Orthographic Repetition Blindness

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RUNNING HEAD: Orthographic Repetition Blindness

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Abstract

Repetition Blindness (RB) is the failure to report the second occurrence of a repeated word, when words are sequentially and briefly displayed (Kanwisher, 1987). RB is also observed for non-identical words, such as *home*, *dome*. Explanations for non-identity RB assume that similarity at the level of the whole word causes the second word to be suppressed ("similarity inhibition"). Three experiments demonstrate that RB is robust for diverse types of orthographic relatedness, including critical words which share only their first initial letter, their last 2 letters, first three letters, middle three letters, beginning and final letters, three alternating letters, and three non-aligned letters (as in *chance hand*).   The theoretical construct of similarity inhibition may be able to account for this data, although one mechanism previously proposed in the literature, neighborhood inhibition, is probably not a useful way to explain the data on RB for words sharing only one or two letters. We introduce an alternative explanation for orthographic RB: only the repeated letters are suppressed, and amount of RB depends on how easily the perceiver can reconstruct the target word from the non-suppressed letters.

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Repetition Blindness (RB) is the failure to report the second occurrence of a visual event, when the two events are briefly displayed (usually for durations of less than 150 msec) and appear within 500 msec of each other (Kanwisher, 1987). RB occurs for diverse visual stimuli including words in lists and in sentences, phonologically similar items (Bavelier & Potter, 1992), pictures, and even between words and pictures (such as a picture of the sun and the word *sun*; Bavelier, 1994). Early reports of "paradoxical" repetition effects occurred in the context of studies using prime-target pairs (Humphreys, Besner, & Quinlan, 1988; Marohn & Hochhaus, 1988). Humphreys et al. (1988), investigating masked and unmasked repetition priming at varied lags, obtained an unexpected result: report of the target in the immediate repeat condition with unmasked primes was worse than in a neutral control condition, which is a reversal of the usual facilitative priming effect observed with masked primes. Marohn and Hochhaus (1988) also demonstrated poorer identification of a target immediately following an identical unmasked prime, compared to an unrelated word control condition.

The most common technique for eliciting RB is by using rapid serial visual presentation (RSVP, Potter, 1984) of word lists and sentences. Kanwisher (1987) found that observers failed to report repeated words at rapid presentation rates, even when the two identical words were presented in different case. But RB is most strikingly demonstrated using RSVP presentations of sentences. When viewing the sentence *Unless they are hot enough, hot dogs don't taste very good*, some experimental participants expressed surprise or outrage (Kanwisher & Potter, 1990). The subjective experience of viewers is not that they forgot the second occurrence or were confused about what appeared, but that they saw one occurrence of the event rather than two.

Kanwisher's explanation for RB is that the visual system fails to individuate the two stimuli as distinct events (Kanwisher, 1987; Kanwisher & Potter, 1990). She refers to this as "type activation without token individuation." This explanation has come to be called token individuation theory. The current paper focuses on RB in words, and so it is helpful to translate Kanwisher's general theoretical statement into one specific for words. A word's type is what word recognition researchers have called its logogen (Morton, 1969), node, or word-level representation (McClelland & Rumelhart, 1981). Activating the word node twice may mean sending it an extra burst (or extra packet) of activation (Park & Kanwisher, 1994). According to Bavelier and Jordan (1992), who also support token individuation theory, the activation curves for the two separate bursts are so close temporally that they will be partially superimposed. The increased activation incurred by the second burst could be (on at least some percentage of trials) indistinguishable from random fluctuations in activation levels that occur in any dynamic, probabilistic system.

Can token individuation theory explain RB in non-identical words? Kanwisher and Potter (1990) found RB for orthographically similar words, such as *cap* and *cape*. One proposal is that the types subject to token individuation failure are individual letters, rather than whole words. Two findings caused Kanwisher and Potter to reject individual letters within words as the relevant level. Kanwisher (1986) found no RB for words sharing the same letters in different positions, such as *layer* and *early.* Second, if perceivers were blind to individual letters, then rapid serial display of *fault* and *heart* (which share the single final letter *t*) should cause observers to report *hear.* Using stimuli like these, Kanwisher and Potter (1990) found no RB and no stripping on a final shared letter.

Kanwisher and Potter (1990) concluded with two speculations for why orthographic similarity may lead to RB.

1. RB for similar words could be due to misreading one of the words as the other, which would then allow the mechanism for whole-word identity RB to apply.
2. RB might happen at a level between letters and words, such as some critical number of contiguous letters.

A different set of explanations for orthographic RB involves word-level inhibition. Bavelier and Jordan (1992) suggested that immediately after a word is recognized, it briefly inhibits itself, resulting in a brief time period during which subsequent presentations of the word will not be detected. Orthographic RB can be explained by assuming that words inhibit not just themselves, but other words that are orthographically similar. Chialant and Caramazza (1997) have also pinpointed word-to-word inhibition as the mechanism underlying orthographic RB. We will refer to these proposals as the similarity inhibition hypothesis.

Proponents of similarity inhibition does not specify whether a critical amount of similarity is required to obtain a repetition deficit. Work on orthographic RB has been largely restricted to words differing by a single letter (in any position); these are called orthographic neighbors (Coltheart, Davelaar, Jonason, & Besner, 1977). It is known that high frequency words disrupt the processing of their low frequency neighbors more than the reverse (Segui & Grainger, 1990). Tentative support for the influence of orthographic neighborhoods in RB was offered by Bavelier, Prasada and Segui (1994). They found stronger orthographic RB when the first critical word (W1) is higher frequency than the second critical word (W2). These authors suggest that the mechanism for orthographic RB could thus be related to the idea that processing one word temporarily interferes with processing of its neighbors. We will call this the neighborhood inhibition proposal. It differs from the similarity inhibition hypothesis mainly in assuming that only the most similar words will result in orthographic RB, whereas similarity inhibition allows graded amounts of RB as a function of similarity.

Orthographic RB when critical words are non-neighbors

Like Kanwisher and Potter (1990), Bavelier et al (1994) also speculated that letter clusters or contiguous letter sequences may be the “type” affected by RB. Whether whole words or parts of words are the types affected by RB thus appears to be an open question. Examining RB in non-neighbors would seem relevant to this question.

Kanwisher and Potter (1990) and Bavelier et al. (1994) refer to unpublished findings of RB for long words (6-7 letters) and words of different length which share only 3-4 consecutive letters (*sirloin sir*). These words share letter clusters but are not generally considered orthographic neighbors (Grainger, 1990). The existence of RB in such words implies neighborhood inhibition may not be the right way to think about all cases of orthographic RB.

Our goal in the current paper is to investigate a diversity of types of orthographic relatedness. If RB is only robustly found for orthographic neighbors, the mechanism of neighborhood inhibition will be supported. If RB is found for non-neighbors, then a more vague explanation in terms of similarity inhibition may be preferred. Finding that amount of RB varies in proportion to the degree of orthographic relatedness would support a “center surround” type of neighborhood, in which the amount of inhibition decreases as a function of orthographic distance.

In investigating orthographic relatedness, we will be alert to the possibility that the locus of RB is at the level of contiguous letter clusters, a possibility previously mentioned by both Bavelier et al (1994) and Kanwisher and Potter (1990)and one supported by our past research (Morris & Harris, 1999). On this view, for word pairs like *insult ensure*, only the repeated sequence is the unit affected by a limitation in type-token binding. Perceivers are at risk for non-report of the second critical word, because suppression of (or blindness to) the *nsu* in *ensure* leaves the word node for *ensure* with too little bottom-up activation to pass its recognition threshold. The more repeated letters there are between W1 and W2, the fewer letters there will be available to provide bottom-up activation to the target critical word. We will call this the letter clusters hypothesis.

A possible complicating issue is phonological similarity. In an authoritative paper, Bavelier et al (1994) compared amount of RB for orthographic neighbors having low phonological similarity (*chair choir*) to the amount of RB for rhyme words that had low orthographic similarity (*boss sauce*). RB for the orthographic neighbors was as high as for identical words, suggesting that amount of RB was not diminished by the lack of phonological similarity. Orthographic RB was generally stronger than phonological RB, with phonological RB showing a different time course (more RB at lag 2 than lag1, the reverse of the pattern with identical words and orthographic neighbors). The authors concluded that orthographic and phonological similarity play “distinct and nonadditive roles in repetition blindness” (Bavelier et al, 1994, p. 1446).

To gather additional information about RB, we measured degree of orthographic, phonological and visual similarity (in terms of visually similar letters) for all stimuli. These were entered into multiple regression analyses to determine strength of statistical prediction of participants’ report of both critical words. These correlational measures do not supplant the need for systematic manipulations of phonological similarity, but were conducted to verify our assumption that phonological similarity is not explaining all of the variability that our experimental manipulations attribute to orthographic similarity.

Our first experiment manipulated the number of letters shared by two critical words using a within-stimulus design. We constructed stimuli such that word pairs of length 5 shared all their letters (**Identical** condition), their final 4 letters (**Neighbor** condition), their final 2 letters (**Endsame** condition), or no letters (**Nonsimilar** condition). Neighborhood inhibition as the mechanism of orthographic RB will be supported if reliable RB is only found for the Neighbor condition. Finding measurable RB when only the final 2 letters are repeated will be consistent with the similarity inhibition hypothesis, or the letter clusters hypothesis.

Experiment 1

Method

Participants. A total of forty-one Boston University students participated for course credit. The data of five participants was discarded because their frequency of reporting both critical words in the Nonsimilar condition was less than 50%, most likely due to inaccuracies in our procedure for determining the appropriate exposure duration for individual participants, as described below. Of the 36 experimental participants used in analysis, 79% were female and 21% male; 31 were monolingual speakers of English and 5 were bilingual but had learned English either from birth or before age 5.

Materials. Forty five-letter words were selected such that each could appear as the second critical word in four stimulus conditions: **Identical** (*fears fears*), **Nonsimilar** (*smoke fears*), **Neighbor,** with different initial letter (*years fears*) and **Endsame**, last 2 letters the same (*yours fears*). The mean log frequency of the second critical word was 3.77, standard deviation 1.2, range 0-6.3. The first critical word was selected to have equivalent frequencies across the stimulus conditions. Mean log frequencies for each condition were: Identical, 3.6; Neighbor, 3.1, Endsame, 3.3, Nonsimilar, 3.3 (standard deviations ranged from 1.2 to 1.6; standard errors of the means ranged from 0.20 to 0.25).

Measuring orthographic, phonological and visual similarity. For this and subsequent experiments, the following four scalar measures of similarity between the critical words were calculated for use in multiple regression. Overall orthographic similarity was calculated using Marmurek and Kwantes'

(1994) OS measure. OS takes into account the lengths of the two words, number of letters in the same position, and number of letters (in any position), and yields a value from 0 to 100. Overall phonological similarity (PHOS) was calculated by applying the OS formula to phonetic transcriptions, based on the International Phonetic Alphabet. These were obtained from the MRC machine-readable database (Coltheart, 1981; Wilson, 1987); syllable boundary diacritics were not included in calculating PHOS, and phonemes that were indicated by two text characters were replaced by a single unique text character for calculation purposes. We were additionally concerned that some repetition deficit could derive from visual similarity between letters. Although case was changed between critical words, letters which preserve their gestalt shape across upper and lower case could be susceptible to apparent motion or visual morphing, as discussed briefly in Chun (1997). Following Jacobs and Grainger (1991), we classified the letters c, k, m, o, p, s, u, v, w, x, y and z as visually similar, on the principle that these letters are identical in their major features (i.e., number of line segments, their curvature and relative position). Our measure of letter-based visual similarity was the proportion of letters in W2 that were visually similar to W1. For use in the regression equation, we also transformed the levels of our orthographic manipulation into a scalar value by dividing the number of consecutive repeated letters by word length. We will refer to this as "proportion of consecutive letters." For example, in the current experiment the values of this variable were 0, 0.4, 0.8 and 1. Note that OS and proportion of consecutive letters differ in that OS includes single letters that appeared in the nonsimilar condition. As shown in Appendix A, about 1/4 of the words in the nonsimilar condition repeated 1 or 2 letters in a different position, as in *shirt river.* (In choosing the unrepeated control word, we did not systematically exclude words that had 1 or 2 repeated letters in different positions, given that previous studies reported negligible RB in these cases; Bavelier & Potter, 1992; Bavelier et al, 1994).

Apparatus. The stimuli for all experiments reported in this paper were presented on a Macintosh IIci, with display of stimuli and collection of response times controlled by the PsyScope experimental control software (Cohen, MacWhinney, Flatt, & Provost, 1993). Participants sat approximately 45 cm. from the screen.

Procedure. Each trial began with a row of asterisks, which served as the signal to participants to press the spacebar when they were ready. The two words were then sequentially displayed. The second word was followed by a masking stimulus of 8 ampersands, which was displayed for the same duration as the stimulus items. The first word was always in lower case and the second always in upper case. Duration of the stimuli was individually set for each participant based on two 5-trial blocks of practice items. In the practice trials, exposure was decreased if participants could report both critical words when they were neighbors, but was decreased if participants failed to report both critical words when they were dissimilar. The mean exposure across participants was 72 ms, standard deviation=20, range 45-105. However, finding the right "RB window" proved to be more difficult than anticipated and we sometimes erred on the side of selecting a too-short exposure duration. The too-short exposure duration then reduced report in the nonsimilar condition. To avoid conducting analyses on widely varying percent report, we excluded participants who correctly reported both the critical words on fewer than 50% of trials.

Displayed items occupied a screen height of 1.3 cm., subtending 1.5 degrees of vertical visual angle. The critical words were all 5 letters long, and extended for 2.4 cm., which subtended 6.0 degrees of horizontal visual angle.

Results and Discussion

One-way of analysis of variance on report of both critical words across the four conditions was highly significant; $F_1(3,105)=130$, $F_2(3,117)=130$; both p's < .0001. As shown in Table 1, the Identical condition had substantially less report of both critical words than the Neighbor condition. This confirms previous reports that identity RB is generally stronger than orthographic RB (Bavelier et al., 1994; Kanwisher & Potter, 1990). The data also revealed poorer report of both critical words in the Endsame condition compared to the Nonsimilar condition; $F_1(1,35)=58$, $p < .001$; $F_2(1,39)=31$, $p < .001$. Reliable RB found when critical words shared only their final two letters is a novel finding and argues against the proposal that orthographic RB is limited to highly similar words.

Table 1 about here

We also calculated the repetition blindness index (RBI, Park & Kanwisher, 1994), a measure which is useful for comparing relative amounts of RB between conditions. RBI simplifies summarizing results since differences in RB between two conditions can be measured as the presence of a main effect in an ANOVA, rather than as an interaction between stimulus type and repeatedness.

RBI is an index that extends between 0 and 1, with 0 indicating maximal RB, 0.5 indicating absence of RB, and 1 indicating priming. The formula for RBI is:

$$\text{RBI} = \frac{\textbf{BothRepeated}}{(\textbf{BothRepeated+BothUnrepeated})}$$

BothRepeated = Report of both critical words in the repeated condition

BothUnrepeated = Report of both critical words in the unrepeated condition. (“Repeated condition” refers to any of the conditions in which critical words contained repeated letters.)

In Table 1, the RBI’s are lower than 0.50 for all three conditions with repeated letters, indicating RB for these conditions. In this experiment, the pattern of report of both critical words is clear enough that calculating RBI adds little, however, this index was useful in Experiments 2 and 3.

The raw correlations between percent report of both critical words and the 4 scalar variables were all within a few percentage points of each other (r=-.70 to r=-.72). This is because the variables were highly inter-correlated, and were essentially similar in recapitulating the difference between the Identical and Nonsimilar condition (e.g., all predictors were 1.0 for the Identical condition except for visual similarity). For this and subsequent experiments, we thus found it useful to remove the Identical condition from regression analysis. The correlations with the four predictors were then -0.42 for orthographic similarity (OS), r= -0.40 for proportion of consecutive letters (the experimental manipulation), r=-0.35 for phonological similarity (PHOS), and r=-.23 for visual similarity (visim). Neither PHOS nor visim accounted for any additional variance beyond that predicted by the orthographic measures.

We were surprised that the Endsame and Neighbor conditions had similar levels of RB, since pilot studies had shown more RB in the Neighbor condition. Put another way, why wasn’t there more RB in the Neighbor condition? One tentative explanation is that the report of critical words in the Neighbor condition is artificially high, and represents participants’ strategy of guessing a rhyming word (c.f.

discussion in Harris & Morris, 1998). While recording participants' serial report during the experiment, we observed that participants apparently produced rhymes as guesses for the second critical word. For example, for the stimulus *prime flame* (Endsame condition), a participant produced *prime crime*. For the stimulus *grain brain*, a participant reported *grain train*. In Experiments 2 and 3 we avoided rhyme stimuli.

We have shown that RB occurs for both neighbors and words sharing only their final 2 letters. According to the hypothesis that orthographic RB results from similarity inhibition, *match* and *teach* show small amounts of RB because *teach* is very slightly inhibited by *match*, with amount of inhibition reflecting the relatively small amount of orthographic similarity. One question is whether the repeated letters need to have similar alignment within their respective words. That is, we found RB between *blame* and *flame*, but would we also find it for *blame and lamb*?

Precise predictions of the similarity inhibition hypothesis await a more thorough specification of how orthographic similarity is calculated. Intuitively, the "dynamic time warping" and multidimensional scaling methods of Bavelier and Jordan (1994) could be of use here, but these techniques have not yet been applied to the specific case of predicting amount of RB and are at present unpublished. For the current paper, we will keep this question at the simpler level of whether or not position-specificity (or alignment) is necessary for orthographic RB.

The letter clusters hypothesis does make the unequivocal prediction that RB will be found for words which share non-aligned consecutive letters. The reason is that repeated letters are hypothesized to be unavailable to feed activation to W2, and thus W2 will be at risk for non-report (relative to the Nonsimilar condition) since it receives less than its standard amount of bottom-up activation.

Experiment 2

Our primary goal was to extend orthographic RB to a special type of non-neighbor: the case in which words share a non-aligned letter sequence, as in *c<u>han</u>ce* *<u>han</u>d* and *c<u>are</u>er* *<u>are</u>a*. We will refer to this type of orthographic similarity as **Beginning-Middle**, to indicate that the beginning of one word is the same as the middle of the other word. Our secondary goal was to add controls for low-level visual effects. Experiment 1 lacked an intervening stimulus between the two critical words. Although the case change rules out simple spatial superposition, it could be claimed that perceptual capture is operating (Humphreys, Besner, & Quinlan, 1988; Hochhaus & Marohn, 1991). "Perceptual capture" refers to the difficulty observers may have in discriminating prime and target as distinct perceptual events, when they are briefly displayed in the same screen position, without an intervening mask. Hochhaus and Marohn (1991) showed that amount of RB was diminished (but not eliminated) when prime and target were displayed in different screen positions. They concluded that some perceptual capture may be a factor in RB.

Hochhaus and Marohn used identical words. To rule out perceptual capture as the single explanation for orthographic RB, in Experiment 2 we displayed the critical words in different screen locations and interposed a masking stimulus after each word. We also manipulated SOA by interposing an additional stimulus word between the critical words on half the trials.

Method

Participants

Participants were 32 Boston University undergraduates who participated for course credit or as volunteers (63% females, 37% males). Three participants were bilinguals, but had been exposed to English from birth, while 29 were monolingual English speakers.

Materials and Design

The experiment had two within-stimulus factors: lag (1 or 0 corresponding to whether or not a filler word appeared between the critical words), and relatedness (**Identical**, **Beginning-Middle**, **Nonsimilar**). To construct the Beginning-Middle condition, all the words of length 4-7 were extracted from the Francis-Kucera (1982) listing. A computer program was written to identify all pairs of words such that the first three letters of the second word (W2) were the same as the middle three letters of the first word (W1). Around 70 pairs met this description; we included as experimental items the 60 pairs that were highest in frequency. In 78% of the pairs, the critical three-letter sequence started with letter position 2 of W1 (as in *sound ounce*), and in 22%, the three-letter sequence started in letter position 3 of

W1 (as in *proper open*).

The second critical word was the same across the three stimulus conditions. W1 for the Nonsimilar condition was length and frequency matched to the word used as W1 for the Beginning-Middle condition. The mean log frequencies for W1 in the Nonsimilar and Beginning-Middle conditions were 4.22 (range 0 to 7) and 4.26 respectively (range 0 to 8). The mean log frequency for W2 was 3.28 (range 0 to 7).

Two filler words were included so that participants saw a sequence of four words. In the lag 0 condition, participants saw the sequence “filler W1 W2 filler”, and in the lag 1 condition, participants saw the sequence “W1 filler W2 filler”. The filler words were between 3 and 6 letters long and had a mean frequency of 4.8 (range 0 to 9). The filler words were selected to minimize repeat of letters with the other words in the sequence. The six versions of each stimulus were counterbalanced across participants (see example in Table 2).

Table 2

Procedure

The procedure was similar to Experiment 1 except for the details concerning screen display, masking and practice trials. We varied screen positions of the first 3 words in the lag 0 and lag 1 conditions. The fourth word (a filler) appeared in same position as word 3. Differences in vertical screen position between adjacent words were equal to 0.95 cm., or 1.1 degrees of visual angle. This difference in visual angle corresponds to the amount used by Hochhaus and Marohn (1991) who found diminution in RB using a change in screen position of 1.1 degrees of visual angle, but no additional reduction in RB for differences in visual angle larger than this.

The first two words were shown in upper case, and words 3 and 4 were in lower case. The first word was displayed in the center of the screen, with successive words displaced .95 cm. to the left. We avoided centering all words on the screen, because centering would have meant that many words would have lined up with identical letters beneath each other.

Each of the four words was followed by a mask of 5 ampersands which was displayed for 30 ms. An inter-stimulus interval (ISI) of 15 ms intervened between word offset and mask onset, and between mask offset and the onset of the next word. This means the total interval between word stimuli was 60 ms.

Practice trials. Exposure duration of the words was set individually for each participant on the basis of three blocks of 6 practice trials. The practice trials contained examples of the three stimulus conditions. The goal of the practice trials was to find an exposure duration such that participants tended to report both critical words in the Nonsimilar condition, while failing to report both critical words in the Identical and Beginning-Middle conditions. The mean exposure duration across participants was 100 msec, standard deviation=18, range 60-135. Including the ISI of 60 msec between words, this means the average stimulus onset asynchrony in the lag0 condition was 160 msec. For the lag1 condition, the SOA for critical words was 320 msec.

When, during the first practice block, participants failed to report both instances of repeated identical items (and nearly all participants failed to do so), the experimenter turned to the participant and said, "By the way, on that last trial, one of the words was repeated, it appeared twice. If you ever see the same word twice in a trial, you should go ahead and just say it twice."

Results

Table 3 shows the percentage of trials in which participants correctly reported both critical words, as well as the repetition blindness index (RBI) described in Experiment 1. Participants were poorer at reporting both critical words in the Identical condition compared to the Beginning-Middle condition, resulting in a large main effect for stimulus conditions, as measured by RBI, $F_1(1,31)=62$, $p < .0001$; $F_2(1,59)=82$, $p < .0001$. No difference was found in RBI across the two lags: $F_1(1,31)=2.1$, $p > .15$; $F_2(1,59)=2.14$, $p > .10$. There was also no lag X stimulus interaction (F's = 1.0).

Place Table 3 about here

We verified that a repetition deficit was present for the Beginning-Middle condition by testing if the RBI's were significantly less than .50, which they were for analyses by subjects, $F_1(1,31)=23$, $p < .0001$; and by items, $F_2(1,59)=24$, $p < .0001$.

As in Experiment 1, we excluded the Identical condition from the multiple regression analysis. The raw correlation between percent report of both critical words and the four scalar predictors was r= -0.28 and r=-0.30 for proportion of consecutive letters (lag 0 and lag 1 respectively), r=-0.23 and r=-0.24 for orthographic similarity (OS), r=-0.18 and r=-0.11 for phonological similarity (PHOS), and r=-0.10 and r=-0.-09 for visual similarity (visim). None of OS, PHOS and visim explained any variance in the dependent measure independently of proportion of consecutive letters.

Proportion of consecutive letters is different from OS because OS counts single letters that happened to be repeated (in different word positions) in the nonsimilar condition, and also additionally counts repeated letters which happen to end up in the same word position, counting from the end of the word, as in *grand rang*. (Forty-four of the 60 stimulus items had position specificity of the three letters, counting from word ending.) The finding that proportion of consecutive letters was a slightly better predictor than OS suggests that merely being in the same position of the word (counting from the end) does not influence orthographic RB, beyond the influence of having three consecutive letters repeated.

Discussion

Neighborhood inhibition as the mechanism underlying RB predicted no RB for non-neighbors like *charm, hard* and *clinic, lint.* Our finding of reliable RB for these items is thus inconsistent with neighborhood inhibition as an explanation for orthographic RB. If RB in these words is to be explained using the more general construct of "similarity inhibition," then an important question is what counts as similarity. One obvious idea is that words are similar if they share an initial consonant cluster or a word body. Consonant clusters and word bodies are known to be important in word recognition, and in some theories even constitute an aspect of lexical representation (Treiman, 1994) However, our critical words shared neither word onset nor word ending, and the shared three letters frequently cut across word-body boundaries.

Our finding of RB for words sharing a non-aligned sequence of three letters is consistent with letter clusters as the unit which is affected by RB, *or* with words being the unit affected by RB, but with similarity inhibition operating in such a way that words sharing a repeated cluster of three letters will inhibit each other. Questions relevant to both these theoretical approaches are whether a single letter is sufficient to cause RB (as in *about aware*), and whether non-consecutive letters are sufficient to cause RB, as in *amaze aware)*. Our next experiment takes up these questions.

The second goal of Experiment 2 was to determine if some component of orthographic RB derives from low-level visual effects. We changed case, varied screen position and interposed a mask of ampersands between the two critical words, and still found RB. In addition, we found only a non-significant trend for less RB when a filler stimulus was interposed between the two critical words. Our results are thus most consistent with RB happening at an abstract level, whether it be abstract letter identity, abstract letter clusters, or word nodes.

Experiment 3

In Experiments 1 and 2 we found RB for words sharing as few as 2 of their final letters, and 3 of their middle letters. The letter clusters hypothesis explains this as due to suppression of the repeated letters, which is presumably due to a token-individuation problem at the level of contiguous letters (Kanwisher & Potter, 1990) or to context-dependent letter representations (Mozer, 1991). RB for a single letter could be explained at the level of whole words if it is assumed that words inhibit each other in proportion to their degree of similarity. On this view, a small amount of RB could be expected for words sharing even a single letter. Both the letter clusters hypothesis and the similarity inhibition account are thus consistent with a prediction of RB for words sharing only a single letter, although such a finding would be a novel one, given Kanwisher and Potter's (1990) failure to find any interference between words sharing their single final letter.

A case where similarity inhibition and the letter clusters hypothesis may make different predictions concerns RB for non-consecutive letters, as in *claim charm* and *rider radar.* If RB increases as a function of similarity between words, and if similarity is simply a matter of number of shared letters, then the prediction is equivalent RB between words sharing three *consecutive* letters and 3 *non-consecutive* letters (e.g., 3 alternating letters). An analogous prediction is more RB between words sharing *three* non-consecutive letters than *two* non-consecutive letters.

Our own view is that orthographic RB does not stem from word-to-word inhibition filtered through similarity, but stems from token-individuation problems at the level of letter clusters. This means that not all letters in a word are created equal. We predict more RB for three consecutive letters (*chalk charm*) than from three alternating letters (*claim charm*). Our motivation for this is the idea that letters in the input activate context-dependent representations similar to the wicklefeatures used by connectionist modelers (Mozer, 1991; Rumelhart & McClelland, 1986; Seidenberg & McClelland, 1989; Wickelgren, 1969). Display of *claim* would activate representations for trigrams such as *_cl, cla, lai, aim,* and *im_* (where _ indicates adjacency to white space). Display of *charm* activates different internal representations, namely *_ch, cha, har, arm, rm_*. It is only when two words share consecutive letters that they will also activate some of the same internal letter cluster representations. (Compare the trigrams in *chalk* to the ones listed above for *charm*: *_ch, cha, hal, alk, lk_*.)

Three letters in the middle of a word is also a different situation from three letters at the beginning of the word, mainly because the blank space next to word onset or ending counts as contextual information for a letter clusters model. For example, *shark* and *charm* share three middle letters, but only one letter trigram (*har*), while *chalk* and *charm* also share three letters, but share two letter trigrams (*_ch* and *cha*).

Mozer's (1991) model of multiple visual word recognition incorporates a variety of context-dependent representations, including digrams and what he called "three of four", meaning that representations spanned letter-positions and include a variable. Under the "three of four" encoding scheme, the letter-cluster representations for *chalk* would include *_c?a, ch?l, h?lk, ha?k* and *a?k_*. Testing Mozer's theory -- and especially the "three of four" representations -- is outside the scope of this paper. However, Mozer's theory does have a role for digrams, and if digrams are included in the representations that map from visual input to word recognition, then our letter clusters view predicts some RB if word pairs share a single initial letter. This is because pairs like *clock*, *charm* do share the initial digram *_c*. If only trigrams play a role in this mapping, then no RB is expected when word pairs share a single initial letter.

This experiment addressed two main questions:

1. Does amount of RB differ for words sharing three letters, depending on where in the word the three letters are? To answer this question, we used word pairs which shared three letters at the beginning (*dandy dance*), and middle (*fancy dance*), and also word pairs in which 3 letters alternated with unique letters (*dense dance*). If only the number of shared letters is important (as may be the prediction of a similarity inhibition model), then amount of RB should be comparable across these three conditions. If contiguous letters are necessary for RB, then we predict more RB for *dandy dance* and fancy dance then for the alternating letters condition. Also, if contiguous letters are important, the prediction is *no* more RB for word pairs with three alternating letters (*dense dance*), than for word pairs just sharing an initial and final letter (*drive dance*).
2. Can RB be found for just a single letter? It is possible that much of the current theoretical focus on whole words as the locus of RB stems from Kanwisher and Potter's (1990) failure to find RB for a single final letter (for stimuli like *fault heart*). Inspection of their stimuli suggests that lack of a report deficit for W2 could result from pattern completion of the missing final letter (or missing final digram). We thus decided to use a single initial repeated letter, out of the intuition that pattern completion of a missing initial letter is more difficult than pattern completion of a single final letter.

Method

Participants. Participants were 37 Boston University undergraduates who participated for course credit or as volunteers (75% females, 25% males). Twelve participants were bilingual, with seven having learned English from birth, four before age 5 and one before age 12. The data of an additional six participants was discarded as they reported both critical words on fewer than 50% of the Nonsimilar trials.

Design and Materials. As in Experiments 1 and 2, a within-stimulus design was used such that the second critical word (W2) was invariant across the 8 stimulus conditions for one experimental item, and W1 was varied to create the different conditions. Conditions were counterbalanced across participants. Three conditions were the **Identical**, **Nonsimilar** and **Singleword** (meaning a blank was shown for W1). Word pairs in the other five conditions shared either 1, 2 or 3 of their letters.

Table 4 lists the eight stimulus conditions and provides examples for two items (one of them a word of length 5 and one a word of length 6). Stimuli were selected as follows. A computer program was written to identify pairs of words of length 5 and 6 in the Francis and Kucera (1982) frequency list such that the two words were the same length and the words would satisfy the "alternating" condition. This condition was that the first, third and fifth letters were identical and the remaining letters were non-identical. The number of such words was approximately 6000. From this pool we identified words which also shared the first three letters with another word, thus satisfying the **First 3 Letters** condition. From there we selected the final set of 48 second critical words (W2's), such that other words existed to make W1-W2 pairs in all the conditions listed in Table 4. Of the 48 stimulus items, 24 used words of length 5 and 24 used words of length 6.

It proved difficult to find words that did not share another letter somewhere else in the word. In the interests of completing the 8 conditions of the design, we allowed about 15% of the items to have an extra repeated letter in a different position in the word. For example, the pair *digit rigid* is from the **Middle 3 Letters Same** condition, but the letter *d* at the end of *rigid* repeats the first letter of *digit*. In statistical analyses of differences in RB between conditions, only items rigorously fitting the conditions were included. In regression analysis, all items were included, since the orthographic and phonological similarity measures are sensitive to additional letters and phonemes that are repeated elsewhere in the word.

Place Table 4 Here

The mean log frequency for W2 words was 3.5 (sd=1.7). Words used for W1 were generally lower frequency than words used for W2 (mean log frequency of 2.59, sd=1.7), except for the Nonsimilar condition, where the log frequency was the same as W2. Because amount of RB can be influenced by large differences in the relative frequency of W1 and W2 (Bavelier et al, 1994), we needed to verify that the average difference between W1 and W2 was similar across our stimulus conditions. This was demonstrated by running a two-way anova on log frequency, using the 5 orthographically similar stimulus conditions and 2 length conditions as predictors. F statistics were less than 1, indicating that mean log frequency did not differ across the stimulus conditions.

Procedure. The procedure and screen display was the same as in Experiment 1, except for a slightly wider horizontal visual angle for the stimuli that were six letters long.

To obtain the optimal exposure duration for individual participants, we programmed our experimental control software to automatically increase or decrease exposure during 24 practice trials based on experimenters' keying of whether the participant correctly reported both, none or one of the words (practice trials contained no orthographically similar words). The mean exposure duration for participants was 60 ms (range 45-90, sd 14). Instructions to participants were that they would see either one or two words displayed briefly and sequentially, and to report what they saw; if the same word was displayed twice, say the word twice.

Results

Table 5 displays percent report of both critical words and RBI. The clearest finding is that RB was greatest in the Identical condition and lowest in the Beginning Letter Only condition. The conditions in which 3 letters were shared had intermediate levels of RB. We used report of both critical words as our dependent measure for specific comparisons between group means, and note in the analysis whether statistics using RBI were comparable. All ANOVAs reported here were conducted using subjects as the random variable.

Place Table 5 Here

RB was found for a single initial letter. The Beginning Letter Only condition showed less report of both critical words (that is, more RB) than the Nonsimilar condition; $F(1,36)=13$, $p < .001$. A comparable F statistics was found for a test of whether RBI in the Beginning Letter condition was reliable less than 0.50. There was a trend for more RB for words sharing a beginning and final letter than words sharing just a single lette, but this is apparent only when comparing RBI scores.

More RB was found when pairs shared their first three letters than when pairs had three alternating letters the same, or three middle letters the same ; $F(1,36)=5.1$, $p < 0.03$. However, this difference was not significant using RBI. A trend was found for more RB in the Alternating Letters condition compared to words that had only the first and last letter the same; $F(1,36)=2.3$, $p < .15$.

Raw correlations between percent report of both critical words and our regression predictors were r= -0.35 for orthographic similarity (OS), r=-0.29 for phonological similarity (PHOS), r=-0.29 for proportion of consecutive letters, and r= -0.12 for visual similarity (after excluding the Identical condition). OS was the best predictor, and none of the other variables had predictive value independently of OS. The finding that OS was a better predictor than proportion of consecutive letters confirms the finding, from comparison of condition means, of reliable RB for conditions with a single repeated letter at the beginning and the word, or three non-consecutive repeated letters.

Discussion

This experiment showed that a single initial letter repeated between two critical words is sufficient to cause deficits in reporting both words, a finding which contradicts Kanwisher and Potter's (1990) conclusion that RB is not observed for a single letter in a word. The experiment also showed that three letters either alternating or consecutive leads to an amount of RB that is greater than for a single repeated letter, but substantially less than is found when the whole word is repeated.

We also found that three non-consecutive letters showed comparable RB to three consecutive letters. RB for three non-consecutive letters might initially appear to require either individual letters or the whole word to be the locus of operation of the RB effect. But according to Mozer's (1991) model, initial and final letters activate digrams. Observed RB for three non-consecutive letters in cases like *dense dance* might reflect the sum of independent suppression of the initial and final digrams, *_d* and *e_*. Our control for this was to compare RB in *dense dance* to RB in *drive dance*. However, we did find a trend for more RB in the former condition (see Table 5). This suggests that the presence of the repeated middle letter does further impair word recognition, which may argue for RB being a result of suppression of individual repeated letters, rather than letter cluster representations.

There was some evidence for greater RB for words which shared their first three letters than words which shared their middle three letters or alternating three letters. This finding is consistent with the letter clusters prediction, since items like *chalk charm* share two trigrams (*_ch, cha*) and three digrams (*_c, ch, ha*); but items like *sharp charm* share only one trigram (*har*) and 2 digrams (*ha, ar*) and items like *claim charm* share no trigrams and only two digrams (*_c, m_*). Alternatively, this finding may speak to the general importance of word-beginnings in visual word recognition.

General Discussion

Across three experiments, we found deficits in reporting orthographically similar word pairs with diverse types of orthographic similarity. We found robust RB for words sharing the first three letters and middle three letters, and for words sharing an initial and final letter. We found RB for words sharing as little as the final two letters or a single initial letter. Repeated letters did not have to share the same position within words, since we found strong RB for pairs such as *clinic lint.* Furthermore, when number of letters shared by the critical words was varied (as in Experiments 1, 2 and 4), more RB was found for word pairs sharing a larger number of shared letters.

Our explanation for orthographic RB is that a token-individuation problem is happening at the level of individual letters or at the level of context-dependent letter cluster representations. Pattern-completion mechanisms or the context-sensitivity of these representations could be what has kept past researchers from finding RB for single letters.

An implication of this view is that RB can be a tool for investigating the orthographic units mediating word recognition. One idea is that the probability of being able to report the second of two similar words (displayed in RSVP) depends on:

- letter co-occurrence statistics calculated across all words (adjusted for word frequency)
- how informative the unrepeated letters are to word identity (e.g., the trigram *fru* is highly diagnostic of the word *fruit*)

This suggests that it should be possible to use the statistical properties of English words to predict relative amounts of RB, even when proportion of shared letters is held constant. Such a statistical model would be a useful addition to the literature on RB and to our understanding of the role of orthography in word recognition.

Alternative Accounts: Neighborhood and Similarity Inhibition

Bavelier et al (1994) were the first to posit that orthographic RB reflects neighborhood inhibition. Chialant and Caramazza (1997) have recently taken up this position, claiming that recognition of the second critical word (W2) is impaired because of the inhibitory effect produced during recognition of W1 on all orthographically similar lexical entries.

Our data could be consistent with this, especially if orthographic similarity were defined in such a way as to encompass words that share as few as two final letters or just the first letter. One clue about how orthographic similarity could be defined in this way comes from the Chialant and Caramazza's remark that inhibition between words occurs under conditions in which lexical items compete for selection. It is possible that as few as a single initial letter leads to RB because a single initial letter shared between critical words is sufficient to make the two lexical items compete for selection. We are thus open to explanations for RB at the level of whole words, if methods can be developed for explaining precisely how variations in orthographic similarity lead to variations in RB.

Explanations based on suppression of individual letters (or letter clusters) makes different predictions from word-level similarity inhibition regarding whether the unique (nonrepeated) letters in W2 are activated and capable of feeding activation to words. The individual letters/letter clusters view says "yes". An implication is that observers may often make a guess at W2, using the nonrepeated letters as the basis for their guess. Indeed, it was our early and frequent observation of participants uttering misreportings of W2 such as those in (1)-(4) that led us to hypothesize a sublexical locus for orthographic repetition blindness (Harris & Morris, 1998; Morris & Harris, 1999). (The first sentence in each pair is the displayed sentence, the second is participants' report; question marks indicate participants' uncertain tone of voice.)

(1) *My <u>sister</u> was unhappy because her <u>blister</u> was hurting.*
My <u>sister</u> was unhappy because of the <u>blinding</u>?

(2) *I can't <u>face</u> my <u>fate</u> back home*
I can't <u>face</u> my <u>plate</u> back home?

(3) *He doesn't ever read a <u>book</u> or <u>cook</u> at home.*
He doesn't ever read a <u>book</u> or <u>cat</u>?

The important aspect of these misreportings is that they contain proportionately more of W2's unique letters than W2's repeated letters. This is consistent with the idea that the repeated letters in W2 are unavailable to activate W2, as would be expected by a token individuation problem at the level of letter cluster representations.

Example (3) is a special type of misreporting. Here the "leftover" *c* of *cook* is blended with the letters *at* to create *cat*. Across more than 8 experiments we have systematically caused participants to report such illusory words by placing a letter fragment in the RSVP stream, as in examples (4) and (5) (Morris & Harris, 1999).

(4) *pain grain avy* -->*pain gravy*

(5) *hate upstate airs*-- >*hate upstairs*

If inhibition from lexical competition is at work in RB, then words which are orthographically similar to W2, such as *gravy* and *upstairs*, should also be inhibited. Another question that the similarity inhibition view needs to address is why the nonrepeated letters are disproportionately represented in the misreportings.

Conclusions

We found robust RB for diverse types of orthographically similar words, including words sharing a single initial letter (*solid sharp*) and words sharing a non-aligned letter sequence (*chance hand*). To account for this data, theories of orthographic RB based on inhibition (or lexical competition, c.f. Chialant & Caramazza, 1997) would need additional theoretical elaboration to make predictions about how amount of RB varies as a function of amount and type of orthographic similarity. The letter clusters view, while novel and thus relatively untested, has an advantage in that it appears capable in principle of making quantitative predictions based on letter cluster statistical co-occurrence frequencies.

Appendix A: Materials for Experiment 1

The second critical word (W2) appeared in upper case.

	W1 for three conditions		W2
Nonsimilar	Endsame	Neighbor	
shirt	river	maker	baker
agent	prime	flame	blame
hours	truck	clock	block
relax	ninth	tooth	booth
music	robin	grain	brain
cloth	solve	grave	brave
tiger	salad	dread	bread
breed	story	harry	carry
shake	groan	glean	clean
naked	stick	track	crack
sting	shame	grime	crime
plain	flesh	brush	crush
women	exist	trust	crust
third	swung	going	doing
newly	swift	craft	draft
lying	slave	grove	drove
dream	yacht	might	fight
shiny	cloak	break	freak
shift	cross	class	glass
sweet	drawn	brown	grown
stool	porch	catch	hatch
enjoy	false	mouse	house
ocean	range	fudge	judge

basic	total	regal	legal
urine	tidal	royal	loyal
thing	local	petal	metal
brink	alley	honey	money
films	teeth	forth	north
shown	super	elder	older
moody	mount	faint	paint
image	bench	ditch	pitch
issue	stand	sound	round
fiber	reply	badly	sadly
flown	tramp	plump	slump
chips	rainy	funny	sunny
flood	quote	paste	taste
screw	match	beach	teach
sever	black	chick	thick
bring	chest	coast	toast
pause	entry	sorry	worry

Appendix B: Materials for Experiment 2

The first filler word (Filler 1) and the first critical word (W1) appeared in upper case.

Filler 1	W1 for two conditions		W2	Filler 2
	Nonsimilar	Begining-Middle		
son	neural	ablaze	lazy	dark
dog	behold	aflame	flax	shut
for	three	again	gait	sunday
red	union	alone	long	high
bed	enter	aware	warm	roof
get	focus	blame	lamb	moving
sun	trust	blind	line	yellow
six	thief	blunt	lung	henry
did	adopt	brace	rack	softly
box	signal	career	area	muscle
was	violin	cement	menu	proof
you	effort	chance	hand	wish
our	sixth	charm	hard	doing
key	toward	church	hurt	base
mop	party	clear	lean	drive
pad	doubly	clinic	lint	reach
war	shall	close	lost	milk
air	stole	creep	reek	what
top	career	design	sigh	almost
pan	spoke	drink	ring	flow
lay	while	during	rink	path
say	better	enough	noun	record
can	beauty	escape	scalp	relief

bit	water	every	verb	couple
him	combine	eyelid	yelp	stuff
now	single	french	rent	common
led	change	future	turn	paint
sir	dozen	grand	rang	happy
war	night	group	round	them
dry	table	heard	earn	cope
bar	zoning	insult	sulk	museum
boy	saying	method	those	apart
ray	spirit	mother	then	bird
fit	shown	peace	each	detail
why	itself	period	riot	scheme
god	right	place	lack	come
car	ground	policy	lice	trap
sex	actual	proper	open	fact
boy	major	school	hood	wash
two	bottle	season	east	pencil
ask	patent	secure	curl	hung
try	court	shall	half	decide
new	quiet	sharp	harm	upon
age	rival	shelf	help	medium
per	wave	skin	king	foot
bay	rabbi	slice	lick	novel
leg	floor	sound	ounce	early
die	valley	spread	press	hotel
guy	having	street	trend	voice
use	wood	strip	trio	jamming

hit	enigma	sweaty	weak	girl
ten	avail	swine	wing	heavy
won	await	tease	easy	stick
sue	drill	thank	hang	act
own	until	think	hind	expect
win	fight	trade	radio	such
arm	honey	treat	real	basic
sit	bomb	wear	earl	plenty
job	where	which	hick	ending
any	bright	window	index	mama

Appendix C: Materials for Experiment 3

Note: The second critical word (W2) was the same across conditions, and always appeared in upper case.

W2	alternating	first 3 letters	mid 3 letters	first, last	first only	nonsim
alone	above	aloof	blond	awake	adapt	syrup
aware	amaze	await	swarm	apple	about	lucky
brace	blame	brain	crack	binge	bluff	might
blind	build	bliss	fling	beard	badge	house
charm	claim	chalk	shark	cream	clock	noise
clear	cheer	clerk	plead	choir	comic	mushy
creep	cheap	creak	green	champ	cabin	fishy
dance	dense	dandy	fancy	drive	dough	photo
frame	flake	frank	cramp	force	fight	block
grand	guard	grass	crane	gourd	ghost	chill
glare	grape	glass	alarm	goose	goofy	hobby
peace	plane	pearl	beach	phone	phony	drift
place	phase	plaid	black	paste	pound	misty
radar	rider	radio	madam	river	roses	check
rigid	raged	right	digit	round	rolls	novel
snows	shoes	snoop	known	swiss	smart	paper
sharp	stamp	shack	chart	sweep	solid	flood
sound	squad	south	young	salad	stage	alive
slice	shine	sling	click	snake	stars	front
treat	theft	trend	bread	tight	thumb	spoon
tease	trade	teach	feast	table	thorn	cliff
think	trick	third	shiny	truck	taxes	frost
whine	write	whisk	china	worse	walks	sport

which	weigh	white	thick	worth	words	nurse
finger	funnel	finish	single	factor	famous	tattoo
racket	richer	racial	nickel	report	ribbon	hollow
rumors	remark	rumble	memory	recess	riddle	liquid
silver	salted	silent	velvet	sulfur*	smooth	bought
season	shadow	search	weasel	slogan	strict	church
sweaty	sheets	swerve	breath	stormy	spring	forbid
taller	tilted	talent	gallon	temper	touchy	poison
turkey	target	turnip	market	trashy	tomato	willow
policy	palace	pollen	splice	plenty	puzzle	autumn
period	pardon	permit	serial	placid	puppet	attack
person	parrot	perish	versus	pigpen	punish	school
potato	petite	potent	estate	psycho	puddle	nuzzle
maniac	mental	mantle	denial	mystic	murder	system
murder	market	murmur	garden	meteor	moving	switch
method	motion	metals	author	morbid	mutual	salary
horrid	heroin	hornet	borrow	hazard	hyphen	nature
butler	bitten	button	titles	beggar	bypass	little
career	curfew	carrot	screen	collar	custom	around
clinic	crisis	client	saline	cognac	cuddle	taught
convey	cancel	confuse**	denver	crummy	cruise	strong
danger	donkey	dangle	tangle	doctor	doodle	filthy
family	female	famous	examine**	frenzy	freeze	course
gender	gunmen	genius	handed	guitar	guilty	should
insult	itself	inside	ensure	import	ironic	toward

*Stimulus-construction error. *Sulfur* contains a middle *l* as does *silver*, but this condition was supposed to share only the initial *s* and final *r* of *silver*. **Seven-letter word as no appropriate six-letter word could be found.

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Table 1

Percent Report of Both Words and Repetition Blindness Index for Experiment 1

Stimulus Condition	Example	% Report of Both Words	Standard Error	RBI
Identical	house HOUSE	2	1.1	0.02
Neighbor	mouse HOUSE	50	3.8	0.37
Endsame	false HOUSE	52	3.1	0.39
Nonsimilar	enjoy HOUSE	77	3.0	--

Table 2

Table 2

Example Materials for Experiment 2

Condition	**RSVP Sequence** Lag0	Lag1
Identical	WAS MENU menu proof	MENU WAS menu proof
Similar	WAS CEMENT menu proof	CEMENT WAS menu proof
Nonsimilar	WAS VIOLIN menu proof	VIOLIN WAS menu proof

Note. Critical words are underlined.

Table 3

Table 3

Percent Report of Both Critical Words and RBI for Experiment 2

	Lag 0			Lag 1		
Condition	%Both Words	SE	RBI	% Both report	SE	RBI
Identical	8	1.4	0.13	16	1.8	0.19
Beginning-Middle	37	3.6	0.40	47	3.5	0.41
Nonsimilar	53	3.4	--	66	2.8	--

Table 4

Table 4

Examples of Stimulus Conditions for Experiment 3

	Five Letter Example		**Six Letter Example**	
Condition	W1	W2	W1	W2
Single Word	--	SHARP	--	RACKET
Identical	sharp	SHARP	racket	RACKET
Alternating Letters	stamp	SHARP	richer	RACKET
First 3 Letters	shack	SHARP	racial	RACKET
Middle 3 Letters	chart	SHARP	nickel	RACKET
Beginning+ End	sweep	SHARP	report	RACKET
Beginning Letter	solid	SHARP	ribbon	RACKET
Nonsimilar	flood	SHARP	follow	RACKET

Table 5

Table 5

Results for Experiment 3

Condition	%Both Report	SE	RBI	N[b]
Identical	5	1.5	0.09	48
First 3 Letters	33	4.2	0.31	38
Alternating Letters	43	4.2	0.32	48
Middle 3 Letters	43	3.5	0.36	40
Beginning + End	53	5.9	0.38	26
Beginning Letter	54	4.1	0.41	39
Nonsimilar	68	4.1	--	38
Single Word	3[a]	1.1	--	48

Notes.

[a] Refers to percent of trials when participant reported seeing the single word twice.

[b]The number of items is less than 48 for some conditions because means were calculated only for the items which which fit the condition exactly (see Materials).

March 5, 1999 **Ref: QJEPA 07897 A**

Dr. Jonathan Grainger
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Universite de Provence
29 Av. Robert Schuman
13621 Aix-en-Provence
France

Dear Dr. Grainger,

Enclosed is a resubmission of my paper with Alison Morris entitled "Orthographic Repetition Blindness," which you tentatively accepted for publication in the *Quarterly Journal of Experimental Psychology* pending revisions. I appreciate the careful reading the paper has received from you and the referees, and have incorporated all of the suggested improvements. Specifically:

- Experiment 1 has been dropped.
- As you noted, phonological similarity is never separated from orthographic similarity. I did not separate these two as a good job at separating was done by Bavelier and Potter (1992) and Bavelier et al (1994). These authors concluded that phonological RB is weaker than orthographic RB, and that independent effects of phonological similarity are only reliably found when orthographic similarity is minimal (as in *ate eight, boss sauce*). (I now briefly discuss Bavelier's conclusions on p.6.) Nonetheless, to determine if phonological similarity plays a role in my stimuli, I devised scalar values of both orthographic similarity and visual similarity (described in the methods section of Experiment 1, page 8) and entered these into a regression equation. Orthographic similarity was always the best predictor of report of both critical words.
- What is the role of visual similarity (lower case o, upper case O)? To respond to referee 2's concern about visual motion morphing, for all stimuli in all experiments, I calculated the percent of letters which are visually similar (as in o and O) and included this as a predictor in the regression equation mentioned above (see method on page 8). Visual similarity was never a significant predictor of RB for any experiment (beyond what was predicted by orthographic similarity).

- The method of measuring RB is homogenous across the three experiments (the percent report of both critical words, and the related measure of RBI). The regression analysis and predictors are also constant across the three experiments.
- All data is present in tables as recommended.
- Interpreting the results: I “toned down” the discussion of support for the letter cluster account of orthographic RB; the data is discussed more neutrally. The main contribution of this paper is empirical; setting out new results that are could be compatible with several different theoretical approaches.
- Critique of Chialant and Caramazza (1997) is eliminated.
- Referee 1 identified some inaccuracies in our materials description (including errors in some stimulus items) for which I am very grateful. I incorporated all of the recommendations for improving clarity offered by both referees.

Let me close by saying that I realize that from the first submissions the referees were very skeptical of the argument and data. You saw the potential of this work, and reached out to urge us to do the necessary additional experiments and resubmit. Thank you.

Sincerely,

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