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Visual and Phonological Codes in Repetition Blindness

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Repetition blindness (RB) is the inability to detect or recall a repeated word in rapid serial visual presentation. The role of visual versus phonological (name) similarity in RB was examined. RB was found for single letters, whether printed in the same or different cases, and for single digits, whether represented verbally (nine), as arabic numerals (9), or in a mixture of the 2 formats. Hence, visual similarity is not necessary to produce RB. RB was obtained between homophonic pairs (won/one), showing that phonological similarity is sufficient to produce RB, although visual identity also contributes to RB. It is proposed that RB results when the codes used for initial registration of the targets in short-term memory are similar. This initial code may be predominantly visual or predominantly phonological.

Recent studies have made clear that the human visual system has difficulties in representing separately two instances of the same event, at least when the two events are in close temporal proximity (Kanwisher, 1986, 1987; Mozer, 1989). Such repetition blindness (RB) is substantial when subjects are presented repeated targets over time using rapid serial visual presentation (RSVP) of words or other stimuli, at rates of about 150 ms per item and higher. The size of the RB effect diminishes as the rate of presentation decreases or as the lag between the repeated items increases during repetition detection or recall tasks (Kanwisher, 1986, 1987). Ordinarily, the first instance (C1) of the repetition is noted but the second instance (C2) is not. (Whether it is C1 or C2 that a subject has recalled is determined by the serial order of recall.[1]) Kanwisher (1986) proposed a two-stage model of visual encoding in which first the visual input activates its corresponding *type* (a mental representation that is accessed through the encoding process), and then, in a second step, a *token* of the type is created. The token is a specific representation of the event available in episodic memory for recall. In this model, RB is attributed to the inability to individuate a second new token from the same type at a very short lag. Thus, only the first instance is represented episodically.

The original hypothesis assumed that a condition for RB was the presentation of two visual events that share a common type; two events that have different types should not be subject to RB. However, Kanwisher and Potter (1990) found RB between nonidentical but similar words such as *cape* and *cap*; recall of C2 was impaired by the presence of C1 earlier in the sentence. Bavelier, Prasada, and Segui (1991) reported a similar finding for French words differing by as many as three letters (e.g., *sort* [fate] and *ressort* [spring] or *baguette* [bread] and *bague* [ring]). Thus, RB appears to occur not only for identically repeated words, but also for pairs of morphologically unrelated, similarly spelled words.

The presence of RB between different words that are orthographically similar suggests that RB is not restricted to just one form of type coding, such as the orthographic lexical entry. The purpose of the present experiments was to examine other relationships between the two items that might be the basis for RB, focusing on cases in which visually distinct stimuli shared the same phonology. In the initial experiments phonological identity and conceptual identity corresponded; in the later experiments, they were dissociated by the use of homophones.

Experiment 1

In Experiment 1 we examined RB between single letters that were the same or different in case. Kanwisher (1987; see also Marohn & Hochhaus, 1988) found RB between words differing in case, but that may have been because word identity was more salient in those experiments than physical form. Earlier experiments (Adams, 1979; Besner, Coltheart, & Davelaar, 1984; Evett & Humphreys, 1981; Friedman, 1980; Morton, 1979; Scarborough, Cortese, & Scarborough, 1977) have indicated that letter identity is abstracted from case and font early in processing, so that it is plausible that RB reflects abstract orthographic or letter-level type identity rather than exact visual identity. In Experiment 1, short RSVP lists of single letters were immediately recalled by subjects. To increase the likelihood that subjects would attend to case differences, subjects were asked to indicate the case of letters they recalled.

Method

Subjects. Twenty-two Massachusetts Institute of Technology (MIT) undergraduates participated in this experiment. All the subjects

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[1] In Kanwisher's initial articles "R1" and "R2" were used, but because R implied "repeated" even for the control (unrepeated) trials, the more neutral "C" (for "critical") is used in Kanwisher (1991) and in this article.

were native speakers of American English and were paid for their participation.

Materials and design. Fourteen practice trials were followed by 96 experimental and 20 filler trials. Each trial consisted of a sequence of six arrays preceded and followed by a row of percentage signs. On the experimental trials, three of the six arrays were single letters, written in uppercase (A) or in lowercase (a). The other three arrays each consisted of a single keyboard symbol. Figure 1 shows a sample trial. The position of the two critical letters (C1 and C2) was varied, but the first letter never appeared as the first item and the two critical letters were always separated by the third intervening letter. On half the trials a symbol also intervened between the two critical letters. The 20 filler trials consisted of two letters (sometimes repeated) and four symbols.

All the letters of the alphabet were used except *i, u, v,* and *l.* These letters were eliminated because they were difficult to discriminate. Adjustments were made to avoid sequences of letters on a given trial that formed a word, but otherwise random permutations of the 22 letters were used to assign the letter identities.

On half the experimental trials, C1 and C2 had the same letter identity (repeated trials), on the other half, they had a different identity (unrepeated trials). Repeatedness was counterbalanced between two versions of the experiment by changing the letter identity of C1. The case of C1 and C2 was varied between items (on 25% of the trials C1 and C2 were both uppercase; on 25%, both lowercase; on 25%, upper-lower, and on 25%, lower-upper). Thus, case of the critical items was the same on half of the trials and different on the other half, crossed with the letter-repeatedness variable. Each subject saw 24 experimental trials in each of these four conditions (repeated/unrepeated by same/different case). A final between-items variable was the lag between C1 and C2: On half the trials in each of the four main conditions, one letter intervened, and on the other half a letter plus a symbol intervened. In the present experiments, RB almost always showed a tendency to be larger at Lag 1 than at Lag 2. This trend is in accordance with the finding that RB decreases when lag increases (Kanwisher, 1986). Because this effect ordinarily did not interact with other variables, it will not be discussed further in this article.

Procedure. Each trial began when the subjects pressed the space bar on the computer keyboard. The row of asterisks present at the same location as the subsequent items disappeared and the items appeared one at a time in the same place, for 100 ms per item (see Figure 1).

Subjects were instructed to read the letters and ignore the symbols; they were asked to write down after each trial the letters they saw, in the order and in the format (upper vs. lowercase) in which they had seen them. They were explicitly told that if they saw a repeated letter, they should write the letter twice. They were also told that there could be one, two, or three letters per trial. Fourteen practice trials preceded the experimental and filler trials.

Apparatus. The stimuli were presented on a cathode-ray tube (CRT) screen with a rapid fade phosphor, controlled by an IBM-XT computer. The experiment was carried out in normal room illumination.

Results

For each condition, we counted the number of recalls of C1 and C2. The percentage of trials in which both C1 and C2 were recalled, for each of the format categories, is presented in Table 1.[2] Analyses of variance (ANOVAs) by subjects were carried out, with repeatedness, sameness of case, and the case of C1 as variables.

An overall repetition effect, $F(1, 21) = 82.5, p < .0001$, was present, but there was no same-different case effect and no interaction between repetition and same-different case, $F(1, 21) = 2.3, p > .15$. For the minor variable of which case came first, there was a significant main effect, $F(1, 21) = 10.7, p < .004$, and an interaction with same-different case, $F(1, 21) = 13.4, p < .001$, suggesting that uppercase letters were recalled somewhat more accurately than lowercase letters.

A triple interaction among repetition, same-different case, and lowercase-uppercase first, $F(1, 21) = 32, p < .0001$, suggested that RB was larger when C2 was a lowercase letter than when C2 was an uppercase letter, independent of the case of C1 (see Table 1).

Separate analyses of each of the four case combinations (C1 and C2 lowercase, C1 and C2 uppercase, C1 lowercase and C2 uppercase, and C1 uppercase and C2 lowercase) showed a significant repetition effect in each condition (all *p*s < .0001).

We also looked at the percentage of times subjects reported C1 or C2 in the wrong case. Altogether, there were few case errors: 8% of the recalled items were reported in the wrong case. The percentage of case errors (given that the item had been recalled) was not affected by repetition or whether the item was C1 or C2.

Discussion

The main finding consisted of a significant negative effect of repetition that was unaffected by difference in case. The size of the RB effect, expressed as the percentage of C1 and C2 recalls in the nonrepeated condition minus the percentage in the repeated condition, was comparable for same (25.5%) and different (21%) formats.

This confirms the previously reported indifference to case of RB for words (Kanwisher, 1986). The finding is consistent with evidence that letter identification happens at an abstract level dissociated from case (Friedman, 1980; Rayner, McConkie, & Zola, 1980).

The comparable size of the RB effect for same and different case letters shows that RB can be independent of specific visual properties but does not rule out the hypothesis that RB could be due to the sharing of abstract, highly overlearned visual features. One's ability to read handwritten text is highly dependent on one's capacity to encode visually different targets into the same letter or word category. This abstraction from configural information (case format as well as font or

[2] Most previous repetition blindness experiments reported the recall of the first instance (C1) and the second instance (C2) separately, and we did such analyses also in the four first experiments. To determine in the repeated case whether C1 or C2 had been recalled, if only one was, we relied on the relative serial position in recall of the target and the item presented between C1 and C2. We found similar results for C2 to those obtained when looking at the recall of both C1 and C2. We also found some repetition effects on C1, but there was uncertainty as to whether C1 was missing or had changed serial position. The recall of both C1 and C2 seemed to be a clearer indicator of the RB effect. In the last three experiments using sentences, there was rarely any ambiguity about whether C1 or C2 was missing, so the two were analyzed separately.

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Experiment 1          Experiment 2          Experiment 3

%%%%%                 %%%%%                 %%%%%
  +                     +++                 >>>>
  =                   nine     [C1]          won     [C1]
  a    [C1]           {{{{                  caught
  c                      8                   +++
  A    [C2]           nine     [C2]          one     [C2]
  >                   <<<<                  }}}}
%%%%%                 %%%%%                 %%%%%
```

Figure 1. Examples of trials from Experiments 1, 2, and 3; displays were presented sequentially at the same cathode-ray tube (CRT) location.

handwriting styles) appears to occur during early stages of visual encoding and is certainly a learned skill. Letter case changes are part of the same representational system, and many upper- and lowercase letters share at least some visual features. Experiment 2 was designed to test whether RB would be found across different formats, when the corresponding systems are more distinct.

Experiment 2

In Experiment 2, the format change involved single digits written either in verbal (nine) or arabic (9) format. Although the spoken names of the two digit formats and their mathematical meanings are identical, the representational systems are distinct both visually and in usage. Although people can read words with a mixture of cases (e.g., capitalized words, or even THis word), mixtures of digit formats are unacceptable. Furthermore, each format system for digits is ordinarily restricted to certain contexts. Calculations, for example, are invariably represented with arabic numerals. The question in Experiment 2 was the same as in Experiment 1: Would there be RB for different-format digits, and if so, would it be as strong as for same-format digits?

Method

The method was the same as that of Experiment 1 unless otherwise specified. Subjects viewed sequential trials that included three single digits mixed with three irrelevant arrays of symbols. Their task was to write down the numbers in the format in which each had been presented.

Subjects. Twenty-eight subjects who did not participate in the previous experiment participated in Experiment 2.

Materials and design. One-digit numbers were used (between 1 and 9) in place of the 22 letters used in Experiment 1. The symbol arrays consisted of rows of three, four, or five identical keyboard symbols. Figure 1 shows a sample trial. The design, procedure, and apparatus were otherwise identical to that of Experiment 1. In particular, there were two versions of the experiment, counterbalancing repeatedness; the other variables (same/different format and lag) were counterbalanced between items and remained constant in the two versions.

Results

The percentage of recalls of both C1 and C2, for each of the format categories, is shown in Table 2. ANOVAs by subjects were carried out on the number of trials in which both C1 and C2 were recalled.

Overall effects of repeatedness, $F(1, 27) = 122.9$, $p < .0001$, and of same–different format, $F(1, 27) = 24.1$, $p < .0001$, were observed. There was, however, a significant interaction between repeatedness and same–different format, $F(1, 27) = 19.3$, $p < .0001$, with a greater repetition effect when the format was the same. In separate analyses of same- and different-format conditions, we observed a significant repetition effect in both conditions ($ps < .0001$).

Table 1
Experiment 1: Percentage of Trials in Which C1 and C2 Were Both Recalled

	Same case			Different case		
Repeatedness	Lowercase/ lowercase	Uppercase/ uppercase	*M*	Lowercase/ uppercase	Uppercase/ lowercase	*M*
Not repeated	66.5	69.5	68	64.5	71.5	68
Repeated	32	52.5	42.5	52	42.5	47
Not repeated–repeated	34.5	17	25.5	12.5	29	21

Note. C1 = first instance; C2 = second instance.

Table 2
Experiment 2: Percentage of Trials in Which C1 and C2 Were Both Recalled

	Same format			Different format		
Repeatedness	Verbal/ verbal	Arabic/ arabic	*M*	Verbal/ arabic	Arabic/ verbal	*M*
Not repeated	84.5	77	80.5	84	80	82
Repeated	56	47.5	52	74	64.5	69
Not repeated–repeated	28.5	34.5	28.5	10	15.5	13

Note. C1 = first instance; C2 = second instance.

An arabic–verbal first effect was also present in the main analysis, $F(1, 27) = 19.3$, $p < .0001$, showing overall better recall of C1 and C2 when C1 was a verbal number rather than an arabic one. No other interactions were significant.

We also looked at the percentage of times subjects reported C1 or C2 in the wrong format. Altogether, there were few format errors: 4.5% of the recalled items were reported in the wrong format. The percentage of format errors (given that the item was recalled) was not affected by repetition or whether the item was C1 or C2.

Discussion

As in Experiment 1, a strong RB effect was found even when the critical stimuli were presented in different visual formats. However, in Experiment 2 the size of the RB effect was greater when the format was the same (28%) than when it was different (13%). Concerning our main question, the presence of substantial RB between different-format digits cannot easily be explained on the basis of the sharing of abstract learned perceptual features by the verbal and arabic forms of a given number. Evidently, visual similarity (however abstract) is not a necessary condition for RB. The reduction in the size of the RB effect for different-format numbers is consistent with the hypothesized existence of two separate pathways to encode verbal and arabic numbers (McCloskey, Sokol, & Goodman, 1986). In contrast, upper- and lowercase letters are unlikely to be processed by different pathways.

The presence of RB between different-format numbers suggests that the RB phenomenon might be located at a higher level of processing than that of visual types and tokens. There are two dimensions on which 9 and *nine* are identical: conceptual and phonological. The conceptual hypothesis would posit that RB between 9 and *nine* occurs because they share a common conceptual type. This could correspond to the internal representation of numbers proposed by McCloskey and Caramazza (1987), which relies on a complex semantic and syntactic system. However, no RB was found between noun synonyms such as *rug* and *carpet* (Kanwisher & Potter, 1990), casting doubt on the conceptual explanation of RB between 9 and *nine*.

The phonological hypothesis would claim that RB between 9 and *nine* occurs because they share a common phonological representation. However, Kanwisher and Potter (1990) found little RB (Experiment 4A) or no RB (Experiment 4B) between heterographic homophones, such as *eight* and *ate*, when embedded in sentences. The small numbers of sentences and subjects they used, as well as the conflicting results they obtained between their two experiments, left the role of phonology uncertain. Moreover, a phonological representation might be expected to play a larger role in short-term recall of an unstructured list (as in Experiments 1 and 2) than in recall of a meaningful sentence. In Experiment 3, homophones were presented in lists to investigate those questions.

Experiment 3

In Experiment 3, subjects viewed trials consisting of three words mixed with three irrelevant arrays of symbols. Their task was to report all the words. The set of words used consisted of pairs of homophones that differed in spelling.

Method

The method was the same as that of Experiment 2 unless otherwise specified.

Subjects. Twelve subjects from the MIT pool participated in Experiment 3. None of them had participated in the previous experiments.

Materials and design. The design was like that of Experiment 2 except that nine pairs of heterographic homophones were used, in place of the nine numbers. The homophones were ate/eight, one/won, know/no, you/ewe, days/daze, hymn/him, right/write, cot/caught, and seas/seize. The symbol arrays consisted of rows of three, four, or five identical symbols. Figure 1 shows a sample trial. Fourteen practice trials were followed by 96 experimental and 20 filler trials. Each trial consisted of a sequence of six arrays preceded and followed by a row of percentage signs. On the experimental trials, three of the six arrays were words from the homophone set and the other three arrays each consisted of a row of symbols. The 20 filler trials consisted of two words from the homophone set (sometimes repeated) and four arrays of symbols.

The design and procedure of this experiment was otherwise identical to that of Experiment 2. Repeatedness was counterbalanced between the two versions of the experiment by replacing C1 with another word in the homophone set. The other main variable, counterbalanced between items, was whether C1 and C2 were repeated as the same word (e.g., won/won) or as homonyms (e.g., one/won). Note that this second variable (same vs. different format) was meaningless for nonrepeated trials. (For letter case or for arabic vs. verbal number, in contrast, C1 and C2 on the nonrepeated trials could have either the same or a different format.) The other between-items variable was, as before, lag.

Results

The percentage of trials in which both C1 and C2 were recalled, for the identical and different spelling conditions, is given in Table 3. ANOVAs by subjects were carried out on the number of trials in which both C1 and C2 were recalled.

An overall repetition effect, $F(1, 11) = 34.2$, $p < .0001$, and an identical-different spelling effect, $F(1, 11) = 29.0$, $p < .0001$, were present; there was a significant interaction between repeatedness and identical-different spelling, $F(1, 11) = 25$, $p < .0001$, indicating that the repetition effect is larger when targets are identical (won/won) than when targets are different words that are homophones (one/won). (The nonrepeated control conditions are equivalent, as they should be; format was a dummy variable for nonrepeated trials.) Separate ANOVAs for the identical- and different-spelling conditions showed a significant repetition effect in both cases, $ps < .005$.

Discussion

As expected, RB was substantial between identical words. The striking result was the clear RB effect found between differently spelled homophones (e.g., ate and eight), contrary to the sentence experiment of Kanwisher and Potter (1990, Experiment 4B). The size of the RB effect was, however, much larger (36% vs. 17%) in the identical- than in the different-spelling condition. This pattern of results is similar to that of Experiment 2 with numbers.

One question is whether the reduction in RB is proportional to the orthographic difference. If so, there should be more RB between homophonic pairs that share a larger number of letters (days/daze) than between those that are clearly not orthographically related (eight/ate). We carried out a post hoc item analysis, comparing three pairs with a large letter overlap (days/daze, him/hymn, and seas/seize) and three pairs with no same-position letter overlap (ate/eight, ewe/you, and one/won). This analysis showed no interaction between repetition and overlap, $F(1, 11) = 1.14$, $p > .3$. However, the initial design of the experiment was not set up to control for this variable. Because it has been shown that RB is found between nonidentical but orthographically similar words (Bavelier & Segui, 1990; Kanwisher & Potter, 1990), a more thorough investigation of the role of orthographic overlap in the RB effect between differently spelled homophones was undertaken in Experiment 4.

Experiment 4

This experiment was designed to test whether the orthographic overlap between the homophone pairs could be responsible for the RB found between differently spelled homophones in Experiment 3. For this purpose, we compared these differently spelled homophones with nonhomophonic control pairs matched for orthographic overlap.

Table 3
Experiment 3: Percentage of Trials in Which C1 and C2 Were Both Recalled

Repeatedness	Identical (ate/ate)	Homophones (eight/ate)
Not repeated	80	82
Repeated	44	65
Not repeated–repeated	36	17

Note. C1 = first instance; C2 = second instance.

Method

The method was the same as that of Experiment 2 unless otherwise specified.

Subjects. Twenty-four subjects from the same pool participated in Experiment 4.

Materials and design. The same nine pairs of heterographic homophones of Experiment 3 were used; for each pair, we constructed a control pair such that the pattern of orthographic overlap between the control items was identical to that between the homophones. That is, the mapping between letters in the homophone pairs was matched by an identical mapping in the control, nonhomonym pairs. For example, the control for one/won was get/age. The following nine sets of two pairs of words were used: one/won–get/age, ate/eight–bed/drive, know/no–work/or, you/ewe–bog/has, days/daze–tofu/toys, hymn/him–menu/man, right/write–above/label, cot/caught–art/accept, and seas/seize–dead/dense. An effort was made to match the frequency of each homophone and its corresponding control.

There were three main variables within subjects: repeatedness, identical–different spelling, and homophone or control pair. Repeatedness and identical–different spelling were counterbalanced within items and subjects; homophones and control pairs were between items. Each homophone or control pair appeared equally often in each order (e.g., ewe/you vs. you/ewe) across the different conditions. Similarly, half the trials in each condition were at Lag 1 (one word between C1 and C2) and half at Lag 2 (one word plus a row of symbols between C1 and C2). Altogether, there were 144 trials. Figure 2 shows a sample trial of each type (homophone or control) in the repeated condition. The procedure of this experiment was otherwise identical to that of Experiment 2.

Results

The percentage of recall of both C1 and C2 for the homophones and the orthographic control conditions is given in Table 4. ANOVAs by subjects were carried out on the number of trials in which both C1 and C2 were recalled, for the different conditions.

An overall repetition effect, $F(1, 23) = 90.5$, $p < .0001$, and an identical–different spelling effect, $F(1, 23) = 63.4$, $p < .0001$, were present. These two variables interacted, $F(1, 23) = 64.5$, $p < .0001$, indicating that when targets are identical the size of the repetition effect is larger than when targets are differently spelled. The identical–different spelling variable also interacted with the type (homophone or control pair) of the targets, $F(1, 23) = 15.5$, $p < .001$; a significant triple interaction among identical–different, repeatedness, and homophone–control, $F(1, 23) = 14.1$, $p < .001$, showed that the size of RB effect in the identical and different conditions was significantly different for the homophone than for the control condition. We ran separate analyses of the identical and different trials.

For the identical condition, there was an overall repetition effect, $F(1, 23) = 106.87$, $p < .0001$, and no homophone–control effect; however, there was a significant interaction between repetition and homophone–control, $F(1, 23) = 5.9$, $p < .023$, indicating a somewhat larger repetition effect for

	Homophone trials identical:	Homophone trials different:	Control trials identical:	Control trials different:
	%%%%%	%%%%%	%%%%%	%%%%%
	===	===	>>>>>	>>>>>
[C1]	one	won	get	age
	{{{{{	{{{{{	+++	+++
	days	days	label	label
[C2]	one	one	get	get
	****	****	<<<<	<<<<
	%%%%%	%%%%%	%%%%%	%%%%%

Figure 2. Examples of trials from Experiment 4.

the nonhomophone control words than for the homophones, even though in both cases C1 and C2 were identical. In a further breakdown, both homophones and controls had highly significant repetition effects, $ps < .0001$.

For the different-spelling condition (one/won and age/get), we found an overall repetition effect, $F(1, 23) = 27.3$, $p < .0001$, an overall homophone–control effect, $F(1, 23) = 13.2$, $p < .001$, and a significant interaction between repetition and homophone–control, $F(1, 23) = 6.0$, $p < .022$, indicating a larger repetition effect for the homophones than for the orthographic control stimuli. Separate analyses for the homophones and the orthographic controls showed a highly significant repetition effect for differently spelled homophones (won/one), $F(1, 23) = 19.1$, $p < .0001$, but a much weaker repetition effect for the orthographic controls (age/get), $F(1, 23) = 5.05$, $p < .035$.

Discussion

The results confirmed the findings of Experiment 3, showing an RB effect for both identical- (won/won) and different-spelling (one/won) homophones. As before, the size of the RB effect was larger (28% vs. 16%) in the identical- than in the different-spelling condition. The control trials in the identical-spelling condition confirmed the standard RB results. However, the main finding of Experiment 4 is that orthographic overlap is not responsible for the sizable RB effect between homophones: Nonhomophone control pairs with the same pattern of letter overlap showed only a small RB effect (85 vs. 80% correct).

In Experiments 1 and 2 we established that visual similarity between C1 and C2 was not necessary for RB; items that were only conceptually and phonologically equivalent (e.g., *9* and *nine*) were subject to RB. In Experiments 3 and 4 we showed that phonologically equivalent words that were not conceptually related could produce RB and that partial orthographic overlap could not account for this result. Taken together, these results strongly suggest that phonology per se plays a role in RB.

This stands in opposition to the findings reported by Kanwisher and Potter (1990) for pairs of homophones embedded in sentences. These authors found no RB effect between differently spelled homophonic pairs given that the orthographic overlap between them was minimal. In an earlier experiment, however, they had found some indications of RB between homophones. These contradictory results were found with targets very similar to those used in the present experiments; the main difference was the context in which the targets were presented. The experiments reported here used a new method with recall of three-word lists, where the words were intermixed with irrelevant rows of symbols. Furthermore, the critical targets appeared repeatedly in the course of the experiment. Finally, the rate of presentation was 100 ms per item, whereas in Kanwisher and Potter's experiment the rate was 117 ms per item. All these factors might have increased reliance on short-term codes such as a phonological

Table 4
Experiment 4: Percentage of Trials in Which C1 and C2 Were Both Recalled

	Homophones		Orthographic controls	
Repeatedness	Identical (won/won)	Different spelling (one/won)	Identical (get/get)	Different spelling (age/get)
Not repeated	80.5	82.5	83	85
Repeated	52	66	44.5	80
Not repeated–repeated	28.5	16.5	38.5	5

Note. C1 = first instance; C2 = second instance.

code, although the fact that subjects wrote down their responses should have encouraged the retention of a visual representation as well. Unlike sentence recall, however, there was no incentive for the subjects to rely on a conceptual representation of these unrelated items. If any of these factors were responsible for the phonologically based RB evident in Experiments 3 and 4 (and possibly accounting for the different-format RB found in Experiments 1 and 2), then such an RB effect should diminish or disappear if the critical pairs are presented in sentences at a rate of 117 ms per item. In Experiment 5, different-format numbers were included in sentences; in Experiment 6, different-spelling homophones were presented in sentences.

Experiment 5

Method

Subjects. Twenty-four subjects of the same pool participated in this experiment, none of whom had participated in Experiment 2 (the previous numbers experiment).

Materials and design. Thirty-two sentences containing a repeated number between 1 and 9 were written. For each sentence, a nonrepeated version was produced by replacing C1 by another number between 1 and 9. C1 and C2 were always separated by one to three words, and C2 was never the last word in the sentence. The sentences were written so that removal of C2 left an ungrammatical or highly anomalous sentence. When possible, the entities to which the two numbers referred were different (e.g., *four o'clock* and *four cars*).

The two variables of interest, repeatedness and same–different format, were counterbalanced over the eight versions of the experiment, together with the format of C1. An example of a sentence in each of its eight versions is given in Appendix A (the unrepeated control word is in parentheses). The 32 sentences and their controls are given in Appendix B.

Each version of the experiment contained 70 sentences: 32 experimental sentences, 28 fillers without numbers, and 10 ungrammatical sentences (intended to discourage guessing). The experimental list was preceded by 10 practice sentences.

Procedure. Each trial began when the subject hit the space bar on the computer keyboard. The row of asterisks then disappeared and was replaced by the sentence appearing one word at a time in the same place, for 117 ms per word. Each word was centered on the screen. Except for the initial capitalized letter of the first word, all words were in lowercase. The last word of the sentence was displayed with a period on its right.

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 they were to report the words just as they saw them, and particularly not to put in words they had not seen to reconstruct a correct sentence. Subjects were not asked to report the format of numbers.

Apparatus. The same apparatus as in Experiment 1 was used.

Results and Discussion

The percentage of recall of C1 and C2, respectively (according to their position of recall within the sentence), was scored. The percentages are reported in Table 5 separately for the same- and different-format conditions.

Overall recall accuracy for the sentences was high. Recall of C1 averaged 89%, which was representative of recall of the other words of the sentences (other than C2). As expected on the basis of previous work, there was marked RB for C2 in the recall of same-format numbers. The primary focus of this experiment was on the recall of C2 in the different-format condition (*9* and *nine*). In this condition, the size of the RB effect (27%) was comparable to that of same-format numbers (26%).

Table 5
Experiment 5: Percentage of Recall of C1 and C2

	Same format (9/9)		Different format (nine/9)	
Repeatedness	C1	C2	C1	C2
Not repeated	88	73	90	76
Repeated	88.5	47	90	49
Not repeated–repeated	0.5	26	0	27

Note. C1 = first instance; C2 = second instance.

ANOVAs by subjects were conducted separately for recall of C1 and of C2. There were no significant effects for C1. There was a main effect of repeatedness for C2, $F(1, 23) = 45.2$, $p < .0001$, no effect of same–different format, and no interaction between repeatedness and same–different format (both Fs < 1.0). A significant main effect of the arabic–verbal format of C2, $F(1, 23) = 14.9$, $p < .001$, suggested that C2 is less readily recalled when it is presented in arabic form (as was found in Experiment 2); there was no higher interaction with this variable.

This set of results confirms a strong RB effect between numbers on the recall of C2, but not C1, reproducing the standard RB phenomenon. Moreover, the RB effect was just as large between two different formats as within the same format, suggesting that when attention is directed to processing meaning rather than format subjects do not (or perhaps cannot) focus on the format of presentation as a way of avoiding RB. The level of representation at which C1 and C2 are indistinguishable (despite a clear difference in format) could either be the level of numerical concept or the level of phonological representation. If it is the former, there should be no RB between homophones under the same conditions. But if the representation producing RB with this material is phonological, then RB would be expected for homophones in sentences, contrary to what Kanwisher and Potter (1990) found. Experiment 6 tested RB between homophones embedded in sentences.

Experiment 6

Method

Subjects. Eighteen subjects from the same pool as the previous experiments participated in this experiment, none of whom had participated in Experiments 3, 4, or 5.

Materials and design. Twenty pairs of heterographic homophones were divided into two sets of 10. One set included only pairs that were orthographically distinct, to reduce the likelihood of visual confusion between them. For this set (cot/caught, won/one, eight/ate, weight/wait, seas/seize, I/eye, you/ewe, write/right, daze/days, and know/no), sentences were written in which each of the two words in a pair appeared. Two sentences were written for each pair, varying the order of the two homophones (e.g., "The dog jumped from the cot and caught the ball" and "The child was caught under the cot in her room"). None of these sentences used identical words.

The other set of 10 homophones (meet/meat, bear/bare, pair/pear, sun/son, week/weak, tale/tail, sail/sale, clothes/close, board/bored, and ants/aunts) was used in sentences that included two occurrences of the same word. Hence, one sentence was written for each of the words of a given pair (e.g., "Each time I meet you here I meet some classmates on the way" and "I like meat but this meat smells awful"). Thus, although all the critical words in the experiment were homophones, the identical- versus different-spelling conditions were between items.

For each sentence a nonrepeated version was produced by replacing C1 with another word, often a synonym, leaving the semantics and the syntax of the sentence almost unchanged. C1 and C2 were always separated by one to three words and C2 was never the last word in the sentence. The sentences were written so that removal of C2 left an ungrammatical or highly anomalous sentence. The 40 sentences and the nonrepeated C1 words are given in Appendix C.

Each version of the experiment contained 40 experimental sentences, 20 filler sentences without homophones, and 15 ungrammatical sentences. The experimental list was preceded by 10 practice sentences.

Procedure. The same procedure as in Experiment 5 was used.

Apparatus. The same apparatus as in Experiment 1 was used.

Results

The percentage of recall of C1 and C2 was scored (when only one was recalled, scoring was based on recall order with respect to other words in the sentence). The percentages are reported in Table 6, separately for the identical- and different-spelling conditions.

Overall recall accuracy for the sentences was high. Recall of C1 averaged 93%, which was representative of the other words of the sentences (other than C2). As expected on the basis of previous work, there was marked RB for C2 in the identical condition. The primary focus of this experiment was on the recall of C2 in the different-spelling condition. As with numbers in Experiment 5, the RB effect was substantial (25%) and was comparable with that of the identical condition (27%).

ANOVAs by subjects and by items were conducted separately for C1 and for C2. There were no significant effects for C1. There was a main effect of repeatedness for C2, $F(1, 17) = 39.1$, $p < .0001$, for subjects and $F(1, 38) = 51$, $p < .0001$, for items. There was a significant effect of the identical–different spelling variable for subjects, $F(1, 17) = 15.5$, $p < .001$, but only marginally for items, $F(1, 38) = 3.2$, $p < .08$. There were no interactions (both Fs < 1.0).

Table 6
Experiment 6: Percentage of Recall of C1 and C2

	Identical (meet/meet)		Different (ate/eight)	
Repeatedness	C1	C2	C1	C2
Not repeated	96	80	94	89.5
Repeated	94	53	93	64
Not repeated–repeated	2	27	1	25.5

Note. C1 = first instance; C2 = second instance.

Discussion

As in Experiments 3 and 4, the results clearly show a strong RB effect between the differently spelled instances of a homophonic pair (won/one). Surprisingly, RB was as strong between two different instances of a homophonic pair (e.g., won/one) as between identical instances (e.g., meet/meet). In Experiment 3 and 4, in contrast, RB was significantly weaker for nonidentical pairs. (In Experiment 7, as will be seen, RB was also weaker for nonidentical pairs.)

The results of Experiment 6 conflict once again with those of Kanwisher and Potter (1990, Experiments 4A and 4B), who found no RB for homophones in sentences. However, a closer inspection of their results suggests that there was some RB for homophones not only in their Experiment 4A (a 23% RB effect on C2), but also perhaps in 4B (a 13% RB effect on C1 and a 2% effect on C2). Other differences that might account for the diverging results between the experiments include, for Kanwisher and Potter's study, a smaller number of items and subjects and the presence of homographs that had distinct pronunciations and meaning as well as homonyms with distinct meanings but identical orthography and pronunciation. Also, in their Experiment 4B subjects had atypical difficulty recalling homophones, both C1 and C2.

Altogether, it seems that phonology plays an important role in the RB effect, even in sentences. Phonological codes are thought to be involved in reading in at least two ways: during word recognition and in working memory. Hence, the phonological effect we observed in RB could occur during the recognition of the word, but prior to registration in short-term memory (STM), or could be a consequence of confusion in STM, manifested at the time of recall.

The latter explanation would account for the repetition effect between homophones (or numbers) in terms of phonological similarity once the items have been stored in verbal STM. There is a large literature showing that a list of similar-sounding items is difficult to memorize and recall. Conrad (1964) reported more errors in the immediate recall of visually presented sequences of consonants when those consonants were phonologically similar (such as B, G, V, P, T) than when dissimilar (such as W, H, K, R, S). Baddeley (1966) confirmed this effect with lists of acoustically similar words (e.g., man, mad, map, mat, max) compared with control lists (e.g., pen, rig, bar, cow, pit). The mean recall score for the acoustically similar sequences was significantly lower than for the control sequences.

Murray (1968) showed that the differential difficulty of acoustically similar versus control lists was reduced or eliminated when subjects were asked to repeat a given word (e.g., *the*) during the visual presentation of the items. Irrelevant concurrent articulation appears to suppress the component of STM that sustains and permits rehearsal of a phonological representation of words. The memory span is reduced and, at the same time, phonological similarity effects are largely eliminated (see Baddeley, 1986, for a review). On the other hand, recent work suggests that articulatory suppression does not interfere with the phonological code derived from printed English and used for lexical access (Besner, 1987a, 1987b; Besner & Davelaar, 1982; Besner, Davies, & Daniels, 1981; Van Orden, Pennington, & Stone, 1990). Hence, articulatory suppression seems to be able to differentiate between a late, post-access, phonological effect due to rehearsal in STM and an earlier phonological effect associated with lexical access.

Experiment 7

In Experiment 7 we tested the hypothesis that RB for homophones is a consequence of phonological confusion in STM by comparing two reading conditions: silent or with concurrent articulation. Experiment 7 was similar to Experiment 6 except that on half the trials subjects articulated a syllable while the RSVP sequence was presented. Thus, we tested the effect of concurrent articulation on the RB effect for identical homophones (meet/meet) versus differently spelled homophones (cot/caught). It is important to note that articulating does not interfere with the recall of RSVP sentences that do not have repeated words (Potter, 1984). When sentences were presented at a rate of 100 ms per word, Potter found no difference in the percentage of omitted words during the recall of sentences, whether subjects were articulating or were silent.

Method

Subjects. Twenty-four subjects from the same pool as the previous experiments participated in this experiment, none of whom had participated in the previous experiments.

Materials and design. The materials were the same as those used in Experiment 6. The list of sentences was separated into two blocks. In each block, there were 10 sentences with differently spelled homophones (e.g., cot/caught) and 10 with identically spelled homophones (e.g., meet/meet). For each block in a given version, 5 sentences of each type were repeated and 5 were nonrepeated (C1 was replaced by another word). Repeatedness was counterbalanced between versions of the materials. Subjects viewed the sentences silently in one block, and repeated the syllable *dadada* . . . about four times per second in the other block. The order of the blocks and the order of the two conditions were counterbalanced.

Procedure. The procedure was like that of Experiment 6, except that in one block the subjects were instructed to begin saying *dadada* . . . before they pressed the space bar to begin the trial, stopping only when the sentence ended. Five practice trials preceded each block.

Apparatus. The same apparatus as in Experiment 1 was used.

Results

The percentages of recall of C1 and C2 were scored (when only one was recalled, scoring was based on recall order with respect to other words in the sentence). The percentages are reported in Table 7 separately for identical- and different-spelling trials for the silent and articulation conditions.

Overall accuracy in recall of the sentences was high. Recall of C1 was comparable in the silent and articulation conditions and averaged 91%, which was representative of recall of the other words of the sentences (other than C2). With identically spelled homophones (meet/meet), there was marked RB in both the silent condition (34%) and the articulation condition (29%). In the different-spelling condition, the RB effect was lower but was equal in the silent condition (13%) and in the articulation condition (12%).

Table 7
Experiment 7: Percentage of Recall of C1 and C2

	Identical (meet/meet)		Different (ate/eight)	
Condition/repeatedness	C1	C2	C1	C2
Silent				
Not repeated	92	86	94	80
Repeated	91	52	92	67
Not repeated–repeated	1	34	2	13
Articulation				
Not repeated	85	80	93	79
Repeated	93	51	87	67
Not repeated–repeated	−8	29	6	12

Note. C1 = first instance; C2 = second instance.

ANOVAs by subjects and by items were conducted separately for C1 and for C2. None of the effects were significant for C1 except the interaction of the identical–different spelling condition with repeatedness in the subject analysis, $F(1, 23) = 9.11$, $p < .006$, but not in the item analysis, $F(1, 38) = 1.2$, $p > .21$ (this interaction does not seem to have a meaningful interpretation). There was a main effect of repeatedness for C2, $F(1, 23) = 72.2$, $p < .0001$, for subjects and $F(1, 38) = 50.3$, $p < .0001$, for items. Also, there was a significant interaction of the identical–different spelling variable with repeatedness, $F(1, 23) = 11.2$, $p < .003$, for subjects and $F(1, 38) = 8.9$, $p < .005$, for items. RB was more marked for identically spelled homophones than for heterographic homophones such as ate/eight. No other significant effects were obtained; in particular, there was no significant effect of silence versus articulation, and no interaction between this variable and any of the others (both Fs < 1.0). Whether the subjects articulated in the first block of the experiment or in the second block was not significant either (both Fs < 1.0).

The significant interaction between identical–different spelling and repeatedness led us to run separate ANOVAs for identical and differently spelled homophones. In the identical condition, there was no effect for C1 and a main effect of repeatedness for C2, $F(1, 23) = 50.6$, $p < .0001$, for subjects and $F(1, 38) = 60.1$, $p < .0001$, for items. No other interactions were present. In the different-spelling condition, there was a small effect of repeatedness for C1, $F(1, 23) = 4.84$; $p < .038$, for subjects but $F(1, 38) = 1.0$, $p < .4$, for items, and a large effect for C2, $F(1, 23) = 17.3$, $p < .0001$, for subjects and $F(1, 38) = 7.3$, $p < .015$ for items. No other interactions were present. In both the identical- and different-spelling conditions, no interaction of repeatedness with articulation approached significance.

Discussion

The results of Experiment 7 confirm that phonological similarity plays a role in RB. Contrary to the findings of Experiment 6, however, the size of the RB effect was significantly smaller for differently spelled homophones than for identically spelled homophones. (Because the materials were the same in both experiments, this difference seems difficult to explain; it was found even in the first block of trials for the silent condition.)

The focus of this experiment was on the effect of articulation on the RB effect. Articulation had no effect on RB, either in the identical-spelling condition or in the different-spelling condition. Because irrelevant articulation has been shown to disrupt phonological rehearsing in STM, this result indicates that the phonological RB effect observed with differently spelled homophones is unlikely to be due to a late phonological confusion during rehearsal in STM. This point is discussed further in the following section.

General Discussion

The present studies indicate that RB cannot be accounted for entirely by visual resemblance between the targets and show that acoustic, phonological, or articulatory identity can play an equally important role. (Although it is not clear exactly what the representation in question is, we follow common practice in terming it *phonological.*) These findings raise the question of the stage of processing at which a phonological representation becomes involved. We propose that phonological RB is not due to phonological confusion after items have been encoded in STM but results from the failure to establish a phonological representation of the second target in STM. RB reflects an inability to select for a second time a phonological representation that has recently been used for registration of information in STM. More generally, we propose that RB is not dependent on the complete type identity of C1 or C2 but on the attributes of the type that are selected for initial registration in STM.

To review our findings briefly, Experiments 1 and 2 indicated that RB can be found between items that share few if any configural properties, such as a letter in lower- or uppercase or a given number in its verbal (nine) or arabic (9) representation. Thus, visual similarity is not a necessary condition for the RB effect. In Experiments 1 and 2 conceptual equivalence might have accounted for RB between items in distinct formats. However, Experiment 3 established the presence of RB between homophonic pairs (won/one) that share phonology but not meaning. This result could not be explained solely by the sharing of some common letters by the homophones (Experiment 4). Hence, it appeared clear that phonological identity of the targets contributed to the repetition effect in these experiments. It was noted, however, that in all instances except letter case RB was reduced when the visual format was different.

Experiments 5 and 6 investigated this result in RSVP sentences, where word or number meaning was expected to be more important than in lists. In Experiment 5 the RB effect was as strong for identical-format (nine/nine or 9/9) as for different-format numbers (9/nine or nine/9). This result could have been due to an increased reliance either on meaning commonality or on phonology when processing sentences. In Experiment 6 a similar result was found for identical and differently spelled heterographic homophones (eye/I) in sentences, indicating that phonological identity, not meaning, was critical. Although the RB effect was equally large for identical and differently spelled homophones in Experiment 6, in Experiment 7 identical words produced a substantially larger RB effect than heterographic homophones (as in Experiments 3 and 4).

This set of experiments clearly establishes that phonology plays a role in RB. We consider two stages of processing at which phonological RB might occur. The first possibility is that the phonological code used to hold and rehearse information in STM is responsible for the RB effect found between homophones. The STM account would explain the effect by arguing that both occurrences of the targets have been stored in STM but, because of phonological confusion between the two targets, only one is recalled. Because RB is hypothesized to come after memory encoding, we call this the *late phonological* hypothesis.

It seems unlikely that RB between different-format items (numbers or homophones) was due to a phonological effect of this kind, because in the list experiments only three items were to be remembered. Furthermore, in the present experiments item recall rather than order recall was measured. The phonological similarity effect in STM is typically reflected in the difficulty of recalling item order, not the items themselves. In most of the experiments reporting a phonological similarity effect (e.g., Baddeley, 1966; Conrad, 1964), correct recall was scored as the number of items reported in their correct order, not the total number of correct items recalled regardless of order, which would be the relevant score to compare with RB. Watkins, Watkins, and Crowder (1974) compared free and serial recall of written words having either high or low phonological similarity. Serial-recall procedures gave a phonological similarity effect, where similarity impaired recall. However, under free-recall conditions similarity actually improved recall. Although these studies clearly show that written stimuli are encoded phonologically in STM, they fail to explain RB because phonological similarity does not impair item recall and may even help it.

The late phonological account also seems to be seriously weakened by the results of Experiments 5 and 6. First, the use of sentences with several different words (with different phonological patterns) between the two targets seems to make the hypothesis of phonological confusion in STM less likely. Second, RSVP sentences in themselves give enough contextual cues to enable a rapid semantic coding of each word as it is identified (Potter, 1984), which should immunize the sound-alike words from a "late" phonological problem. The results of Experiment 7 also suggest that the RB effect observed is not happening at the level of phonological rehearsal in STM. In Experiment 7, articulatory suppression did not interact with the RB effect, whether the targets were identical words or differently spelled heterographic homophones. This finding suggests that the phonological RB effect happens before the establishment of a memory trace in STM rather than afterward.

The *early phonological* hypothesis proposes that the phonological effect we observed is localized in an early stage of processing. There is considerable evidence in the literature that phonological information about a written word becomes available almost immediately (Lukatela & Turvey, 1991; Perfetti & Bell, 1991; Perfetti, Bell, & Delanay, 1988; Van Orden, 1987; Van Orden et al., 1990). Although most such studies are concerned with the question of whether access to the lexicon (and hence to meaning) is "direct" (based on visual information) or "phonologically mediated," all agree that encoding of the orthographic input leads directly to retrieval of a phonological or articulatory code, whether retrieval or computation of the phonology precedes identification of the word, follows it, or runs in parallel with lexical access. Indeed, in experiments using brief, masked presentation of visual strings, perceivers may ordinarily encode information phonologically (Hawkins, Reicher, Rogers, & Peterson, 1976). Large effects of stimulus word phonology have also been found in reading experiments using a lexical decision task (Coltheart, Davelaar, Jonasson, & Besner, 1977; Rubenstein, Lewis, & Rubinstein, 1971) and a categorization task (Van Orden, 1987). All of these results show that the visual presentation of an orthographic string leads to the rapid activation of its corresponding phonological representation.

This early phonological level of encoding, we propose, is the locus of the RB effect found with homophones or numbers in different formats. Our claim is that in the present experiments subjects usually relied on this early phonological code for initial registration of the information in STM. The RB mechanism has been characterized as an inability to individuate a second new token from a type that has just been token individuated (Kanwisher, 1986, 1987). Accordingly, we propose that a second, phonologically identical code is not available for registration in STM for some interval of time after the same phonological code has been selected. However, if the initial registration based on the phonological code is successful, then other attributes (e.g., semantic or visual) will also be attached to this new token established in STM.

To fully understand the role of phonology in RB, some questions remain to be answered. The influence of particular tasks on the phonological effect needs to be clarified. Using short lists, we found a stronger RB effect when targets shared both phonology and orthography than when they shared only phonology, but the orthographic contribution disappeared (except in Experiment 7) when using sentences. It may be that with short lists visual as well as phonological codes were used in tokenizing items, whereas with sentences only phonological information was used. Phonology may have been less important in lists than in sentences because written recall was required for lists, but spoken recall for sentences. Moreover, in written recall subjects were always instructed to use the format they had seen. Thus, the information used to initially register an item in STM may be under some degree of subject control.

Another question is whether phonologically based RB would be found in tasks that do not require recall. Kanwisher (1986) first demonstrated RB by studying the ability of subjects to detect a repeated word in an RSVP list; the task did not require recall, although, of course, it required memory for the sequence. In another task not requiring recall, she showed that subjects are more likely to falsely rate RSVP sentences as ungrammatical when they contain repeated words than when they do not. Using a recognition probe technique, Bavelier and Segui (1990) were also able to demonstrate the presence of RB. Whether phonological RB would be observed in such tasks is not known.

It will also be important to know whether the phonological effect generalizes to phonologically similar but not identical stimuli. If RB does not occur between phonologically similar items, it will suggest that the phonological representation involved is lexical rather than sublexical. The fact that semantic differences do not prevent RB for phonologically identical targets and that semantic similarity alone does not produce RB (e.g., synonyms; Kanwisher & Potter, 1990) points to the phonological representation of a word as the trigger for RB. This does not necessarily imply that the sublexical phonological representation of the word (Seidenberg & McClelland, 1989; Van Orden et al., 1990) is the relevant one, because even if activated lexically the phonological information could be used independently of the semantic information.

Even if, as just shown, questions remain with respect to the nature of phonological RB, the fact that phonological identity alone can produce RB challenges the leading interpretation of this phenomenon. RB has been interpreted as an instance of the type–token problem that reflects a general limitation on visual information processing, and thus would not be expected between events that share few or no visual (even abstract visual) properties (Kanwisher, 1987, 1991; Kanwisher & Potter, 1989, 1990). We suggest, to the contrary, that RB is not invariably dependent on common visual properties of the two targets, but on common attributes of the type that are used for initial registration of the events in STM. RB will arise whenever the codes used in initial registration of C1 and C2 in STM are too similar, regardless of the actual stimuli the subject saw. If this initial code is subject to RB, then the other attributes of the type (e.g., semantic) are apparently not registered.

This initial code that is subject to RB is often phonological, consistent with a wide range of evidence for the importance of phonology in STM for written material. Perfetti and McCutchen (1982) suggested that an immediate effect of phonological encoding ("speech recoding") in reading is "reference securing," in which the notion conveyed by a word is held in active memory by a combination of semantic and phonological (name) codes. Moreover, it has also been established that if the phonological code proves to be dysfunctional for the task required, subjects may switch to nonphonological codes (possibly semantic or visual) to succeed in the task (Hawkins et al., 1976; Scarborough, 1972; Spoehr, 1978; see Carr & Pollatsek, 1985, for a review). Accordingly, the present studies suggest that stimuli were implicitly named when recognized, providing a phonological basis for RB. Experiments that have been taken to show that RB happens at the level of single visual features, such as color (Kanwisher, 1991), may conceivably be explained by naming. However, as the results of our list experiments indicate, visual format can also be used for initial registration in STM if subjects are required to focus on it or if it is more efficient for the task required. Moreover, as the high accuracy of format recall in the list experiments suggests, if the code selected for initial registration has been successfully established in STM, then other information linked to that code is also represented in the token established in STM. But if the code selected for initial registration has been subject to RB, then the other codes (e.g., visual or semantic) are unable to overcome RB.

Depending on the task, the initial code selected for registering information in STM may be predominantly visual or predominantly phonological. Under these assumptions, RB should depend not so much on the stimuli presented as on the way the task encourages or forces the subjects to encode those stimuli for later recall. In this view RB can still be seen as a type–token problem, in the sense of a distinction between identifying a stimulus (type activation that can even be unconscious) and registering the stimulus in STM, enabling later conscious recall of the item.

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(*Appendix A follows on next page*)

Appendix A

The Four Repeated Versions of One Sentence, Counterbalancing Format: Experiment 5

A collision of four (nine) cars at four o'clock was reported to the police.

A collision of 4 (9) cars at four o'clock was reported to the police.

A collision of four (nine) cars at 4 o'clock was reported to the police.

A collision of 4 (9) cars at 4 o'clock was reported to the police.

Appendix B

Materials Used in Experiment 5

I put aside two (six) eggs and two peaches for the cake.

Jeremy painted one (three) chair(s) and one desk over the weekend.

A collision of four (nine) cars at four o'clock was reported to the police.

Gary lost five (eight) dollars in five seconds playing poker.

I can only see three (five) plants in three different pots.

My father planted eight (four) trees eight months ago in the garden.

We had to answer seven (nine) questions in seven minutes on the test.

Maggie has already fried nine (seven) eggs and nine sausages for the breakfast.

Tony added six (four) units after dropping six last term.

At the zoo there are one (two) adult rhino(s) and one baby.

That experiment will require seven (eight) subjects coming seven times each.

Jacob woke up at two (three) and had two big mugs of coffee before he left.

The temperature dropped off nine (seven) degrees in nine hours.

A carpet that is four (two) yards long and four feet wide will fit here perfectly.

This T-shirt costs five (six) dollars less five percent.

In this expedition there were eight (five) camels and eight donkeys for carrying baggage.

The Smiths bought four (one) kitten(s) four months ago after their wedding.

We had to learn two (four) poems and write two papers to get credit.

Peter will serve the three (six) cakes on three plates.

They put handcuffs on seven (two) men and seven young boys.

I added the nine (three) beers to the nine bottles of ale on the table.

I discovered I was missing six (five) plates and six cups after I moved.

We discovered three (five) bird nests under three of the windows of the house.

There are one (two) computer(s) and one printer in this room.

The cash-box contained only seven (four) bills and seven sale slips.

This lamp will not fit in an eight (nine) by eight foot box.

William lost four (seven) keys and four wallets in less than a year.

This recipe called for the juice of three (nine) lemons mixed with three cups of sugar.

Dad came back with six (one) pineapple(s) and six mangoes from the market.

I have two (one) hour(s) to finish two problem sets.

They sold this bowl at an advertised price of nine (six) dollars and nine cents.

Their income increases five (eight) percent every five years.

Appendix C

Materials Used in Experiment 6

Identical-Word Condition

Of my many aunts (relatives) two old aunts are living in Europe.

My father thought we got rid of the ants (insects) but there were ants all over the kitchen.

Ron learned to sail (navigate) so he could sail on our boat.

The store's sale (bargains) included a sale on sofas.

John wanted to have a (some) pear (fruit) but the pear turned out to be rotten.

Maggie prefers that pair (those boots) to my pair of shoes.

We lay in the sun (garden) until the sun disappeared behind the clouds.

Dan is not my son (nephew) but the son of a friend.

This cat had such a furry tail (body) that the tail of my kitten looked skinny.

Jan made an hilarious tale (story) from the tale she heard yesterday.

I like meat (steak) but this meat smells awful.

Each time I meet (take) you here we meet some classmates on the way.

The floor was bare (dirty) and the walls bare of any pictures.

They had an old bear (tiger) and a bear from the Rockies on the show.

The whole place will close (shut down) the day they close the bar.

I do need some new clothes (outfits) but the clothes I saw were awful.
Bob was bored with (tired of) her and bored in general with life.
Don was leaning on the board (wall) when the board fell down.
This week (Both today) and next week he will miss class.
William is too weak (kind) not to be weak with his children.

Different-Word Condition

This is the one (craft) that won the race last year.
Last time Lucy won (played) and got one free ticket for the show.
Last night Bob ate (dropped) the eight cookies in the box.
For eight (ten) days we ate their strange food and felt sick.
The dog jumped from the cot (bed) and caught the ball.
The child was caught (found) under the cot in her room.
The pirates roamed over the seven seas (oceans) to seize any ships they found.
The navy decided to seize (invade) the seas that surround the enemy country.
The farmer will show you (us) the white ewe he bought last week.
The little ewe (calf) comes to you to get food.
You have to write (find) the right answer as soon as possible.
Journalists have no right (reason) to write such obnoxious articles.
Pat spent many days (hours) in a daze after her accident.
John was in a daze for several days before taking his midterm.
As soon as I (we) touch your eye you must close it.
If you open your eye (mouth) once again I won't play.
There is no (one) theatre that I know of in this area.
The people I know (met) at work have no children but lots of cats.
John has to wait (stand) to get his weight taken by the nurse.
My doctor asked me to record my weight (diet) daily and wait for his call.

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