Memory & Cognition
1977, Vol. 5 (5), 566-579

The effects of lexical and semantic information on same-different visual comparison of words

RODERICK W. BARRON
University of Guelph, Guelph, Ontario, Canada N1G 2W1

and

LESLIE HENDERSON
The Hatfield Polytechnic, Hatfield, Herts, England AL10 9AB

Previous research has indicated that phonemic and orthographic factors cannot account for the fact that words (clear/clear) are responded to more rapidly than orthographically legal nonwords (creal/creal) in a same-different visual comparison task. However, the role of semantic and lexical factors is less certain. The effects of semantic similarity on both same and different judgments were evaluated in several experiments. In the first experiment, subjects were not any slower on semantically related (rang/rung) than on unrelated (rang/rank) different judgments even with a 3,000-msec interval between the first and second word. In Experiment 2, subjects based their judgments on whether or not the first letter of each word was visually identical. Same judgments were not any faster for semantically related than unrelated items even though other evidence indicated that subjects were processing the whole word and not just the first letter. Experiment 3 showed that the word/orthographically legal nonword difference could be replicated with the first-letter visual comparison task employed in Experiment 2. These and related results were discussed with reference to the idea that the word/orthographically legal nonword difference is due to the facilitating effects of a lexical entry upon the encoding, but not the comparison of an item.

In a same-different visual comparison task (e.g., Eichelman, 1970), subjects are required to respond "yes" or "same" if two words are visually identical (e.g., read/read); otherwise, they are required to respond "no" or "different" (e.g., word/read). Although there is nothing in the requirements of this task that necessitates access to the internal lexicon, several recent experiments can be interpreted as indicating that lexical access does, in fact, take place. The basic evidence (Barron & Pittenger, 1974; Chambers & Forster, 1975) is that same judgments for words (e.g., clear/clear) are made more rapidly than for orthographically legal nonwords (e.g., creal/creal). This result has also been obtained by Baron (1975), who showed that same judgments for words are 23 msec faster than for legal nonwords. In addition, similar word/legal nonword differences have been obtained in visual search (Kreuger, 1970) and in tachistoscopic probe-recognition tasks (Manelis, 1974; McClelland, 1976; Juola, Choe, & Leavitt, Note 1) where, as with the visual comparison task, lexical access is not a logical requirement of task performance.

Besides lexical access, there are several other ways of accounting for the word/legal nonword difference obtained in the visual comparison task. It is possible that words may differ from the legal nonwords used in these studies in their conformity to the structure of English orthography as well as in their possession of a lexical entry. However, even if this were the case, it could not be used to account for Chambers and Forster's (1975) finding that same judgments for high-frequency words (e.g., bird/bird) are faster than for low-frequency words (e.g., beef/beef). Furthermore, it cannot be used to account for the results obtained by Henderson (1974) that same judgments for meaningful, but orthographically illegal nonwords (e.g., FBI/FBI) are faster than for items which are both nonmeaningful and orthographically illegal (e.g., IBF/IBF). In summary, the evidence for lexical access in visual comparison tasks cannot be explained solely by differences in orthographic structure.

It is possible, however, that the results obtained by Chambers and Forster (1975) and by Henderson (1974) can be interpreted as involving semantic rather than just lexical access. We use the term lexical to refer to the idea that a word has an address or location in the internal lexicon which may represent that word without

This research was supported by National Research Council Grant A9782 to Roderick W. Barron and by Social Science Research Council Grant 3301/1 to Leslie Henderson. We thank Lynne Dennis and David Woodhouse for testing the subjects in Experiments 1a and 1b, respectively, and Colleen MacFadden for testing the subjects in Experiments 3 and 4. We also thank Derek Besner, Alexander Pollatsek, and Harvey Marmurek for their comments on an earlier draft of this paper. Portions of these data were presented at the Canadian Psychological Association Meetings, Toronto, Canada, June 1976. Requests for reprints should be addressed to Roderick W. Barron, Department of Psychology, University of Guelph, Guelph, Ontario, Canada N1G 2W1.

necessarily embodying its semantic characteristics. Hence, READ and FBI would have entries in the lexicon, whereas REAT and IBF would not. We use the term semantic to refer to the idea that an item (e.g., READ or FBI) actually undergoes semantic processing in addition to obtaining access to an entry in the internal lexicon. According to our lexical-semantic distinction, semantic processing can be said to have taken place when information becomes available about a word's semantic properties such as its location in the semantic memory system (e.g., Collins & Loftus, 1975; Meyer & Schvaneveldt, 1971) or its semantic features (e.g., Smith, Shoben, & Rips, 1974).

Neither the word/legal nonword difference nor the frequency effect obtained by Chambers and Forster (1975) allows us to distinguish lexical from semantic access interpretations of visual comparison data. Furthermore, the FBI-IBF difference obtained by Henderson (1974) can be interpreted as either a lexical or a semantic effect. What is needed, then, is a uniquely semantic manipulation in a visual comparison task whereby the semantic similarity of the words is varied. In our first experiment, we attempted to show that different judgments in a same-different visual comparison task are influenced by semantic similarity by comparing pairs of words which are related in meaning (e.g., rang/rung) to pairs of words which are unrelated in meaning (e.g., rang/rank). If semantic access is involved in visual comparison judgments, then the different judgments for the semantically related pairs should take longer than the semantically unrelated pairs because of the greater likelihood that the semantically related items are adjacent or share features in semantic memory.

The question of whether semantic similarity would also influence the same judgments in a visual comparison task was addressed in Experiment 2. Chambers and Forster (1975) have shown that different judgments for words and legal nonwords do not differ even when 80% of the letters are shared between the words making up each pair and the location of the nonidentical letter is in the middle and final serial positions. These results contrast sharply with the highly reliable word/legal nonword difference which has been obtained with same judgments. This and other differences in the variables which influence same and different judgments have prompted a number of investigators (e.g., Bamber, 1969; Barron & Pittenger, 1974; Egeth & Blecker, 1971; Henderson, 1974; Henderson & Henderson, 1975; Krueger, 1973) to argue that same judgments are relatively fast and holistic, whereas different judgments are slower and more analytic.

In order to deal with the possibility that semantic similarity may have different effects upon same than upon different judgments, the subjects in our second experiment were required to respond "same" if the first letter of one word was identical to the first letter of the second word in a pair (e.g., rang/rung); otherwise, a "different" response was required (e.g., depth/teeth). If semantic access is involved in same judgments, and if it can be shown that subjects actually process the whole word when they are required to base their decisions upon the first letter of each word in a pair, then the semantically related pairs (e.g., rang/rung) should be faster than the semantically unrelated pairs (e.g., rang/rank). In addition, using same judgments to assess the effects of semantic similarity on visual comparison avoids the problems of interpretation associated with the possibility that semantic similarity may facilitate encoding, but slow comparison processes for different judgments. Semantic similarity should facilitate both encoding and comparison processes for same judgments.

Experiments 3 and 4 were carried out in order to counter possible criticisms of the single-letter visual comparison task used in Experiment 2 and the strength of the semantic relatedness manipulation in Experiments 1 and 2. Specifically, Experiment 3 was designed to find out whether the word/legal nonword difference could be obtained when subjects were required to decide whether the first letter of one word was identical to the first letter of the other word in a pair. Experiment 4 was designed to find out how subjects would rate the word pairs used in Experiments 1 and 2 in semantic relatedness, and how these ratings correlated with performance.

EXPERIMENT 1

Method

Stimulus materials. Sixty pairs of words requiring a same judgment and 60 pairs of words requiring a different judgment were used. Thirty of the different judgment pairs were semantically related (SR) and the other 30 pairs were semantically unrelated (SU). In order to maximize the likelihood that subjects would base their different judgments on semantic rather than graphemic information, the SR and SU pairs were constructed so that the words making up each pair were identical in length (mean = 5.43 letters) and shared a large number of letters in common. The average percentage of identical letters in corresponding letter positions (e.g., a G in the third-letter position in both words) was 61% for both the SR and SU conditions. In addition, the first letter of the first word was identical to the first letter of the second word for all pairs in both conditions. Finally, the SR and SU words were identical in length and the number of shared letters at each letter position was highly correlated ($r = +.96$) between the two conditions. Based on the Kučera and Francis (1967) word-frequency norms, the SR and SU conditions were very similar in overall frequency (mean = 23.61 and mean = 24.83, respectively) and in the frequency difference between the two words making up each pair (mean = 24.27 and mean = 24.10, respectively). The SR and SU word pairs are presented in Appendix A. The 60 words used for the same judgments averaged 5.40 letters in length and had an average frequency of 20.92.

Procedure. The word pairs were presented in a different random order to each subject on a four-channel Iconix tachistoscope, with the constraint that neither a response nor a word type could appear more than four times in succession. In Experiment 1a, both words appeared simultaneously one above the other (the top-bottom order of the words was reversed for half of the subjects) for 500 msec. The visual angle subtended by each word was .28 deg on the vertical axis and ranged between 1.09 and 2.03 deg on the horizontal axis. The vertical axis visual angle for the complete display was .96 deg. Experiment 1b was identical to Experiment 1a except that the first word of each pair appeared for 500 msec and was replaced by a patterned mask which lasted 3,000 msec. This mask was then replaced by the second word of the pair which also appeared for 500 msec. The two words were located one above the other with the top-bottom order being reversed for half of the subjects. The visual angle subtended by each word in Experiment 1b was .28 deg in the vertical axis and ranged from 1.09 to 2.03 deg in the horizontal axis. The words were printed in uppercase letters in both experiments. The subject's latency to respond was recorded in milliseconds from the onset of the display in Experiment 1a and from the onset of the second word in Experiment 1b. In both experiments, the timer was stopped by a vocal "yes" or "no" response via a Scientific Prototype audio threshold device. These responses represented the same and different decisions, respectively.

The subjects were instructed to fixate a small cross in the center of the viewing field and were told that they could press the button which they held in their hand when they were ready to see the display. The display appeared as soon as they pressed the button. They were instructed to respond "yes" if the two words were visually identical, and otherwise to respond "no." In addition, the subjects in Experiment 1b were told that there would be a delay between the presentation of the first and second words. Both groups of subjects were cautioned against making errors. In order to familiarize the subjects with the procedure and apparatus, 20 practice trials were given using words which did not appear in the actual experiment.

Subjects. Thirty-two subjects participated in Experiment 1a and 30 subjects in Experiment 1b. All 62 subjects were students in undergraduate psychology courses at the University of Guelph.

Results and Discussion

Mean reaction times based on the correct latencies were obtained in each condition both for individual subjects (summed across word pairs) and individual word pairs (summed across subjects) in Experiments 1a and 1b. The means for individual subjects were used in an F_1 analysis of variance and the means for individual word pairs were used in an F_2 analysis of variance. A min F' was computed using these F_1 and F_2 values (Clark, 1973). Table 1 shows that same judgments were made more rapidly than different judgments in both Experiments 1a [$F_1(1,31) = 10.00$, $p < .005$] and 1b [$F_1(1,29) = 9.11$, $p < .01$]. An analysis of the different judgments (Table 1) shows that the semantically related pairs were not faster than the semantically unrelated pairs in Experiment 1a [min $F'(1,65) < 1$; $F_1(1,31) = 2.69$, $p > .10$; $F_2(1,62) < 1$] or in Experiment 1b [min $F'(1,65) < 1$; $F_1(1,29) = 6.70$, $p < .05$; $F_2(1,58) < 1$]. The only exception to this finding was the significant F_1 in Experiment 1b. Table 1 also shows that the error rates were low (3.61% in Experiment 1a and 3.05% in Experiment 1b) and did not differ between the SR and SU conditions in either Experiment 1a [$F_1(1,31) < 1$] or 1b [$F_1(1,29) = 1.48$, $p > .10$].

The failure to obtain a semantic similarity effect with the different judgments in either Experiment 1a or 1b indicates that semantic information is not used in making different visual comparisons. These results were obtained even though there was considerable letter overlap between the word pairs which should minimize the use of purely graphemic information in deciding that two words are different. Furthermore, semantic information does not appear to be used even when there could be a memory advantage to representing the first word in a semantic code over the 3,000-msec interword interval in Experiment 1b.

Table 1

Mean Reaction Times (RT) and Percent Errors (%E) for the "Same" Responses and for the Semantically Related (SR) and Unrelated (SU) "Different" Responses in Experiments 1a and 1b (3,000-msec Interword Delay)

	Response Type		
	Same	SR Different	SU Different
	Experiment 1a		
RT	899	921	932
%E	2.92	4.05	3.85
	Experiment 1b		
RT	635	660	649
%E	4.17	2.11	2.88

Finally, our failure to find a semantic similarity effect with the different judgments does not conflict with the findings of Schaeffer and Wallace (1970), who did obtain a semantic similarity effect. The subjects in Schaeffer and Wallace's experiment were required to make a judgment about whether two words belonged to the same semantic category, whereas our subjects were only required to decide whether two words were visually identical.

EXPERIMENT 2

Despite the fact that we did not obtain semantic similarity effects for the different judgments in Experiments 1a and 1b, it is possible that such effects might be obtained with same judgments because same judgments are supposed to be holistic and because word/legal nonword differences have been obtained with them most often. Experiment 2 was addressed to this problem. Since pairs of words which are semantically similar (e.g., rang/rung) cannot also be visually identical, it was necessary to alter the visual comparison task in order to accommodate this problem. Our solution was to require the subjects to respond "yes" if the first letter of the first word was visually identical to the first letter of the second word (e.g., advise/advice) in a pair of words; otherwise, the response was "no" (e.g., cedar/radar). We predicted that if semantic access is involved in same judgments, then the semantically related pairs should be faster than the semantically unrelated pairs.

There was another reason for carrying out Experiment 2. It is possible that our failure to find a difference between the semantically related and unrelated words in Experiments 1a and 1b might be due to semantic similarity slowing word comparison, but facilitating word encoding for different judgments (e.g., the word which is encoded first might serve as a priming stimulus for the second word). These two effects might cancel out each other, thus producing the results we obtained.[1] Experiment 2, however, avoids this problem because semantic similarity should facilitate both encoding and comparison processes for same judgments.

In order to find out if the subjects were processing the whole word and not just the first letter (on which they based their decisions), we included same word pairs which were both visually, and therefore, semantically identical (e.g., part/part). If subjects were processing the whole word in making same judgments, then these identical pairs should be faster than the pairs which were just semantically similar. Conversely, if only the first letter was being processed, then there should be no differences among the three same judgment conditions. As a further check on whether the subjects were processing the whole word or just the first letter, half of the different judgment pairs were constructed so that they shared a high percentage of their letters in corresponding letter positions (e.g., depth/teeth) and the other half were constructed so that they shared a low percentage of their letters in corresponding letter positions (e.g., chant/fence). Since several investigators (e.g., Chambers & Forster, 1975) have shown that reaction time is positively correlated with letter overlap, we predicted that the high letter-overlap pairs should be slower than the low letter-overlap pairs if subjects were processing more of the word than the first letter.

Method

Stimulus materials. All of the word pairs used for the different judgments in Experiments 1a and 1b were used for the same judgments in Experiment 2. In addition, 10 word pairs were added to each condition for a total of 40 semantically related (SR) and 40 semantically unrelated (SU) same judgment pairs. As in Experiments 1a and 1b, the length of the words making up each word pair was identical. The average length of the words in the SR and SU conditions was 5.44 letters. The SR word pairs shared 63% of their letters in corresponding letter positions and the SU word pairs, 60%. The correlation between the SR and SU pairs in the number of shared letters in each letter position was $r = +.98$. The overall frequency (Kučera & Francis, 1967) of the SR words was 28.33 and that of the SU words was 31.10. The average frequency difference between the two words making up each pair was 29.38 for the SR word pairs and 31.28 for the SU word pairs. There were 40 visually identical same pairs, hereafter referred to as the identical (I) pairs. The average length of these word pairs was 5.33 letters and their average frequency was 30.70. Finally, the average frequency of the first letter (Mayzner & Tresselt, 1965) of the words in the I (225), SR (185), and SU (187) conditions did not differ [$F(2,111) < 1$], hence any differences in reaction time among the three conditions cannot be attributed to differences in the frequency of the letters on which subjects based their decisions.

Eighty different judgment pairs were also used. Forty of these different pairs shared approximately the same percentage of letters (60.15%) as the SR and SU pairs (e.g., rush/push), although not in the same positions as the SR and SU pairs (i.e., there were no shared letters in the first-letter position). Hereafter, we will refer to these letter pairs as the high shared-letter different pairs (HSL). Both members of the pair were identical in number of letters and their average length was 5.28 letters. Their overall frequency was 30.15, and the average frequency difference between the two words making up each pair was 34.38. The other 40 different pairs were comparable to the HSL pairs in overall length (5.05 letters), overall frequency (29.95), and frequency difference (30.65). They differed from the HSL pairs because a very small percentage of the letters were shared between the two words making up each pair (3.68%). Hereafter, these word pairs will be referred to as low shared-letter (LSL) different pairs. Finally, the average first-letter frequency for both the HSL and LSL words was 232. The words used in Experiment 2 are presented in Appendix B.

Procedure. All 200 word pairs were presented in a different random order to each subject on an Electronics Developments two-channel tachistoscope with the constraint that neither a response nor a word type could appear more than four times in succession. The words were printed in lowercase type, appeared one above the other, and were presented simultaneously. The visual angle of each word in the vertical axis was .15 deg and the visual angle of the words in the horizontal axis ranged from .4 to 1.2 deg. The visual angle for the vertical axis of the display (i.e., two words) was .7 deg. The subjects were instructed to respond "yes" by pushing a button with their dominant hand if the first letter of the first word was identical to the first letter of the second word in a pair of words. Otherwise, they were instructed to respond "no" by pressing a second button with their nondominant hand. Hand dominance was established by asking the subjects which hand they wrote with. As in Experiments 1a and 1b, presentation of the stimuli was self-paced. The word display appeared as soon as the subject pressed a button located between the two response buttons. Ten practice trials made up of words not appearing in the experiment were given to each subject in order to insure acquaintance with the procedure and apparatus. Latency to respond was recorded from the onset of the display until the subject pressed a response button. The subjects were cautioned against making errors.

Subjects. Twenty-four undergraduate students at Hatfield Polytechnic served as subjects in the experiment. They were paid 50 pence for their participation.

Results and Discussion

As in Experiments 1a and 1b, mean reaction times based on the correct latencies were obtained in each condition for individual subjects and word pairs. These means were used in separate analyses of variance for the same and different judgments. The two types of judgments were not directly compared because the same judgments were more frequent and all subjects used their dominant hand to respond "same."

A one-way analysis of variance on the same judgments indicated a significant main effect for condition [$\min F'(2,112) = 15.70$, $p < .001$; $F_1(2,46) = 26.81$, $p < .001$; $F_2(2,117) = 37.86$, $p < .001$]. Table 2 shows that the I same pairs were faster than either the SR or SU same pairs. This was confirmed by an orthogonal comparison of the I pairs with the SR and SU pairs [$\min F'(1,123) = 28.83$, $p < .001$; $F_1(1,46) = 53.36$, $p < .001$; $F_2(1,117) = 62.73$, $p < .001$]. More importantly, Table 2 also shows that there was

Table 2
Mean Reaction Time (RT) and Percent Errors (%E) for the Semantically and Visually Identical (I), Semantically Related (SR), and Semantically Unrelated (SU) "Same" Responses, and for High Shared-Letter (HSL) and Low Shared-Letter (LSL) "Different" Responses in Experiment 2

	Response Type				
	Same			Different	
	I	SR	SU	HSL	LSL
RT	516	552	555	615	592
%E	.94	2.92	3.44	4.48	2.81

no significant difference between the SR and SU same judgments [min $F'(1,119) < 1$; $F_1(1,46) < 1$; $F_2(1,117) < 1$]. The different judgment data are also presented in Table 2. They indicate that the HSL (high shared letter) condition was slower than the LSL (low shared letter) condition [min $F'(1,100) = 8.38$, $p < .005$; $F_1(1,23) = 43.06$, $p < .001$; $F_2(1,78) = 10.41$, $p < .01$]. The overall error rate was low (2.92%) and neither the SR and SU same judgments [$F_1(1,23) = 2.39$, $p > .10$] nor the HSL and LSL different judgments [$F_1(1,23) = 3.17$, $p > .05$] were significantly different from each other in error percentage.

The failure to obtain a significant difference between the semantically related and unrelated words for the same judgments parallels the results we obtained for the different judgments in Experiments 1a and 1b. As was the case with the different judgments, the same judgments do not appear to have involved the use of semantic information. Furthermore, the absence of a difference between the SR and SU words cannot be attributed to differential effects of semantic similarity on encoding and comparison. The fact that the I same judgments were faster than the SR and SU same judgments indicates that subjects were processing the whole word and not just the single letter on which they were instructed to base their decisions. Accordingly, these data suggest that our failure to find a difference between the SR and SU pairs cannot be attributed to a lack of sensitivity of our task. Finally, our finding that different word pairs with a high percentage of shared letters (HSL) were slower than those with a low percentage of shared letters (LSL) is similar to the results obtained by Barron and Pittenger (1974) and Chambers and Forster (1975), who found that degree of letter overlap correlated positively with reaction time for different judgments.

EXPERIMENT 3

One possible criticism of the results of Experiment 2 is that we do not know if the word/legal nonword difference can be replicated with the first-letter visual comparison task we used. If it cannot be replicated with our task, then the results of Experiment 2 (i.e., no difference between semantically related and unrelated word pairs) could be interpreted as a task-specific phenomenon which offers no evidence one way or the other about whether semantic information is involved in the word/legal nonword difference in visual comparison. In order to respond to this possible criticism, we attempted to replicate the word/legal nonword difference with our first-letter visual comparison task by using the words and legal nonwords employed by Chambers and Forster (1975) in their second experiment.

Method

Stimulus materials. Forty pairs of words and 40 pairs of orthographically legal nonwords were used for the same judgments; similarly, 40 word and 40 orthographically legal nonword pairs were used for the different judgments, for a total of 160 pairs of items. All of the words were five letters in length. The pairs of items used for our same judgments were taken directly from the Appendix for Chambers and Forster's (1975) second experiment. Although the items making up our different pairs were also taken from the Appendix for their second experiment, they were rearranged so that the items making up a pair did not have identical first letters. The average percentage of identical letters in corresponding letter positions (two through five) between the items in a pair was 4.06% for the words and 8.13% for the legal nonwords. The word and legal nonword pairs used in Experiment 3 are presented in Appendix C.

Chambers and Forster (1975) constructed their legal nonwords so that they had higher mean bigram (Mayzner & Tresselt, 1965) and trigram (Mayzner, Tresselt, & Wolin, 1965) frequency counts than their words (i.e., 325 vs. 240 and 79 vs. 44 for bigrams and trigrams, respectively). These bigram and trigram frequency counts have been interpreted as gross measures of orthographic regularity (e.g., Gibson, Shurcliff, & Yonas, 1970) because the frequency of an individual letter cluster was computed separately for each position it could occupy within a word. Finally, the frequency of the first letter (Mayzner & Tresselt, 1965) was 255 for words and 260 for nonwords for same judgments [$F(1,78) < 1$], and 237 for words and 278 for nonwords for the different judgments [$F(1,158) = 3.83$, $p > .05$].

Procedure. The word pairs were typed one above the other in lowercase type onto 2.5 cm x 4.0 cm white labels. These labels were pasted onto white stimulus transport paper and outlined in black for presentation in a single channel of a Scientific Prototype three-channel tachistoscope. The visual angle of a pair of items was .32 deg in the vertical and .53 deg in the horizontal dimension. The subjects were instructed to respond "yes" or "same" by pressing one telegraph key with their dominant hand if the first letter of one item was identical to the first letter of the other item in a pair. If the letters were not identical, then they were instructed to respond "no" or "different" by pressing a second telegraph key with their nondominant hand. Hand dominance was established by asking the subjects which hand they wrote with. A trial was initiated when the experimenter said "ready" and pressed a button which started the tachistoscope. Five hundred milliseconds after the experimenter pressed the button, a word pair was displayed for 500 msec. The subject's reaction time was recorded from the onset of the display until either the same or different telegraph key was pressed. The subjects were instructed to respond as fast as they could, but they were cautioned against making errors.

The 160 same and different word and legal nonword pairs were divided into four lists of 40 pairs made up of 10 same word, 10 same nonword, 10 different word, and 10 different nonword pairs. Each list of 40 pairs was randomized with the constraint that an item pair or a response type could not appear more than four times in succession. The order of the four lists was varied across subjects so that each list was presented first, second, third, or fourth equally often. The subjects were given 20 practice items which did not appear in the experiment proper in order to acquaint them with the apparatus and procedure.

Subjects. Thirty-two subjects participated in the experiment. They were all students in undergraduate psychology courses at the University of Guelph.

Results and Discussion

As in the previous experiment, mean correct reaction times were obtained in each condition for both individual subjects and item pairs. Overall, same judgments were faster than different judgments [$F(31) = 9.99$, $p < .005$]. Table 3 shows that the same judgments were 42 msec faster for the words than for the orthographically legal nonwords [min $F'(1,104) = 5.46$, $p < .025$; $F_1(1,31) = 28.84$, $p < .001$; $F_2(1,78) = 6.74$, $p < .025$]. The error rate for the same judgments was very low (.82%) and the words did not differ from the nonwords [$F(1,31) < 1$]. The different judgments, however, were not significantly faster for the words than for the legal nonwords [min $F'(1,96) = 1.30$, $p > .10$; $F_1(1,31) = 11.16$, $p < .005$; $F_2(1,78) = 1.47$, $p > .10$]. The only exception to this finding was the significant F_1 analysis. The error percentage for the different judgments was also very low (.82%), and Table 3 shows that the subjects made more errors on the words than on the legal nonwords [$F(1,31) = 6.82$, $p < .025$]. These error data suggest the possibility that subjects may have reduced their accuracy in order to increase their speed on the words relative to the nonwords. Mean reaction times for the individual word pairs are presented in Appendix C.

The results of this experiment indicate that we were able to replicate the word/legal nonword difference for same judgments (Chambers & Forster, 1975) with our first-letter visual comparison task. Furthermore, we were able to replicate Chambers and Forster's (1975) finding that different judgments for words are not faster than those for legal nonwords. These results provide additional support for the idea that the absence of a semantic similarity effect for same judgments in Experiment 2 was not simply due to the characteristics of the first-letter visual comparison task, because we have shown that a word/legal nonword difference for same judgments can be obtained with that task. The results of Experiment 3 are also consistent with the idea that subjects were processing the whole word and not just the individual letter identities of the words in the same judgment condition in Experiment 2. If subjects were only processing individual letter identities in a first-letter visual comparison task, then it is unlikely that we would have obtained our word/legal nonword difference.

Table 3
Mean Reaction Time (RT) and Percent Errors (%E) for "Same" and "Different" Responses to Words and to Orthographically Legal Nonwords in Experiment 3

		Response Type	
Type of Item		Same	Different
Words	RT	838	877
	%E	.70	1.25
Legal Nonwords	RT	880	896
	%E	.94	.39

EXPERIMENT 4

Another possible criticism of the results of Experiment 2, as well as those of Experiments 1a and 1b, is that our manipulation of the semantic similarity variable was weak. Our word pairs were matched on frequency, number of letters, and degree of letter overlap (which was over 60%); consequently, it was difficult to satisfy also the criteria that one half of the pairs be semantically related and the other half be semantically unrelated. Although at least half of the semantically related word pairs had the same morphological root, we needed to obtain a more objective measure of the semantic relatedness of our word pairs. Therefore, we required subjects to rate each word pair on the extent to which its members were related in meaning. These ratings were then correlated with the subjects' performance in Experiments 1a, 1b, and 2.

Method

Materials. The word pairs we designated as being semantically related and unrelated in Experiment 2 were typed onto a sheet of paper in random order. These 80 word pairs included all of the word pairs designated as semantically related and unrelated in Experiments 1a and 1b and they were preceded and followed by five buffer word pairs which were not used in any of the other experiments.

Procedure. The subjects were instructed to rate each pair of words on a 5-point scale on the extent to which its members were related in meaning. The subjects were told that a rating of 5 meant highly related in meaning, 4 meant related in meaning, 3 meant moderately related in meaning, 2 meant slightly related in meaning, and 1 meant unrelated in meaning. The subjects were instructed to mark their rating on a line next to each word pair and to take as long as they needed to complete the list.

Subjects. Thirty-two subjects rated the word pairs in Experiment 4 immediately after participating in Experiment 3, but before they were debriefed about its purpose. None of the subjects had participated in Experiments 1a, 1b, or 2.

Results and Discussion

The average rating for the semantically related word pairs was 3.53 and the average rating for the semantically unrelated word pairs was 1.07. Every subject gave the semantically related words a higher rating than the semantically unrelated words. The average rating for each of the individual word pairs was also determined and the range of the values obtained for the semantically related and unrelated pairs overlapped by only 2.5%. The difference between the semantically related and unrelated pairs was highly significant [min $F'(1,93) = 153.32$, $p < .001$; $F_1(1,31) = 1{,}543.70$, $p < .001$; $F_2(1,78) = 170.23$, $p < .001$].

In order to find out if the semantic similarity ratings were related to performance in our experiments, we correlated the mean ratings for the individual word pairs with the mean reaction time for those word pairs in Experiments 1a, 1b, and 2. The mean ratings for the individual words are reported in Appendix A (Experiments 1a and 1b) and Appendix B (Experiment 2). All of the correlations were low and nonsignificant. [The correlation was $r = -.10$, $t(58) < 1$ in Experiment 1a; $r = +.02$, $t(58) < 1$ in Experiment 1b; and $r = -.05$, $t(78) < 1$ in Experiment 2.] In addition, we recomputed the correlations for those word pairs with mean ratings which were no less than 4.00 and no greater than 1.00. Thirty word pairs met these criteria in Experiments 1a and 1b, and 40 word pairs met these criteria in Experiment 2. All of the word pairs with mean rating scores no less than 4.00 were semantically related and all of the word pairs with mean ratings no greater than 1.00 were semantically unrelated. Again, the correlations were low and nonsignificant. [The correlation was $r = -.13$, $t(1,28) < 1$ for Experiment 1a; $r = +.10$, $t(28) < 1$ for Experiment 1b; and $r = -.05$, $t(38) < 1$ for Experiment 2.]

The results of this rating study indicate that the word pairs which we designated as being semantically related in Experiments 1a, 1b, and 2 obtained ratings of relatedness in meaning which were substantially higher than those obtained for the word pairs which we designated as being semantically unrelated. Furthermore, we found that degree of semantic relatedness was not correlated with performance even when extreme rating scores were used. We think, therefore, that the evidence indicates that the absence of a difference in reaction time between the semantically related and unrelated word pairs in Experiments 1a, 1b, and 2 is not due to a weakness in our semantic similarity manipulation.

GENERAL DISCUSSION

The major purpose of the experiments we have reported was to find out if the word/legal nonword difference in the same-different visual comparison task can be attributed to the use of semantic information. We have been unable to obtain any evidence that semantic information is used in either same or different visual comparison judgments. Experiments 1a and 1b both showed that the different judgments were not influenced by semantic similarity even though the SR and SU pairs shared a large percentage of their letters in corresponding letter positions and there was a 3,000-msec delay between the two words making up each pair (Experiment 1b). Experiment 2 showed that the same judgments were not influenced by semantic similarity when subjects based their judgments on whether or not the first letter of one word was identical to the first letter of a second word, even when other evidence indicated that they were processing the whole letter string. Finally, Experiment 3 showed that the word/legal nonword difference can be obtained with the first-letter visual comparison task we used in Experiment 2, and Experiment 4 showed that our manipulation of semantic similarity in Experiments 1a, 1b, and 2 was not weak.

The absence of any evidence that semantic information is used in same-different visual comparison is consistent with the results of a recent experiment by Rosch (1975, Experiment 5). She found that category names (e.g., furniture) did not prime visually identical (good) category members (e.g., chair/chair) under instructions to respond "same" only on the basis of visual identity. According to Rosch (1975), the category-name prime did not facilitate visual matching because there was not a common (i.e., semantic) mode of processing between the prime and the visually identical category instances. Rosch's (1975) results provide further support for our conclusion that semantic information is not used in same-different visual comparison.

Given that semantic access cannot be used to account for the word/legal nonword difference obtained in a same-different visual comparison task, we would like to consider several alternative explanations of that result. The first possibility is that words are faster than legal nonwords because words are easier to code phonemically. However, Baron (1975) and Pollatsek, Well, and Schindler (1975) have shown that phonemic codes are not used in simultaneous visual comparison. They found that different judgments for homophone pairs (e.g., four/fore) were not any slower than nonhomophone pairs which shared the same number of letters (e.g., sore/sour) in corresponding letter positions. Henderson and Chard (1976) have obtained similar results with same judgments. They found that the superiority of meaningful (e.g., FBI/FBI) over nonmeaningful initials (e.g., IBF/IBF) disappeared when the initials were presented in lowercase type (e.g., fbi), thus indicating that the effect of meaningfulness cannot be attributed to subjects' being able to retrieve more rapidly the phonemic code for meaningful initials. These results indicate that the word/legal nonword effect in simultaneous visual comparison cannot be attributed to the greater ease of coding words phonemically.

Orthography is a second possible basis for the word/legal nonword difference. As mentioned earlier, it is possible that words conform more closely to the structure of English orthography than legal nonwords and, for that reason, are responded to more rapidly.

The word/legal nonword difference cannot be attributed to differences in orthographic regularity, at least as measured by bigram or trigram positional frequency (e.g., Mayzner & Tresselt, 1965; Mayzner, Tresselt, & Wolin, 1965), because this frequency factor was equated for among the high- and low-frequency words and the legal nonwords in Chambers and Forster's (1975) experiment, and because the nonwords had higher bigram and trigram frequencies than the words in our third experiment and in Chambers and Forster's second experiment. It is possible, however, that the words used by Chambers and Forster (1975) differed in single-letter positional frequency (Mayzner & Tresselt, 1965). Mason (1975) has recently proposed that single-letter, rather than bigram and trigram, positional frequency may more accurately measure the spatial redundancy in English orthography which, she argues, is used to facilitate word perception.

In order to find out if the word/legal nonword difference can be attributed to differences in spatial redundancy, we computed the summed single-letter positional frequency value for each word and legal nonword used in Chambers and Forster's (1975) experiments. We found that the correlations between the mean same judgment reaction times for individual words and legal nonwords and their respective summed single-letter positional frequencies were low and not significant for Chambers and Forster's (1975) first [$r = -.12$, $t(58) < 1$] and second [$r = -.12$, $t(78) = 1.07$, $p > .10$] experiments, and for our third experiment [$r = +.02$, $t(78) < 1$]. In order to avoid the possibility that Mayzner and Tresselt's (1965) frequency counts might be unreliable because they were based on a relatively small corpus of words (20,000), we repeated the above analyses of Chambers and Forster's words with the single-letter positional frequency counts recently reported by Solso and King (1976). These frequency counts are based upon the Kučera and Francis (1967) word list of one million words. Again we obtained correlations which were low and nonsignificant between the mean same judgment reaction times for individual words and nonwords and their respective summed spatial frequencies in Chambers and Forster's (1975) first [$r = -.11$, $t(58) < 1$] and second [$r = -.13$, $t(78) = 1.16$, $p > .10$] experiments and our third experiment [$r = -.02$, $t(78) < 1$]. These results indicate that the word/legal nonword difference in visual comparison cannot be attributed to differences in orthographic structure as measured by single-letter positional frequency or by bigram or trigram positional frequency.

The idea that lexical access is involved in same-different visual comparison was proposed earlier as an alternative to the semantic hypothesis. Since the semantic as well as the phonemic and orthographic hypotheses appear questionable, we would like to elaborate upon the lexical hypothesis and show how it can be used to account for the results of our experiments as well as those of others. There are two issues which we need to address. The first is concerned with why having a lexical entry facilitates same visual comparison of high-frequency over low-frequency words, and words over orthographically legal nonwords. The second issue is concerned with why the above frequency and word/legal nonword differences are not generally obtained with different judgments.

We assume that a lexical entry can influence either the encoding or the comparison of an item. A lexical entry might facilitate the encoding of an item by constraining the feature and letter information which is used in forming a representation of the word. Unlike the information specifying a representation of a nonword, this information would have to be consistent with the fact that the item has an entry in the internal lexicon as well as with the orthographic structure of English. There are at least two possible conceptions of how a lexical entry could facilitate encoding (Henderson, in press). The first is based on the idea that there may exist features which represent units larger than single graphemes: transgraphemic features. Accordingly, words might be responded to more rapidly than legal nonwords because fewer transgraphemic features are necessary to form a representation of a word than a legal nonword. McClelland (1976), however, has obtained evidence which is not consistent with the notion of transgraphemic features. He found that the word/legal nonword difference is obtained in tachistoscopic recognition even when transgraphemic features are broken up by presenting the letters making up the items in alternating case (e.g., rEaD vs. rEaT).

The second view of lexical facilitation of encoding involves the assumption of a continuous interaction between the processes of visual feature extraction and stored information about an item's graphemic, orthographic, and lexical characteristics. If these sets of stored information could be interrogated independently and simultaneously, then words would be faster than legal nonwords because visual feature information would have to be consistent with the constraints specified by an item's lexical characteristics as well as by its orthographic and graphemic characteristics.

A lexical entry could also facilitate the comparison process by allowing items with lexical entries to be compared as whole units, whereas legal nonwords might require multiple comparisons at the level of individual letters or letter clusters. Although the word/legal nonword difference would appear to be accounted for by lexical facilitation of either encoding or comparison, we tend to favor an encoding interpretation because it is difficult to understand, as Chambers and Forster (1975) point out, why high-frequency words would be compared more rapidly than low-frequency words. It is more likely that high-frequency words place additional constraints upon the information which can specify a word's representation, or that high-frequency words can be searched for more rapidly.

The fact that lexical effects have not been obtained for different judgments (i.e., Barron & Pittenger, 1974; Chambers & Forster, 1975) may be part of the more general phenomenon that variables which influence the speed of same judgments may not also influence the speed of different judgments. Nevertheless, we offer an account of the absence of a word/legal nonword difference on different judgments which may not generalize to other stimulus domains. We propose that subjects may alter the way in which they encode two items if differences between those items are detected during comparison. We think that the subject begins the comparison process before he completely forms a representation of a word; in fact, encoding and comparison may begin at the same time. If a difference is detected between two words on the basis of visual feature, graphemic, orthographic, or lexical information, then a slower letter-by-letter or letter-cluster-by-letter-cluster encoding process is used. Consequently, words which do not differ by many letters will be more likely to show a word/legal nonword difference (or at least a word/orthographically illegal nonword difference; e.g., Chambers & Forster, 1975) because the encoding process, which we assume is more rapid for words, is more likely to be completed before differences are detected. Conversely, words which differ by many letters may be responded to very quickly (e.g., Chambers & Forster, 1975) because the encoding process may have only just started before there is sufficient evidence from the comparison process to respond "different." Finally, given the arguments presented above, the high degree of letter overlap (60%) of the words used to make up the word pairs in Experiments 1a, 1b, and 2 would appear to offer an opportunity for demonstrating semantic similarity effects in visual comparison because encoding and comparison processes should be fairly well advanced before featural, graphemic, orthographic, or lexical mismatches are detected and further processing is forced to proceed at the level of letters or letter clusters.

In conclusion, we have presented evidence which indicates that the word/legal nonword difference in visual comparison cannot be attributed to semantic, phonemic, or orthographic factors. We argued that lexical factors can account for this difference in word perception by influencing the rate at which information is encoded. In addition, we argued that the reason the word/legal nonword difference is not obtained with different judgments is that subjects use a slower encoding process based on letters or letter clusters if they detect any differences between two words. Hence, the advantage of a lexical entry for encoding could be lost unless the words are visually similar.

REFERENCE NOTE

1. Juola, J. F., Choe, C. S., & Leavitt, D. D. *A reanalysis of the word superiority effect*. Paper presented at the meeting of the Psychonomic Society, Boston, Mass., November 1974.

REFERENCES

Bamber, D. Reaction times and error rates for same-different judgment of multidimensional stimuli. *Perception & Psychophysics*, 1969, **6**, 169-174.

Baron, J. Successive stages in word recognition. In P. M. A. Rabbit & S. Dornic (Eds.), *Attention and performance V*. New York: Academic Press, 1975.

Barron, R. W., & Pittenger, J. B. The effect of orthographic structure and lexical meaning on same-different judgments. *Quarterly Journal of Experimental Psychology*, 1974, **26**, 566-581.

Besner, D., & Jackson, A. Same-different judgments with words and nonwords: A word superiority/inferiority effect. *Bulletin of the Psychonomic Society*, 1975, **6**, 578-580.

Chambers, S. M., & Forster, K. I. Evidence for lexical access in a simultaneous matching task. *Memory & Cognition*, 1975, **3**, 549-559.

Clark, H. H. The language-as-fixed-effect fallacy: A critique of language statistics in psychological research. *Journal of Verbal Learning and Verbal Behavior*, 1973, **12**, 335-359.

Collins, A. M., & Loftus, E. F. A spreading activation theory of semantic processing. *Psychological Review*, 1975, **82**, 407-428.

Egeth, H., & Blecker, D. Differential effects of familiarity on judgments of sameness and difference. *Perception & Psychophysics*, 1971, **9**, 321-326.

Eichelman, W. H. Familiarity effects in a simultaneous matching task. *Journal of Experimental Psychology*, 1970, **86**, 275-282.

Gibson, E. J., Shurcliff, A., & Yonas, A. Utilization of spelling patterns by deaf and hearing subjects. In H. Levin & J. P. Williams (Eds.), *Basic studies in reading*. New York: Basic Books, 1970.

Henderson, L. A word superiority effect without orthographic assistance. *Quarterly Journal of Experimental Psychology*, 1974, **26**, 301-311.

Henderson, L. Word recognition. In N. S. Sutherland (Ed.), *Tutorial essays in experimental psychology*. Hillsdale, N.J: Lawrence Erlbaum, in press.

Henderson, L., & Chard, J. On the nature of the facilitation of visual comparisons by lexical membership. *Bulletin of the Psychonomic Society*, 1976, **7**, 432-434.

Henderson, L., & Henderson, S. E. Visual comparison of words and random letter strings: Effects of number and position of letters different. *Memory & Cognition*, 1975, **3**, 97-101.

Krueger, L. E. Search time in a redundant visual display. *Journal of Experimental Psychology*, 1970, **83**, 391-399.

Krueger, L. E. Effect of irrelevant surrounding material on speed of same-different judgment of two adjacent letters. *Journal of Experimental Psychology*, 1973, **98**, 252-259.

Kučera, H., & Francis, W. N. *Computational analysis of present-day American English*. Providence, R.I: Brown University Press, 1967.

Manelis, L. The effect of meaningfulness on tachistoscopic word perception. *Perception & Psychophysics*, 1974, **16**, 182-192.

Mason, M. Reading ability and letter search time: Effects of orthographic structure defined by single letter positional frequency. *Journal of Experimental Psychology: General*, 1975, **104**, 146-166.

Mayzner, M. S., & Tresselt, M. E. Tables of single-letter and digram frequency counts for various word length and letter position combinations. *Psychonomic Science Monograph Supplements*, 1965, **1**, 13-32.

Mayzner, M. S., Tresselt, M. E., & Wolin, B. R. Tables of trigram frequency counts for various word length and position combinations. *Psychonomic Science Monograph Supplements*, 1965, **1**, 33-78.

Meyer, D. E., & Schvaneveldt, R. W. Facilitation in recognizing pairs of words: Evidence of a dependence between retrieval operations. *Journal of Experimental Psychology*, 1971, **90**, 227-234.

McClelland, J. L. Preliminary letter identification in the perception of words and nonwords. *Journal of Experimental Psychology: Human Perception and Performance*, 1976, **2**, 80-91.

Pollatsek, A., Well, A. D., & Schindler, R. M. Familiarity affects visual processing of words. *Journal of Experimental Psychology: Human Perception and Performance*, 1975, **1**, 328-338.

Rosch, E. Cognitive representations of semantic categories. *Journal of Experimental Psychology: General*, 1975, **104**, 192-233.

Schaeffer, B., & Wallace, R. The comparison of word meanings. *Journal of Experimental Psychology*, 1970, **86**, 144-152.

Smith, E. E., Shoben, E. J., & Rips, L. J. Structure and process in semantic memory: A featural model for semantic decisions. *Psychological Review*, 1974, **81**, 214-241.

Solso, R. L., & King, J. F. Frequency and versatility of letters in the English language. *Behavior Research Methods & Instrumentation*, 1976, **8**, 283-286.

NOTE

1. Similar difficulties of interpretation appear to exist in a recent experiment by Pollatsek, Well, and Schindler (1975). They found that different judgments for pairs of homophones (e.g., SITE/CITE), which differed by only one letter, produced a word/orthographically illegal nonword (e.g., BSHA/DSHA) difference which was of the same magnitude as that obtained for different judgments of two identical words which differed only in letter case (e.g., cITE/CITE vs. dSHA/DSHA). Similar results have been obtained by Besner and Jackson (1975). Pollatsek et al. (1975) argued that their results rule out a semantic or lexical (they did not make the distinction) interpretation of the word/orthographically illegal nonword difference, at least at the comparison level, because their familiarity effect was of the same magnitude regardless of whether the subject responded to semantically identical or nonidentical words. It is possible, however, that their case-different word pairs were encoded more rapidly, but compared more slowly than their letter-different word pairs. This differential tradeoff between the speed of encoding and comparison of the two types of word pairs could have produced their findings.

(Received for publication May 3, 1977; revision accepted May 13, 1977.)

Appendix A

The word pairs used in Experiments 1a and 1b are listed below together with the mean reaction time in milliseconds for each pair and the mean semantic relatedness score (R) for the semantically related and unrelated pairs.

"Same" Judgments

	1a	1b		1a	1b
bleed/bleed	945	586	disgust/disgust	868	611
rank/rank	960	694	sleep/sleep	788	558
dish/dish	814	588	fiend/fiend	929	702
algebra/algebra	924	718	peel/peel	778	604
defeat/defeat	890	659	quartet/quartet	979	701
skirt/skirt	857	619	antigen/antigen	1023	650
charge/charge	861	615	pole/pole	898	763
unify/unify	812	608	confine/confine	871	637
icy/icy	760	587	chores/chores	894	636
adverb/adverb	893	616	duct/duct	856	579
advice/advice	892	630	electron/electron	852	682
confide/confide	984	627	untie/untie	943	729
poet/poet	843	604	discard/discard	874	616
frock/frock	864	655	arabia/arabia	922	676
duel/duel	886	652	sang/sang	990	603
shine/shine	862	592	algiers/algiers	1037	695
blast/blast	882	602	define/define	823	654
grunt/grunt	902	613	quarrel/quarrel	910	684
ancient/ancient	877	638	groom/groom	913	600
bland/bland	983	643	antique/antique	852	637
shell/shell	827	580	sleep/sleep	843	607
blame/blame	1071	630	archive/archive	1033	742
election/election	930	673	choral/choral	951	634
smirk/smirk	900	595	dart/dart	839	586
arctic/arctic	891	723	archery/archery	959	642
gleam/gleam	861	591	beer/beer	880	552
soon/soon	828	616	peep/peep	843	590
choice/choice	880	625	smelt/smelt	1082	641
inn/inn	826	610	bred/bred	1030	631
rung/rung	962	626	glide/glide	929	652

Semantically Related (SR) "Different" Judgments							
	1a	1b	R		1a	1b	R
electric/electron	876	633	2.41	arabia/arabic	979	673	4.66
disgust/disdain	866	686	3.88	confide/confess	879	659	3.77
dart/dash	907	659	3.75	sleep/sheet	872	665	2.00
gleam/glint	846	623	4.06	ancient/antique	916	624	4.44
quartet/quarter	999	717	2.00	blast/blaze	863	640	1.78
archaic/archive	877	679	3.90	rang/rung	971	652	4.63
ancient/archive	904	643	4.09	poem/poet	917	646	4.38
bleed/blood	862	611	4.50	grunt/groan	882	614	4.06
smile/smirk	869	655	4.09	defeat/defend	885	630	1.63
ice/icy	909	673	4.56	algiers/algeria	927	716	4.09
sang/song	920	643	4.53	advise/advice	1047	730	4.59
choice/choose	934	647	4.38	fiend/freak	915	671	1.69
choral/chorus	906	616	4.03	brew/beer	908	626	4.31
duel/duet	996	701	1.41	shirt/skirt	1045	781	3.19
peep/peer	1003	662	1.47	unify/unite	1005	643	4.06

Semantically Unrelated (SU) "Different" Judgments							
	1a	1b	R		1a	1b	R
glide/glint	857	616	1.75	electric/election	896	669	1.00
poem/pole	838	596	1.00	algebra/algeria	1025	782	1.00
shine/shirt	882	657	1.00	brew/bred	992	642	1.25
defend/define	876	707	1.06	arabic/arctic	980	655	1.13
ice/inn	874	612	1.03	sheet/shell	919	637	1.16
freak/frock	875	592	1.00	ancient/antigen	912	677	1.13
blood/bland	874	601	1.03	charge/choose	910	631	1.06
unite/untie	1146	880	1.09	blame/blaze	1014	638	1.00
quarrel/quartet	975	656	1.00	advise/adverb	896	658	1.00
duet/duct	929	655	1.00	rang/rank	1021	644	1.00
sang/soon	983	642	1.00	groan/groom	930	626	1.00
smile/smelt	960	616	1.00	disdain/discard	845	642	1.22
archaic/archery	941	636	1.06	confine/confess	851	650	1.09
ancient/archery	942	598	1.03	dish/dash	920	622	1.06
chores/chorus	1041	692	1.03	peer/peel	893	639	1.00

Appendix B

The word pairs used in Experiment 2 are listed below together with the mean reaction time (RT) in milliseconds for each pair and the mean semantic relatedness score (R) for the semantically related and unrelated pairs.

Visually Identical (I) "Same" Judgments			
	RT		RT
position/position	492	purple/purple	486
tool/tool	515	grin/grin	552
dune/dune	499	snap/snap	515
attack/attack	507	dump/dump	519
donkey/donkey	527	bug/bug	537
player/player	530	bait/bait	498
laugh/laugh	504	adore/adore	516
mine/mine	521	armory/armory	533
billion/billion	514	arbor/arbor	513
tomorrow/tomorrow	508	discord/discord	518
alive/alive	514	concise/concise	513
strike/strike	559	belt/belt	505
vice/vice	502	furnish/furnish	491
define/define	500	wrap/wrap	529
cow/cow	496	lark/lark	529
pistol/pistol	517	carbon/carbon	554
access/access	537	stem/stem	518
pupil/pupil	520	radical/radical	543
fault/fault	499	blanket/blanket	518
phony/phony	491	crucial/crucial	492

Semantically Related (SR) "Same" Judgments					
	RT	R		RT	R
advise/advice	500	4.59	choral/chorus	566	4.03
algiers/algeria	539	4.09	confide/confess	571	3.77
ancient/archive	545	4.09	defeat/defend	554	1.63
ancient/antique	493	4.44	duel/duet	554	1.41
arabia/arabic	502	4.66	electron/electric	540	2.41
fiend/freak	606	1.69	disgust/disdain	545	3.88
bleed/blood	494	4.50	grunt/groan	606	4.06
blast/blaze	580	1.78	ice/icy	591	4.56
brew/beer	541	4.31	dart/dash	594	3.75
choice/choose	532	4.38	peep/peer	533	1.47
gleam/glint	620	4.06	intend/intent	531	3.94
poem/poet	563	4.38	major/minor	556	2.28
quartet/quarter	539	2.00	tones/tonal	550	4.31
rang/rung	576	4.63	adversity/adversary	538	1.40
sang/song	528	4.53	foot/feet	559	4.56
skirt/shirt	570	3.19	bland/blank	508	1.41
sleep/sheet	555	2.00	pelvic/pelvis	505	2.40
smile/smirk	550	4.09	flora/fauna	622	3.13
unify/unite	578	4.06	worse/worst	578	4.53
archaic/archive	514	3.90	frost/froze	567	4.41

Semantically Unrelated (SU) "Same" Judgments					
	RT	R		RT	R
advise/adverb	514	1.00	chores/chorus	534	1.03
algebra/algeria	516	1.00	confine/confess	511	1.09
ancient/archery	533	1.03	defend/define	546	1.06
ancient/antigen	563	1.13	duet/duct	540	1.00
arabic/arctic	563	1.13	electric/election	504	1.00
freak/frock	591	1.00	disdain/discard	543	1.22
blood/bland	536	1.03	groan/groom	553	1.00
blame/blaze	536	1.00	ice/inn	702	1.03
brew/bred	567	1.25	dish/dash	542	1.06
charge/choose	583	1.06	peer/peel	604	1.00
glide/glint	539	1.75	intend/intake	544	1.06
poem/pole	536	1.00	major/magic	597	1.00
quarrel/quarter	561	1.00	tones/tooth	533	1.00
rang/rank	688	1.00	advertise/adversary	581	1.16
sang/soon	522	1.00	feed/feet	542	1.00
shine/shirt	539	1.00	block/blank	589	1.16
sheet/shell	568	1.16	pelvic/pencil	529	1.00
smile/smelt	530	1.00	flora/flake	504	1.06
unite/untie	550	1.09	worst/worth	546	1.00
archaic/archery	584	1.06	frown/frost	565	1.00

High Shared-Letter (HSL) "Different" Judgments			
	RT		RT
hook/lack	638	snake/flake	582
poke/cake	619	suspect/protect	596
hide/fade	614	insect/direct	595
block/stack	606	mental/dental	641
soap/camp	595	depth/teeth	616
map/tap	652	lunch/touch	613
hate/kite	651	plot/slot	628
psychology/immunology	618	sinner/winter	597
plant/grant	632	whirl/pearl	567
rush/push	644	turtle/purple	582
meat/heat	658	tumble/rumble	681
carrot/parrot	614	trash/flash	716
cedar/radar	614	trust/crust	569
cavern/tavern	572	mould/could	603
fascinate/negotiate	544	fair/pair	644
drown/frown	568	dollar/pillar	689
bright/flight	624	cough/touch	597
joke/sake	578	dream/steam	586
stapples/nipples	638	drink/trick	600
yoke/fake	605	reflect/neglect	652

Low Shared-Letter (LSL) "Different" Judgments

	RT		RT
reason/ground	585	motor/diary	575
crucial/passion	569	advice/scream	622
weight/player	581	credit/sorrow	565
lane/oral	573	grew/rude	573
medicine/profound	567	chant/fence	581
laugh/sneak	599	broom/pitch	636
sand/mart	614	casino/injury	568
shade/blimp	563	eject/drama	600
trial/mourn	524	drip/cure	629
campus/pacify	579	coax/dawn	613
horn/cake	555	tavern/sewage	570
improve/nursery	582	idiot/cloud	560
forty/steep	574	apostle/blanket	642
drunk/crisp	627	proton/modest	611
exist/tower	588	boil/fled	645
wide/acid	617	blew/iron	582
fund/term	636	ironic/pursue	601
coast/aloud	581	dot/ton	654
hence/scrub	562	pony/sunk	572
eat/spy	630	veto/slum	583

Appendix C

The item pairs used in Experiment 3 are listed below together with the mean reaction time for each pair.

Words ("Same" Judgments)				Nonwords ("Same" Judgments)			
	RT		RT		RT		RT
wheat/wheat	1032	queen/queen	980	blout/blout	902	chand/chand	924
guard/guard	745	paint/paint	859	sonth/sonth	997	blong/blong	824
smoke/smoke	918	score/score	843	graim/graim	822	chall/chall	807
learn/learn	805	price/price	760	pight/pight	881	stire/stire	834
fruit/fruit	851	scale/scale	887	selch/selch	883	banch/banch	779
catch/catch	771	noise/noise	928	minch/minch	1010	whoce/whoce	843
brush/brush	849	cloth/cloth	822	fleep/fleep	827	brult/brult	813
drink/drink	842	pride/pride	794	starp/starp	879	chist/chist	853
fight/fight	765	state/state	849	thest/thest	807	litch/litch	837
sleep/sleep	796	sound/sound	821	rilse/rilse	863	pring/pring	770
short/short	966	found/found	725	hilch/hilch	961	dring/dring	921
spend/spend	809	would/would	895	thove/thove	947	therp/therp	893
stage/stage	873	death/death	820	drash/drash	925	sterk/sterk	928
knife/knife	941	worth/worth	766	slart/slart	989	sping/sping	836
build/build	876	threw/threw	771	frind/frind	838	shint/shint	852
faith/faith	816	three/three	798	smace/smace	1073	woult/woult	884
guess/guess	868	space/space	796	blace/blace	844	glast/glast	881
porch/porch	776	plant/plant	830	bling/bling	806	preat/preat	909
stand/stand	882	train/train	819	theam/theam	910	broul/broul	918
white/white	747	voice/voice	896	shisk/shisk	858	chesk/chesk	825

Words ("Different" Judgments)				Nonwords ("Different" Judgments)			
	RT		RT		RT		RT
blood/world	827	cheer/flesh	815	brone/chout	815	thear/whosk	895
grain/north	900	sleep/broad	888	geark/carth	954	wherp/clest	984
beach/thick	855	share/house	887	bruld/theng	941	thire/shong	854
dress/might	914	shook/month	925	drout/nould	868	dreak/wonth	856
class/earth	962	green/block	850	cound/trong	875	brean/flost	845
mount/bring	929	store/thank	847	moulk/breet	893	coure/thace	901
youth/grass	832	crowd/smell	795	yould/thare	937	thead/sterm	939
brave/touch	914	chain/shell	855	brich/shice	920	shain/cherd	906
blame/chief	807	clean/track	809	briss/shend	862	smain/trand	801
bound/grant	812	grand/stock	883	boult/cloor	938	plard/wouch	819
horse/brown	1016	child/round	844	worch/plart	873	moung/roult	829
trick/clear	893	dream/flame	854	trind/smair	935	couse/friss	805

Words ("Different" Judgments)				Nonwords ("Different" Judgments)			
	RT		RT		RT		RT
shall/chair	1019	march/grave	837	chard/shair	904	mousk/sould	1012
small/crown	813	speak/count	896	starm/thean	1002	shace/grich	1006
think/storm	908	judge/south	894	thice/courm	891	bleam/coulk	847
black/greet	836	smile/glass	857	flast/breat	919	stirm/gound	902
mouth/shoot	875	field/press	880	wouth/dreat	875	shent/prout	924
stick/cheek	928	stone/teach	873	shing/thirp	868	cousk/truld	850
bread/sharp	836	heart/brain	1034	whesk/theak	940	gruld/beark	827
flash/sweet	795	teeth/flood	936	clast/whert	852	jance/frone	884