F'_{min}(1, 51) = 27.7$, $p < .001$; pair type, $F'_{min}(3, 52) = 5.8$, $p < .005$; and a significant Repeatedness × Pair Type interaction for the subject analysis, $F_1(3, 66) = 4.5$, $p < .01$, but not the item analysis, $F_2(3, 32) = 2.7$, $p = .06$. Separate analyses of each pair type showed that the repeatedness effect was highly significant for all pair types except homographs, which reached significance in the item analysis, $F_2(1, 8) = 5.3$, $p = .05$, but not the subject analysis, $F_1(1, 22) = 3.0$, $p < .10$.

The fact that homographs showed only marginally significant repetition blindness is surprising. Correct recalls of R2 for homographs in the repeated condition were in the same range as other word types; what seems to be different about the homographs is instead their performance in the *unrepeated* condition, which was much lower (and higher in variance) than the other item types.

There is a hint (see Table 4, upper portion) that part of the RB effect may have been located in R1 for homographs, as reflected in the significant F_1 interaction between repeatedness and type for R1 (reported above).

Experiment 4A confirms the tentative conclusion from Experiments 2 and 3 that when two identically spelled words

Table 4
Percentage of Correct Recalls of R1 and R2, Experiments 4A and 4B

	Critical word			
	R1		R2	
Pair type	Rep.	Unrep.	Rep.	Unrep.
Experiment 4A				
Identical *cat–cat*	94	86	50	94
Homonym (the)/(she) *rose*	96	86	38	82
Homograph (he)/(the) *wound*	76	89	43	60
Homophone *thyme–time*	93	96	76	99
Experiment 4B				
Identical *cat–cat*	93	89	54	93
Homonym (the)/(she) *rose*	91	85	48	85
Homograph (they)/(the) *wind*	89	85	50	87
Homophone *eye–I*	65	78	67	69

Note. Rep. = repeated; Unrep. = unrepeated.

are repeated in a sentence, differences in their meanings as determined by the sentence context are ineffective in preventing repetition blindness. The seemingly smaller RB effect for homographs and the substantial effect for homophones together seem to suggest that similarity of pronunciation may be a factor in RB. That would be very surprising, given the failure to observe RB for spoken sentences (Kanwisher & Potter, 1989). The possibility of a phonological component to RB was investigated further in Experiment 4B, which was a partial replication of Experiment 4A.

Experiment 4B

Two findings from Experiment 4A warranted further study: the weakness of repetition blindness for homographs and the apparent RB for homophones. These two issues were explored in Experiment 4B, which was identical to Experiment 4A except in two respects. First, it seemed possible that the apparent RB for homophones resulted from the orthographic similarity of the homophone pairs used (e.g., *knight/night*). Thus, in Experiment 4B new homophone pairs were selected that differed more from each other (e.g., *eye/I*; *colonel/kernel*). Second, in Experiment 4A repetition blindness for homographs may have been diminished by the unexpectedly low recall of unrepeated homographs (heterophonic homographs are known to be more difficult to process than homophonic homographs; e.g., Kroll & Schweickert, 1978). For Experiment 4B, we wrote new homograph sentences, using sentence context to boost overall R2 report (e.g., "... legal *contract*", "... proudly *bow*").

Method

Subjects. Eighteen subjects participated. All were undergraduates at the University of California at Berkeley, who participated in exchange for course credit.

Materials. Stimulus items were the same as those used in Experiment 4A except that the new homograph and homophone sentences (given in Appendix C) replaced the homograph and homophone sentences used in Experiment 4A. The design of the experiment was identical to that of Experiment 4A.

In addition to the 36 test sentences (9 of each of the four types), 9 additional sentences containing the old homographs were included in the experiment to test another hypothesis.

Design and procedure. All other aspects of the design and procedure were the same as in Experiment 4A.

Results and Discussion

Data were analyzed as in Experiment 4A; again, overall recall accuracy was high. Percentage of correct recall of R1 and R2 is given in Table 4, lower portion. Analysis of variance of the R1 data showed a significant main effect of type, $F_1(3, 51) = 5.2$, $p < .005$, but no main effect of repetition, $F_1(1, 17) < 1.0$, and no interaction of repetition by type, $F_1(3, 51) < 2.0$, $p > .1$.

Analyses of variance of the R2 data showed a significant main effect of repetition $F_1(1, 17) = 50.0$, $p < .001$ and $F_2(1, 32) = 22.5$, $p < .001$, and a significant interaction of repetition by type, $F_1(3, 51) = 7.7$, $p < .001$ and $F_2(3, 32) = 2.2$, $p = .11$. When the same analysis was repeated without the homophone data, it showed a significant main effect of repetition, $F_1(1, 17) = 60.3$, $p < .001$ and $F_2(1, 24) = 23.4$, $p < .001$, but no interaction of repetition by type, $F_1(2, 34) = 0.2$ and $F_2(2, 24) = .01$, $p > .99$. Thus the interaction seems to consist of the differential effect of repetition on homophone items.

These data indicate that repetition blindness occurs to the same extent for repeated identical, homonym, and homograph word pairs. On the other hand, there is no evidence of repetition blindness for homophones that are not homographic. Thus, RB requires orthographic identity (or similarity) but is indifferent to pronunciation. This further reinforces the claim that RB is a specifically visual phenomenon.

Experiment 5

If it is abstract letter clusters rather than visual morphemes that are susceptible to repetition blindness, then one might expect a repetition deficit to occur when two types of similarly spelled words are embedded in a sentence. In Experiment 5 two types of similarly spelled word pairs were embedded in sentences, which subjects recalled. One type consisted of words that were not transparently related etymologically differing by the addition of a single letter (e.g., *cap* and *cape*). The other type consisted of a word plus a one-letter suffix (e.g., *walk, walks*). If RB is a strictly word-level phenomenon, then one might expect it to occur for neither of these pair types, only for the identical word pairs.[1]

[1] The results for identical words were reported previously in Kanwisher (1987).

Method

Subjects. Thirty-six subjects participated, from the MIT pool previously described.

Materials. There were three groups of nine sentences each: (a) sentences with two identical words, and their controls; (b) sentences with two orthographically similar words, and their controls; and (c) sentences with two words that were identical except for a suffix, and their controls. The similar words differed by the addition of one letter to one word to create two etymologically unrelated words (e.g., *cap* and *cape*). The suffix pairs also differed by one letter, but this letter added a morpheme (e.g., *walk* and *walks*). Each sentence was written in two different forms: In the R2-short form, R2 was the shorter of the two words; in the R2-long form, R2 was the longer of the two words. The two forms of the sentence were written so as to be as similar to each other as possible.

Each sentence appeared in three conditions, repeated, unrepeated, and blank. For the similar word pairs, the repeated condition entailed a repetition of letter clusters, and for suffix word pairs, a repetition of the stem morpheme. The sentences and their controls are shown in Appendix D.

Design and procedure. The three versions of each sentence (repeated, unrepeated, and blank) appeared in different versions of the experiment, counterbalanced so that a given subject saw 3 sentences of each kind for each of the three sentence types (identical, similar, and suffix), for a total of 27 sentences per subject. Whether the shorter word came first or second was a between-subjects variable, with 18 subjects in each group. Otherwise, the design and procedure were identical to those of Experiment 1.

Results and Discussion

The percentage of recalls of R1 and R2 is shown in Table 5. As in earlier experiments, recall of R1 was high overall, and there were no significant main effects or interactions. For recall of R2, there was a significant main effect of repetition, $F'_{min}(1, 24) = 30.5$, $p = < .01$; a marginal main effect of group (short vs. long word first), $F_1(1, 34) = 2.5$, $p = .12$ and $F_2(1, 24) = 4.1$, $p = .06$; and no main effect of sentence type (both *F*s < 2.0). There was a Type × Repetition interaction, $F_1(2, 68) = 4.4$, $p < .02$ and $F_2(2, 24) = 5.1$, $p < .02$. Separate analyses showed that repetition was significant for each item type: identical, $F'_{min}(1, 40) = 74.5$, $p < .01$; similar, $F'_{min}(1, 40) = 15.2$, $p < .01$; and suffix, $F'_{min}(1, 40) = 9.0$, $p < .01$. No other interactions were significant.

Because the group variable (whether the longer or shorter word came first in the sentence) was a dummy variable for identical sentences, a separate analysis of just the similar and suffix conditions was carried out. The result of interest is a marginally significant interaction between group and repeatedness, $F_1(1, 34) = 3.9$; $p = .056$ and $F_2(1, 16) = 3.6$, $p = .076$. As inspection of Table 5 shows, RB was more marked when the longer word came first.

Thus repetition blindness appears to occur not only for identically repeated words but also for pairs of similarly spelled words—morphologically related or not. This might indicate that RB is indifferent to morphemic structure. However, the issue was not fully resolved by Experiment 5. One possible morpheme-level account of these findings is that when R1 has been recognized, its logogen or recognition unit remains activated and falsely recognizes R2 as R1. Once R2 is taken to be a repetition of R1, the mechanism responsible for RB comes into play. Thus *cap* and *cape* (and *walk* and *walks*) may suppress each other because the second is incorrectly perceived to be the same word as the first (at a stage before RB). This possibility was evaluated in Experiment 6.

Table 5
Percentage of Correct Recalls of R1 and R2, Experiment 5

Pair type	R2 long[a] Rep.	R2 long[a] Unrep.	R2 short[a] Rep.	R2 short[a] Unrep.
	R1 recall			
Identical *couch/couch*	92	91	89	98
Similar *cap/cape*	80	91	89	74
Suffix *walk/walks*	74	91	87	87
	R2 recall			
Identical *couch/couch*	22	78	23	80
Similar *cap/cape*	52	76	28	72
Suffix *walk/walks*	50	74	33	78

Note. Rep. = repeated, Unrep. = unrepeated.
[a] The R2 long/short variable was a dummy variable in the case of identical word pairs.

Experiment 6

In Experiment 6 we used a threshold technique (from Kanwisher, 1987) to test the hypothesis that similarly spelled words exhibit repetition suppression not because repetition blindness is a letter-level phenomenon but because second instances of similarly spelled word pairs are often misread as identical to first instances. In other words, *cap* may be misread as *cape* when it follows soon after *cape* in the RSVP sequence. If similarly spelled words are in fact misread in this fashion, they may be subject to word-level RB, even though R1 and R2 are in fact different words.

In order to test for this type of misreading error, subjects were asked to name the last, masked word in a rapidly presented list of unrelated words. The experiment was designed to investigate the effect of an earlier occurring word (R1), which was similar but not identical to the target (R2). It was predicted that the target word would occasionally be misread as its cohort when that word appeared earlier in the same list.

Method

Subjects. Thirty-six subjects participated from the MIT pool previously described.

Materials. Lists of unrelated words were constructed. All words appeared in lowercase, to match the conditions of Experiment 5. The 36 test lists contained five, six, or seven words (including R1 and R2). R2 was always the last word in the list, and R1 was always the fourth-to-last word in the list; that is, there were always two words between R1 and R2. Eighteen of the R1–R2 pairs were the similar and suffix pairs used in Experiment 5, and 18 were new pairs of the same two types. Similar pairs were morphologically distinct and differed by the addition of a single letter (e.g., *cap* and *cape*). Suffix pairs shared the same stem and also differed by the addition of a single letter (e.g., *walk* and *walks*).

There were six versions of each list (see Table 6) generated by crossing the two variables of R1–R2 order and repetition condition. The order variable determined whether the target word (R2) was the long or the short word of the R1–R2 pair. For each order, each item appeared in three different conditions: either R1 was identical to R2 (the identical condition), or R1 was the orthographically overlapping partner of R2, that is, R1 was either similar to or morphologically related to R2 (the overlap condition), or R1 was completely unrelated to R2 (the unrepeated condition).

Filler trials with short lists were included to encourage subjects to pay attention throughout the list. There were six filler lists each with lengths of two, three, and four words, containing no repeated or similar words.

Design and procedure. Items were counterbalanced such that each subject saw six lists (3 with suffix pairs and 3 with similar pairs) in each of the six conditions generated by crossing order (long or short) with condition (identical, overlap, or unrepeated). This design is shown in Table 6. The 18 short-list filler trials were intermixed pseudorandomly. There were 12 practice trials.

Each trial began when the subject pressed the space bar. A row of Xs appeared for 500 ms at the same location as the subsequent words, followed by the RSVP list at 117 ms per word. The last (target) item was displayed for only 67 ms, followed by a 117-ms mask consisting of a row of percent signs.

As soon as the list ended, subjects named the word they thought had appeared last in the list, guessing if they were unsure. They were instructed to answer as quickly and as accurately as possible. They were also told that the last (target) word in each list might be identical or similar to a word that appeared earlier in the same list.

Results and Discussion

A preliminary analysis showed no difference between the old items (taken from Experiment 5) and the new items, so they were combined in the subsequent analyses. Overall, subjects correctly named the target (last) word in 36% of identical trials, 22% of overlap trials, and 43% of unrepeated trials.

The misreading errors of interest were those in which subjects named, not the target word, but its similarly spelled partner (e.g., they said "cap" for *cape*, "walks" for *walk*, or vice versa); these errors are called *overlap misreadings.* The percentage of correct responses and overlap misreading errors in each condition are shown in Table 7. The main finding in this experiment is that there were many overlap misreadings in the overlap condition (17%), almost as many such misreadings as there were correct responses (22%); in contrast, such misreadings were rare in the identical (2%) and unrepeated (5%) conditions.

Table 6
Design of Experiment 6 With Examples of R1–R2 Pairs

	Condition		
Pair type	Identical	Overlap	Unrepeated
Similar			
R2 short	cap–cap	cape–cap	scarf–cap
R2 long	cape–cape	cap–cape	scarf–cape
Suffix			
R2 short	walk–walk	walks–walk	eat–walk
R2 long	walks–walks	walk–walks	eat–walks

In separate sign tests in each condition, similar trials showed significantly more overlap misreadings in the overlap than unrepeated condition for R2-short ($p < .001$) but not R2-long trials. On the suffix trials, the overlap and unrepeated conditions differed in overlap misreadings for both R2-short ($p < .05$) and R2-long ($p < .05$) targets.

Intrusions of R1 in recall cannot be distinguished from correct responses in the identical condition, or from overlap misreadings in the overlap condition. However, R1 intrusions are recognizable in the unrepeated condition because R1 is unlike the target word. The R1 control word was intruded in 3.5% of unrepeated trials, which provides a baseline for true intrusions rather than misreadings. Most of the 17% of overlap misreadings in the overlap condition were not simple intrusions of R1 but were indeed misperceptions of R2 that were influenced by the prior presentation of a similar-looking word, R1.[2]

Implications for repetition blindness. Experiment 6 shows that the predicted misreading errors do occur when two words on a list share all but one letter. The high proportion of such misreading errors (17% vs. 22% correct) is of interest because it may explain part of the apparent RB for similarly spelled but nonidentical words observed in Experiment 5 as well as the RB for differently spelled homophones in Experiment 4A. Once a word has been misperceived as a repetition, the mechanism responsible for RB may prevent token instantiation of the second word. The size of the RB effect in Experiment 5 differed as a function of whether R2 was shorter or longer than R1: RB was somewhat greater when R2 was shorter, as in *cape–cap.* The same asymmetry in misreadings of R2 was observed in Experiment 6 for the similar pairs, although not for the suffix pairs. For the similar pairs, in the R2-short condition (*cape–cap*) the second word was misread as the first on 29% of the trials and was read correctly on only 4%, whereas almost the reverse was true for the order *cap–cape* (see Table 7).

If this explanation for *cape–cap* blindness is correct, then RB may be predominantly a whole-string or morpheme-level effect rather than a letter-level effect. In Experiment 7 we tested a prediction of the strict letter-level account of RB: Would a single letter in a word suppress later occurrences of the same letter in the same position in another word?

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[2] As Table 7 indicates, subjects performed better overall in the unrepeated condition than in the identical condition. Although only marginally significant ($p = .05$), this result stands in contrast to earlier findings referred to in the introduction (Kanwisher, 1987, Experiment 3, and a subsequent replication of that experiment), in which repetitions helped threshold naming. There were some minor differences between the current Experiment 6 and the earlier experiments, which may have resulted in different subject strategies. In ongoing research we are investigating the many factors that can either enhance or reverse the repetition benefit in this kind of threshold task.

Table 7
Percentage of Correct Responses and Intrusions of the Overlap Word, Experiment 6

	Condition					
	Identical		Overlap		Unrepeated	
Pair type	Correct	Intr.	Correct	Intr.	Correct	Intr.
Similar						
Short (*cap*)	30	0	4	29	28	5
Long (*cape*)	37	0	33	5	40	2
Suffix						
Short (*walk*)	33	4	27	19	54	5
Long (*walks*)	44	3	25	16	54	7
M	36	2	22	17	43	5

Note. Intr. = intrusion of the overlap word (R1 in the overlap condition).

Experiment 7

If single letters or single letters associated with particular locations in strings are the units that enter into repetition blindness, then one might expect the word *fault* to suppress the *t* on the end of *heart*, yielding *hear*, when *heart* follows *fault* in a list of words. If, however, it is only morphemic units that enter into RB, then *fault* might not convert *heart* to *hear*, but *hoped* might convert *tuned* into *tune*. (Results reported by Kanwisher, 1986, seemed to indicate that this might be the case.) Finally, if single letters never enter into RB—whether they are morphemes or not—then one might not expect either. In this experiment these and related questions were tested in a free-recall task with RSVP word lists.

Method

Subjects. Forty-two subjects participated from the MIT pool, 18 in one group and 24 in another.

Materials. Lists of four unrelated words were constructed such that no two words began with the same letter. Each list was randomly assigned to one of two serial position groups: critical words R1 and R2 were added into the list either in serial positions 2 and 4 or in serial positions 3 and 5; all lists were six words long.

All R2 words were chosen so that removal of their last letter would yield a new word. Items were of three main types: the final letter of R2 was either a suffix (like the *d* on *glued*), a pseudosuffix (like the *y* on *pansy*), or a nonsuffix (like the *t* on *heart*). R1 always had the same number of letters as R2. For each R2 type there were three R1 conditions: repeated, unrepeated, and various. In the *repeated* condition, the last letter of R1 was the same as the last letter of R2 . (For about half of the pairs, the next-to-last letter was also identical; all the other letters were different.) The last letter of R1 was a nonsuffix for nonsuffix items and a suffix for both suffix and pseudosuffix items. In the *unrepeated* condition R1 was changed to a different word that shared no same-position letters with R2. The repeated and unrepeated pairs are shown in Appendix E. Finally, in the *various* condition there were a variety of relationships between R1 and R2 (such as *wrote-gazed*). Results from this condition were intermediate between those of the repeated and unrepeated conditions and will not be discussed further.

Design and procedure. There were 36 test lists: 6 nonsuffix items, 6 pseudosuffix items, and four different subsets of suffix items (6 each). The three R1 conditions (repeated, unrepeated, and various) were counterbalanced across subjects and items. Lists were presented at a rate of 117 ms/word to one group and 150 ms/word to the other. In the 117-ms group, all words were in uppercase, whereas in the 150-ms group, case was randomized within lists and R1 and R2 were always in different cases (upper vs. lower). In each list, the other words were half in uppercase and half in lowercase, in quasi-random order. Subjects were instructed to read each list and recall as many words as they could as soon as it ended. There were four practice trials.

Results

R2 responses were classified as either correct or stripped (i.e., correct except that the last letter was omitted). The percentage of such responses is shown in Table 8, for each group. The main question in the experiment was how often subjects omitted the last letter of R2 in their recall, as a function of repetition condition and item type. For nonsuffix and pseudosuffix items, no R2s were reported stripped in either the repeated or the unrepeated conditions. A sizable number of recalls in the suffix condition were stripped (14% vs. 21% correctly recalled in the 117-ms group, and 13.5% vs. 30% in the 150-ms group), but there was no differential effect of repetition on stripping, $t(17) = 0.14$, $p > .3$ in the 117-ms group and $t(23) = 1.41$, $p > .10$ in the 150-ms group.[3]

Discussion

Evidently, the overlap of a single letter between two words separated by another word does not produce RB for that letter, even when removing that letter would leave a real word (e.g., *heart/hear*). Nor does a suffix cause RB for the same suffix on another word. Thus RB for words cannot readily be explained as the sum of independent effects of RB for each component letter. The units of repetition blindness in serially presented word lists are probably neither letters nor words but some intermediate level units, such as abstract letter clusters or perhaps stem morphemes.

An interesting additional finding is that although R2 suffixes are often stripped spontaneously in recall (independently of suffix repetition), pseudosuffixes are never stripped. In

[3] In the 150 ms/word group, there was an unexplained RB effect on correct recall of R2. Because there is no sign of this pattern on the 117 ms/word group, we suspect that it is not reliable.

Table 8
Percentage of Correct and Stripped R2 Responses, Experiment 7

Pair type	Repeated Correct	Repeated Stripped	Unrepeated Correct	Unrepeated Stripped
Nonsuffix (*fault–heart*)				
117 ms/word	17	0	17	0
150 ms/word	25	0	60	0
Pseudosuffix (*lucky–pansy*)				
117 ms/word	36	0	39	0
150 ms/word	48	0	71	0
Suffix (*glued–timed*)				
117 ms/word	18	12	24	15
150 ms/word	25	15	35	12

other words, *pansy* is never reported as *pans* although *lucky* is often reported as *luck*. This indicates that such spontaneous suffix stripping is a post-lexical-access phenomenon, perhaps one that occurs in short-term memory (spontaneous suffix stripping was rare in the unrepeated threshold condition of Experiment 6 in which there was only one word to report and hence a minimum memory load). The fact that RB does not occur at this postaccess stage of processing is consistent with the idea that RB itself occurs at an access or preaccess level of processing.

Although Experiment 7 provides clear evidence against letter-level RB (but see Footnote 3), this may be because the stimuli were whole words and the task was recall of words (not letters). If the level at which RB occurs is a function of task requirements or stimulus format, then one might expect to see RB for letters when they are the relevant units. Indeed, Mozer's (1989) "homogeneity effect" appears to be just such a case of RB for simultaneously presented letters that do not form words.

Experiment 8

To make letters rather than words the dominant perceptual unit, in Experiment 8 we presented single letters one at a time in RSVP sequences that either contained a repetition or did not. Pilot studies showed that when the strings were composed of random letters, overall recall performance was so low that it was difficult to determine whether R1 or R2 was being reported. In order to increase overall recall, letter lists were presented that spelled words or pronounceable nonwords. Critical "repeated" words were chosen such that removal of the second occurrence of the repeated letter would yield a new word; for example, removal of the second *a* in *manager* yields *manger*. The ideal unrepeated control for such a word would be a word identical to *manager* but with (a) the first *a* changed to a different letter to yield another word and (b) the remaining *a* removable, to yield a new word. This criterion could rarely be met precisely. An additional problem was that word frequency, which is correlated with length, might bias the subject toward the R2-omitted version of the word. To get around these problems, we also used pronounceable nonwords as stimulus items, which made exact unrepeated controls possible (e.g., *conotle* was changed to *canotle* in the unrepeated condition).

If letter-by-letter presentation produces RB for letters, that would indicate that the perceptual unit in a given task determines the level at which RB occurs. An additional possibility is that only nonwords would show RB, because when letters spell real words, the relevant unit of analysis might still be the word.

Method

Subjects. Twenty-four subjects from the MIT pool participated in this experiment.

Materials. There were 12 repeated words and 12 repeated nonwords in this experiment. The items had only one letter repetition (except for one item with two), and there were one to three letters intervening between the two occurrences (R1 and R2). Items varied in length from 5 to 7 letters. For each word, an unrepeated control word in which R2 was also "removable" was chosen to be as close as possible in length and consonant–vowel structure, for example, *plan(t)* was the control for *star(t)*. Each nonword was generated by following the consonant–vowel structure and R1–R2 serial position patterns of one of the word items, but changing the letters (e.g., *po[p]lar/ma[p]les* was changed to *ro[r]tal/so[r]tal*). Stimulus items are given in Appendix F.

Design and procedure. Each subject saw 12 words and 12 nonwords in random order, counterbalanced for repeatedness. Letters were presented in uppercase at the rate of 133 ms/letter, each letter in the same location on the screen. After the last letter a percent sign appeared (as a mask) for 133 ms. Subjects were instructed to "sound out" the letter list as it appeared and then to write it down as accurately as possible on the sheet of paper provided. They were told that some items would spell out real words and some nonsense words but that their task was simply to write down as much of the word or nonword as they could see. There were 10 practice trials.

Results and Discussion

Results were scored in two different ways. First, responses were collected in which (a) the subject wrote down the exact correct response ("exact") or (b) the subject responded correctly except for the omission of R2 ("R2 omitted"). However, these two cases made up a minority of responses; on most trials subjects made additional errors. Therefore, a separate analysis was made to compare how often the subjects included both R1 and R2 in their response (called "both" responses) as a function of whether the item was repeated or unrepeated. The results of these analyses are shown in Tables 9 and 10.

Averaging across word and nonword trials, in the repeated condition on 18% of the trials the response was exactly correct, and on 19% R2 was omitted. (Recall that R2-omitted responses are always incorrect—for example, writing "manger" after viewing *manager*.) In contrast, for the unrepeated control stimuli 27% of the responses were correct, and on only 5% was R2 omitted. A sign test showed that there were significantly more R2-omitted responses in the repeated condition than in the unrepeated condition ($p < .05$).

The percentage of recalls of both R1 and R2 on the same trial (shown in Table 10) gives a similar picture. Subjects included both R1 and R2 in their response on 67% of unrepeated trials but only 34% of repeated trials. The percentage

Table 9
Percentages of Exact and R2-Omitted Responses, Experiment 8

	Condition			
	Repeated		Unrepeated	
List type	Exact	R2 omitted	Exact	R2 omitted
Words	30	24	38	6
Nonwords	7	13	17	4
M	18	19	27	5

of "both" responses showed a significant main effect of repetition, $F'_{min}(1, 36) = 43.5$, $p < .001$, and a significant advantage of words over nonwords for subjects, $F_1(1, 23) = 17.0$ $p < .001$, but not items, $F_2(1, 22) = 1.9$, $p > .10$. The interaction of word/nonword by repetition was not significant (both $Fs < 1$).

These findings demonstrate that subjects had more difficulty encoding and remembering repeated letters than unrepeated letters. Thus, when letters are presented one at a time in RSVP lists, they are the units that enter into repetition blindness. Because subjects did eventually encode the letter strings as words (as the overall word advantage shows), is one justified in concluding that RB in this experiment depends on initial letter-by-letter perception? If the letter repetition effect is unrelated to the letter-by-letter mode of presentation, one would expect a comparable RB effect for a simultaneously presented word such as *manager*. Recent data (Kanwisher, 1989) indicate that RB in such a case is much reduced (although still significant), a result supporting the conclusion that the major perceptual unit in a given task is the main locus of RB.[4] The fact that Mozer (1989) found that repeated letters or digits in a simultaneous array led to an underestimate of the number of items, relative to a row of unrepeated characters, is consistent with this conclusion, because the single letters or digits were the relevant unit in Mozer's tasks.

General Discussion

The experiments reported here provide new evidence about the levels of processing that are involved in repetition blindness; the implications of each experiment are summarized in Table 11. Experiment 1 showed that the phenomenon occurs before the conceptual level, because synonym pairs are not subject to RB. Other findings suggest that RB may occur even below the level of whole words or lexical entries. First, RB occurred between a single word and a compound incorporating that word, in Experiments 2 and 3. Because compounds and their components are lexically distinct, RB cannot require strict lexical identity. Second, RB was found for orthographically identical homonyms in Experiment 4, even though in the stimulus sentences the words were lexically distinct. This indicates that RB is not based on a disambiguated lexical type. RB was found whether or not the two disambiguated homonyms had the same pronunciation, whereas there was little (Experiment 4A) or no (Experiment 4B) RB for words with identical pronunciation but different spelling. Third, in Experiment 5 RB was found for pairs of similarly spelled words, independently of whether they shared the same root (there was, however, less RB for these overlap words than for identical pairs). RB between overlapping words might, however, be explained by misreading errors that preceded RB, as suggested by the results of Experiment 6.

Table 10
Percentages of Responses That Included Both R1 and R2, Experiment 8

Letter string	Condition	
	Repeated	Unrepeated
Words	40	78
Nonwords	27	62
M	34	67

Taken together, these findings indicate that distinct lexical entries for R1 and R2 do not prevent RB if the words have orthographic identity (or perhaps just orthographic overlap). Because there is reason to believe that disambiguation of homonyms occurs within about 500 ms of presentation (Seidenberg, Tanenhaus, Leiman, & Bienkowski, 1982), this result provides further evidence that RB occurs during visual processing rather than at a later stage.

Candidate lower levels of processing at which RB could occur include the single-letter level (abstracted from case) or a level that represents the orthography of letter clusters, whole letter strings, or morphemes. The evdience here is somewhat conflicting. First, Experiment 7 showed that a single letter in a word did not block a later occurrence of that letter in the same position in another word, even when a permissible word would have resulted. This suggests that RB for words cannot be the sum of *independent* letter-level effects. On the other hand, Experiments 4 and 5 demonstrated RB for word pairs that overlapped orthographically but were distinct morphologically. One possibility is that it takes a certain minimum number of shared letters for words or their major components (e.g., parts of compounds) to be suppressed by repetition. The fact that components of compounds were less readily suppressed when the compound was presented as a unit is consistent with this possibility. However, the current data do not resolve this issue definitively.

Relation Between Repetition Blindness and Repetition Priming

There is a vast literature on repetition priming or "the repetition effect," which refers to the improved identification of a stimulus with repetition. This literature is reviewed by

[4] When Experiment 8 was run in a simultaneous presentation format, subjects correctly reported R1 and R2 (both) in 31% of repeated trials and 40% of unrepeated trials (Kanwisher, 1989). This reduced RB could result from either (a) the change from letters-as-units to words-as-units or (b) a weaker RB effect for spatially (as compared with temporally) distributed items. Evidence against the latter account comes from the fact that RB for four letters in simultaneously presented square arrays is robust (Kanwisher, 1989).

Table 11
Summary of Results From Experiments 1 Through 8

Experiment	Pair type	RB?	Implications
1	Synonyms *sofa/couch*	No	RB is not at a conceptual level.
2	Compounds *dogs/hot dogs*	Yes	RB is not strictly lexical.
	Closed class *to/to*	Yes	RB is not sensitive to syntactic class.
3	Glued compounds *dogs/hotdogs*	Yes	RB is not prevented by bound morphemes.
4	Homonyms (the) *rose*/(she) *rose*	Yes	RB occurs for any pairs with orthographic identity regardless of differences in meaning or sound.
	Homographs (the) *wound*/(she) *wound*	Yes	
	Homophones *ate/eight*	No	
5	Similar pairs *barn/bar*	Maybe	RB may occur for similar words, but this may be partly due to misreading, not to letter-level RB.
6	Misreadings	—	
7	Bound letters fault/heart	No	
8	Free letters *M A N A G E R*	Yes	RB level depends on perceptual unit.

Monsell (1985), who noted that there are at least two types of repetition effects, one that persists relatively briefly (i.e., for a few seconds) and one that lasts for minutes, days, or longer. At first glance the positive effect of repetition priming appears to conflict with RB, which involves a *decrement* in performance for repeated items. However, this apparent contradiction can be resolved by noting that the two effects occur under different conditions. Most of the work on (short-term) repetition priming has been done under conditions that facilitate token individuation of R2 targets, either by making individuation of R1 unlikely or by enhancing the individuation of R2 with increased interstimulus intervals (ISIs) or R2 durations. In contrast, RB for R2 is observed only when R1 can be individuated, when the (filled) ISI is no more than about 500 ms, and when R2 is presented for less than 200 ms (Kanwisher, 1987).

The literature on repetition priming addresses many questions parallel to those raised here, however; for example, it has been shown that repetition priming persists when prime and target are in opposite case (Scarborough, Cortese, & Scarborough, 1977). Evett and Humphreys (1981) reported priming for graphemically similar words, independently of case, although they noted that the word repetition effect is stronger than the graphemic priming effect. The studies on the role of morphemes in repetition priming are not consistent. Murrell and Morton (1974) reported evidence that morphemic units must be repeated for priming to occur; they found priming for stem repetitions (*bored–boring*), but not for word pairs that merely overlapped orthographically (*born–boring*). In contrast, Monsell (1985) reported that although well-lexicalized compound nouns can be primed by their constituents (e.g., *rope–tightrope*), this occurs to the same extent for pseudocompounds (e.g., *fur–furlong*), which suggests that morphemic structure is irrelevant.

It would be interesting if the R1–R2 relationships or units that lead to repetition blindness are the same as those that lead to (short-term) repetition priming.[5] This would be expected if both effects are due to repeated type activations and if the word recognition system has only certain kinds of preexisting types (e.g., it may contain units that encode whole words and/or morphemes, but not letter clusters). On this hypothesis, if a pair of items (sharing letters, letter clusters, morphemes, or anything else) show positive priming under conditions favorable for token individuation of targets (such as long ISIs), they would show repetition blindness under conditions that made individuation of R2 difficult. A systematic comparison of RB and repetition priming is required to evaluate this hypothesis.

One reason for the complexity and seeming inconsistency of the repetition priming literature is the variety of priming paradigms used, including masked versus unmasked priming. The difference in the results in these two conditions may reflect the differential stability of tokenized (unmasked) and untokenized (masked) primes. Forster and Davis (1984) and Forster, Davis, Schoknecht, and Carter (1987) made similar suggestions. The present interpretation reflects even more closely Humphreys et al.'s (1988) suggestion that "qualitative differences between masked and unmasked primes. . .[can be] attributed to effects occurring *within* a perceptual event (with masked primes) relative to those occurring *across* events (with unmasked primes)" (Abstract, p. 51). Investigations of RB allow one to generalize the idea of "perceptual event" to include events that span several intervening type activations.[6]

Conclusions

The experiments reported here show that repetition blindness occurs at a level of processing prior to the attainment of conceptual representations and the disambiguation of ortho-

[5] This idea was first suggested to us by Susan Lima.
[6] This issue has also been studied by Forster (1987).

graphically identical homonyms. These findings confirm earlier suggestions (Kanwisher, 1987; Kanwisher & Potter, 1989) that RB is a visual phenomenon. Whether RB occurs at the level of an orthographic representation of a whole word (rather than at the level of letter clusters) is less clear. However, the level at which RB occurs is determined in part by the visual unit that is most relevant to the task at hand: words (but not single letters) in Experiments 1-7, and single letters in Experiment 8. Indeed, if RB reflects a general property of visual information processing—the need to identify types and represent tokens of those types (Kanwisher, 1987)—it is not surprising that the phenomenon can appear at more than one level in letter and word processing. Whether tokens can be individuated at several different levels in parallel, or whether instead perceivers can only attend to and tokenize entities one level at a time, is a question for future research.

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(*Appendixes follow on next page*)

Appendix A

Stimulus Materials, Experiment 1

R1 and R2 are italicized; for R1, the repeated word is given first, then the synonym, then the unrepeated control word.

1. We were anxious for *autumn/fall/apples* well before *autumn* arrived.
2. The company's new *poison/toxin/product* might *poison* many people accidentally.
3. The *rug/carpet/department* store sold a *rug* from the Far East.
4. The new *students/pupils/girls* worked with *students* who could help them.
5. We worked in the *dirt/soil/garden* until *dirt* covered our clothes.
6. They sat in the *center/middle/seats* because the *center* offered the best view.
7. She wandered along *a path/a trail/the beach* before discovering the *path* she wanted.
8. His *tale/story/life* was a *tale* of hard work and success.
9. His *films/movies/favorites* are long *films* about war.
10. The slaves wanted *freedom/liberty/to escape* although *freedom* wasn't attainable.
11. We couldn't see the *display/exhibit/painting* because the *display* was being rearranged.
12. She was terrified *in cellars/in basements/down there* because *cellars* have spiders.
13. We bought the *cloth/fabric/pattern* while *cloth* was on sale.
14. The administrator demanded a *reply/answer/raise* although no *reply* was forthcoming.
15. That *cab/taxi/truck* passed our *cab* very quickly.
16. When he lost his *vision/sight/glasses* suddenly *vision* seemed very important.
17. His birthday *gift/present/cake* was an unexpected *gift* from his parents.
18. She always manages to have *courage/bravery/strength* when *courage* is required.
19. The worst *smells/odors/memories* are the *smells* at the school cafeteria.
20. He poured in *fluid/liquid/oil* until the *fluid* reached the liter mark.

Appendix B

Stimulus Materials, Experiment 2

Repeated R1s and R2s are italicized; noun phrase and unrepeated R1s are shown in parentheses.

Compound Sentences

1. His *real estate* (family's estate, real property) bordered the *estate* she owned.
2. Next to the *saw horse* (model horse, saw rack) his *saw* hung on a nail.
3. To prevent the thief's *escape* (departure) the *fire escape* (other's escape) was blocked.
4. The *pine* (tree) dropped many *pine cones* (much pine sap) last year.
5. They make *fish sticks* (those sticks, fish specialties) from *fish* and bread crumbs.
6. My favorite *flower* (plant) in that *flower bed* (flower collection) was the daffodil.
7. The man had a *heart attack* (heart murmur, epilepsy attack) during the *attack* by terrorists.
8. When they got *frost bites* (snake bites, frost accumulation) the *frost* covered everything.

mark.

9. Sailors in *bars* (pubs) discuss *sand bars* (city bars) which are dangerous.
10. Our own *ice cream* (iced dessert, farm's cream) has better *cream* in it.
11. Where there are *sea horses* (swimming horses, sea animals) the *sea* is warm.
12. She bought *butter* (honey) because *peanut butter* was unavailable (because the butter was cheap).
13. She went to the *post office* (post man, lawyer's office) before her *office* opened.
14. My neighbor's *dogs* (cats) like *hot dogs* (other dogs) in the park.
15. The *lobster* (crab) entered the *lobster pot* (lobster tank) slowly.
16. The chemist had attached several *tubes* (stoppers) to *test tubes* (other tubes) already.

Closed Class Sentences

1. Before *the* (that) man drank *the* milk shake he sat down.
2. I will dispose *of* (dispense with) the rest *of* the crumpled paper.
3. We painted the blue lake, *then* (and) we ate, *then* we returned.
4. In the tropics, water *is* (was) necessary and *is* hard to find.
5. We watched the fire works *with* (and) some people *with* binoculars.
6. The cash box contains bills *and* (with) sales slips *and* change.
7. They put hand cuffs on *a* (the) man and *a* woman.
8. Those bugs *at* (on) the beach *at* night were big flies.
9. The sea weeds were *so* (very) long and *so* tangled the boat got stuck.
10. *There* (that) is one *there* on the large plate.
11. I found the play bill *in* (near) the closet *in* my room.
12. We'll need a large chair *if* (so) he'll go *if* it is sunny.
13. It was either a lichen *or* (and) a mushroom *or* a fungus.
14. We always had *to* pay (paid) money *to* hear the popular singer.
15. We played with the dry ice *on* (and) a mirror *on* the floor.
16. He sat on a chair *by* (near) the wall *by* the stair case.

Appendix C

Stimulus Materials, Experiment 4

R1s and R2s are italicized; the repeated R1 is given before the unrepeated R1.

Identical Word Sentences

1. We added *peas/carrots* to the *peas* in the bowl.
2. We will go *skiing/out there* whenever good *skiing* is available.
3. They asked *questions/things* although *questions* were unwelcome.
4. The squirrel had just hopped from one *tree/branch* to that *tree* nearby.
5. Yesterday's *soup/pie* and this *soup* were truly disgusting.
6. The *hotter/bad* weather was *hotter* than last summer even.
7. He chased her *cat/dog* and the *cat* ran away.
8. To drink *beers/them* you'll need *beers* with twist tops.
9. She read *books/stories* whenever good *books* came her way.

Homonym Sentences

1. When she saw the *rose/tulip* she quickly *rose* from her chair.
2. He had to *watch/look at* his friend's *watch* constantly.
3. To see if it *matches/is*, we'll need *matches* and a candle.
4. The horse did not like the *bit/metal* so he *bit* her.
5. She loves *to fly/planes* but a *fly* was bothering her.
6. When he *saw/found* my new *saw* he was very impressed.
7. She heard the wedding bells *ring/clang* and the *ring* on her finger felt strange.
8. The butcher weighs out two *pounds/kilos* and then *pounds* it until it is tender.
9. The cigarette was *ground/stamped* into the *ground* before the teacher came.

Heterophonic Homograph Sentences, Experiment 4A

1. The *lead/steel* pipe will *lead* them to suspect wrongdoing.
2. Indeed, that farmer *does shoot/never shoots* the *does* he discovers in his garden.
3. She *bound/wound* the patient's *wound* with bandages.
4. In the *desert/arctic* nobody would *desert* the army anyway.
5. The farmer will feed the *sow/sheep* and then *sow* more seeds.
6. The administrator *objects to/protests about* those *objects* in the museum.
7. It is a *project/show* where they *project* images on walls.
8. The teacher *subjects/exposes* students to *subjects* like economics.
9. When those kids get too *close/near* we often *close* the candy jar.

Heterographic Homophone Sentences, Experiment 4A

1. The *knight/warrior* rode all *night* through the storm.
2. The boy *threw/tossed* the ball *through* the hoop.
3. She was afraid to eat the apple *which/after* the nasty *witch* left.
4. The *pair/couple* bought a *pear* and an apple in the market.
5. They decided they *would/might* need dry *wood* in the hut.
6. She was in a *daze/frenzy* for many *days* after the exam.
7. Yesterday we *ate/dined* at about *eight* in the evening.
8. The cook only added *thyme/pepper* since no *time* was left.
9. The *maid/woman* always first *made* some cookies.

Heterographic Homophone Sentences, Experiment 4B

1. The wealthy woman's *heir/son* walked with an *air* of contentment.
2. Even the skeptical *colonel/officer* detected a *kernel* of truth in the argument.
3. If he punches me in the *eye/nose* then *I* will press charges.
4. If the purebred *ewe/lamb* wins the show then *you* will hear about it.
5. In tropical *seas/waters* narcotics agents *seize* drug traffickers.
6. As he tries on pants of the next *size/cut* the man *sighs* wistfully.
7. Burdened by the extra *weight/package* we had to *wait* for a taxi.
8. They like to cook dinner in their *wok/oven* and then *walk* in the park.
9. At the camp we usually *ate/dined* at about *eight* in the evening.

Heterophonic Homograph Sentences, Experiment 4B

1. The musician wanted to *record/make* a platinum *record* by next year.
2. The business will either expand or *contract/not*, and no legal *contract* will matter.
3. The fresh farm *produce/vegetables* never fail/s to *produce* fine culinary results.
4. When she tried to *defect/escape* a serious *defect* in her plan arose.
5. After spilling juice on the *console/table*, Donald had to *console* the audio engineer.
6. The singer will straighten her *bow/dress* and proudly *bow* to the audience.
7. If there is R: a heavy *wind* tonight/ U: only a heavy *table*, he might *wind* up without (R:patio) furniture.
8. His mother will *present/give* the wedding *present* to the couple.
9. Although she knows it will *incense/anger* him, Susan burns *incense* in her room.

(*Appendix continues on next page*)

Appendix D

Stimulus Materials, Experiment 5

Repeated R1s and R2s are italicized; unrepeated condition R1s are in parentheses. The two versions (a and b) of each sentence reversed the order of the critical words, for similar and suffix sentences.

Identical Word Sentences

1. (a) The brown *couch* (sofa) and black *couch* were stolen.
   (b) (same)
2. (a) To use *a radio* (the headphones) the *radio* must have batteries.
   (b) If you put batteries in the *radio* (machine) the *radio* will work.
3. (a) We asked for *water* (wine) although *water* was unavailable (available).
   (b). There wasn't much *water* (wine) although *water* was desired.
4. (a) When she spilled the *ink* (liquid) there was *ink* all over.
   (b) (same)
5. (a) We got into this *van* (vehicle) and another *van* for the commute.
   (b) This *van* (vehicle) and another *van* will be used for the commute.
6. (a) His collection of *books* (things) will include more *books* about travel.
   (b) They read *books* (articles) about travel and *books* on history.
7. (a) It was *work* (day) time so *work* had to get done.
   (b) She tried to *work* (study) but the *work* was too difficult.
8. (a) Her jacket was *red* (pink) because *red* is conspicuous.
   (b) The wallpaper was *red* (pink) although (because) *red* is conspicuous.
9. (a) We were *eating* (dining) although *eating* was unnecessary.
   (b) (same)

Similar Word Sentences

1. (a) The scores in the swimming *event* (contest) were *even* at halftime.
   (b) The swimming team's scores were *even* (tied) throughout the *event* last weekend.
2. (a) She made a black *cape* (scarf) and *cap* for winter.
   (b) She made a black *cap* (scarf) and *cape* for winter.
3. (a) They converted the old *barn* (house) into a *bar* last spring.
   (b) They converted the old *bar* (house) into a *barn* last spring.
4. (a) Watering the *lawn* (garden) was against the *law* during the drought.
   (b) It was against the *law* (rules) to water the *lawn* during the drought.
5. (a) They towed the *cart* (trailer) behind the *car* yesterday.
   (b) We need a *car* (truck) not a *cart* to move the beds.
6. (a) The brightly colored *paint* (light) caused *pain* to everyone.
   (b) It was a *pain* (mess) when *paint* was spilled all over.
7. (a) The sailor sought *cover* (shelter) when the *cove* became stormy.
   (b) The sheltered *cove* (island) provided *cover* from the storm.
8. (a) People who eat *liver* (garlic) sometimes *live* longer.
   (b) The patient won't *live* (survive) unless *liver* function returns.
9. (a) When she saw the *brown* (ketchup) stain her *brow* wrinkled.
   (b) His *brow* (beard) was almost *brown* although his hair was blonde.

Suffix Sentences

1. (a) The *silky* (expensive) blouse had *silk* and gold threads woven throughout.
   (b) The *silk* (expensive) blouse was *silky* and elegant.
2. (a) Much food is *wasted* (leftover) although *waste* is discouraged.
   (b) Although we discourage *waste* (encourage saving) they *wasted* food often.
3. (a) On their morning *walks* (strolls) the ladies *walk* several miles.
   (b) On her morning *walk* (stroll) Susan *walks* several miles.
4. (a) Her young *admirer* (friend) would *admire* her charm and grace.
   (b) Her friends will *admire* (meet) Clara's *admirer* at the dance.
5. (a) The *explorer* (pirate) ventured to *explore* new lands.
   (b) To *explore* (cross) deserts an *explorer* must bring many supplies.
6. (a) The *spicey* (tasty) dish contained a *spice from India.*
   (b) The spice (ginger) cookies were *spicey* and sweet.
7. (a) The *consumer* (public) will generally *consume* a variety of products.
   (b) Poor families don't *consume* (buy) what the average *consumer* does.
8. (a) The damaged *wiper* (mop) cannot *wipe* away water.
   (b) To effectively *wipe* (clean) off raindrops, *wiper* blades are necessary.
9. (a) The popular theatre *shows* (performs) every *show* that was on Broadway.
   (b) The popular theatre will *show* (perform) only *shows* with great reviews.

Appendix E

Stimulus Materials, Experiment 7

R1 Repeated/Unrepeated – R2 pairs are as follows.

Nonsuffix pairs

1. fault/sound – heart
2. yard/bolt – mend
3. result/symbol – forget
4. total/punch – model
5. truck/brown – spank
6. front/prove – sight

Pseudosuffix pairs

1. lucky/white – pansy
2. shown/ – raven
3. biker/cheat – cover
4. hilly/whisk – party
5. hiker/ankle – liver
6. broken/pursue – heaven

Suffix pairs

1. glued/brick – timed
2. baker/month – wider
3. years/wharf – hopes
4. paints/poetry – images
5. rocky/choke – salty
6. trails/change – flakes
7. bumpy/globe – rusty
8. dirty/quick – milky
9. named/while – dared
10. hairy/quote – picky
11. risen/shack – grown
12. taken/coral – woven
13. laced/churn – bored
14. amazed/person – shared
15. stapled/society – bounced
16. dreams/folder – claims
17. horses/tumble – speaks
18. squares/machine – strokes
19. wired/blunt – gazed
20. tuned/steam – waved
21. ruled/chain – saved
22. roped/stray – taped
23. cared/break – zoned
24. danced/friend – chased

Appendix F

Stimulus Materials, Experiment 8

R1 and R2 are italicized.

Words	Nonwords
1. *r*epo*r*t (*d*epo*r*t)	*l*evo*l*t (*m*evo*l*t)
2. br*e*ath*e* (c*l*oth*e*)	bl*e*ask*e* (b*l*oask*e*)
3. clo*s*e*s*t (b*e*a*s*t)	cop*r*a*r*s (cop*l*a*r*s)
4. li*n*e*n*s (ra*v*e*n*s)	*m*a*m*ber (*g*a*m*ber)
5. m*a*n*a*ger (b*l*o*a*ts)	c*o*n*o*tle (c*a*n*o*tle)
6. *p*o*p*lar (*m*a*p*les)	ra*l*e*l*s (ra*m*e*l*s)
7. *d*e*d*uce (*m*e*d*als)	*r*o*r*tal (*s*o*r*tal)
8. *b*i*b*le (*t*a*b*le)	*n*e*n*tal (*s*e*n*tal)
9. dive*r*s*e* (mo*r*al*e*)	wabe*r*n*e* (wabo*r*n*e*)
10. *t*i*t*les (*v*i*t*als)	*f*u*f*le (*g*u*f*le)
11. s*t*ar*t* (p*l*an*t*)	c*h*ot*h* (c*r*ot*h*)
12. de*n*s*e* (lu*n*g*e*)	fe*r*g*e* (fa*r*g*e*)

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