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THE USE OF ABSTRACT GRAPHEMIC INFORMATION IN LEXICAL ACCESS

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Three experiments investigated the nature of the information required for the lexical access of visual words. A four-field masking procedure was used, in which the presentation of consecutive prime and target letter strings was preceded and followed by presentations of a pattern mask. This procedure prevented subjects from identifying, and thus intentionally using, prime information. Experiment I established the existence of a semantic priming effect on target identification, demonstrating the lexical access of primes under these conditions. It also showed a word repetition effect independent of letter case. Experiment II tested whether this repetition effect was due to the activation of graphemic or phonemic information. The graphemic and phonemic similarity of primes and targets was varied. No evidence for phonemic priming was found, although a graphemic priming effect, independent of the physical similarity of the stimuli, was obtained. Finally Experiment III demonstrated that, irrespective of whether the prime was a word or a nonword, graphemic priming was equally effective. In both Experiments II and III, however, the word repetition effect was stronger than the graphemic priming effect. It is argued that facilitation from graphemic priming was due to the prime activating a target representation coded for abstract (non-visual) graphemic features, such as letter identities. The extra facilitation from same identity priming was attributed to semantic as well as graphemic activation. The implications of these results for models of word recognition are discussed.

Introduction

In order to understand the process of reading, it is necessary to discover how the meaning of a written word is accessed. It is generally assumed that the reader possesses an internal lexicon in which knowledge about words is represented. The reader is thought to understand a written word once its lexical representation has been accessed by information extracted from the stimulus. The present experiments aimed to investigate the nature of the information required for lexical access.

Two routes to the internal lexicon have been proposed (e.g., Coltheart, Davelaar,

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Jonasson and Besner, 1977; Frederiksen and Kroll, 1976; Meyer, Schvaneveldt and Ruddy, 1974; Shulman, Hornak and Sanders, 1978). One route operates directly from a visual coding of the word ("graphemic access"), while the other requires phonemic recoding of the visual information ("phonemic access"). Much evidence indicates that, while there are situations in which either route may operate, for skilled readers lexical access usually occurs by means of the graphemic access route (see Coltheart, 1978, for a review).

However, it remains necessary to outline the type of information utilised in graphemic access. Several recent experiments suggest that this information is abstract, in the sense that it does not specify the literal visual format of words. For example, McConkie and Zola (1979) found that eye movements to a text of words made up of letters alternating in case were not affected by changing the case of the letters during the saccades. A similar result has been reported by Rayner (1979). He presented a word in parafoveal vision and instructed subjects to make an eye movement to the stimulus, which was to be named as quickly as possible. Changing the case of the word while the saccade was being made had no effect on naming latency. This was not due to priming phonemic information: words which retained their initial letter but altered the first phoneme did not disrupt the performance relative to words in which both the initial letter and phoneme were constant. Nevertheless, changes in the identity of letters in target words have marked effects on both eye movements and naming latencies (Rayner, 1975, 1979). These examples indicate that abstract information from the parafoveal word affects recognition of the foveal target. Further, Scarborough, Cortese and Scarborough (1977) have shown that case-independent priming effects can occur with foveal presentation of primes in a task requiring lexical access. They found that lexical decisions to repeated foveal words and nonwords were faster than lexical decisions to non-repeated stimuli, the size of this effect being the same regardless of case changes between primes and targets.

One of the problems with this type of study, however, is in determining whether any priming effects occur automatically, or whether they are strategy-dependent. Rayner, McConkie and Ehrlich (1978) have shown that standard parafoveal priming effects (see above) only occur when subjects attend to the spatial location of the prime; while subjects in the study of Scarborough *et al.* (1977) were aware that stimuli would be repeated.* It seems possible that priming in both cases could have been mediated by intentional processes on the part of the subjects. Under such circumstances, subjects may generate expectations of targets from primes (Neely, 1977; Posner, 1978). Since these expectations could be generated after the lexical access of prime words, the studies do not show that abstract graphemic information is automatically extracted during lexical access. For

* Scarborough, Gerard and Cortese (1979) have more recently shown that repetition effects can occur in a running lexical-decision task of the type used by Scarborough *et al.* (1977) when subjects are not aware that items will be repeated. Unfortunately these effects were not produced using stimuli differing in case. Automatic, case-independent repetition effects therefore remain to be demonstrated. Further, we may note that, while the result of Scarborough *et al.* (1977) indicates that case independent priming of the lexicon can occur, the long-lasting effects generated in the running lexical-decision task may be produced by different mechanisms to those investigated in the present paradigm. Nevertheless, given our current lack of knowledge about the differences between long-term and short-term priming, their result is at least consistent with the proposed argument.

instance, an expectation coded independently of visual format could be generated following the lexical access of primes from specific (case dependent) visual information.

The present experiments attempted to overcome these objections by using a priming technique which prevented the intentional usage of primes by subjects. This was accomplished by pattern masking primes to minimise their explicit identification. It has long been suggested that stimuli can access stored conceptual knowledge when their accurate report is limited by presentation conditions (Dixon, 1971). Indeed, Marcel (in press) has recently shown that semantic priming effects can occur even when primes are backward pattern masked so that subjects cannot report their presence. This indicates that lexical access may not only operate prior to an identification response becoming available, but also prior to any subjective awareness of the word. Obviously, an ideal way to prevent the intentional usage of primes would be to present them under conditions in which subjects cannot report their occurrence. However, we elected to use the more lax criterion of minimising correct prime identification because of difficulties in obtaining any semantic priming using a presence/absence criterion (Evett, unpublished). It is important to realise that, providing the minimal identification criterion is met, the argument that any priming must occur automatically stands (Posner, 1978).

Priming effects were examined using a four-field masking paradigm (Turvey, 1978). Letter string primes were briefly presented and backward pattern-masked by target words. In addition, presentation of the prime and target stimuli was preceded and followed by the presentation of a pattern mask, so the presentation sequence was as follows: MASK – PRIME – TARGET – MASK. There were no inter-stimulus intervals. Subjects were required to identify any words they thought were present in the display. Pilot work suggested that priming effects could be obtained successfully using this paradigm without subjects being able to explicitly identify primes. This claim is validated and considered in more detail in the following experiments.

When subjects are unable to use prime information intentionally, any effect of a prime on a target is attributable to the information automatically extracted from the leading stimulus (Posner, 1978). If graphemic access to the lexicon operates independently of the visual characteristics of words, priming effects should occur as a function of the letters in common between primes and targets, regardless of their physical similarity.

In order to interpret any priming effects in terms of the processes involved in lexical access, it is necessary to demonstrate that lexical access for primes does occur using the above presentation technique. To do so unequivocally, it is necessary to demonstrate priming based on a semantic relationship between stimuli. Experiment I was performed for this purpose. Experiments II and III investigated the nature of the lexical access routes.

Experiment I

As a test of whether primes accessed their lexical representations, a condition was included to determine whether the semantic relationship between the prime and target affected target identification (cf. Meyer and Schvaneveldt, 1971). In addition, to study the nature of the information used in lexical access, a condition was included to determine whether target recognition was influenced by the structural relationship between the stimuli. In this test, priming between different-case stimuli with the same identity was examined (cf. Scarborough *et al.*, 1977).

One problem with the present paradigm concerns the choice of an appropriate control condition to provide a baseline for the possible facilitatory or inhibitory effects of priming. This is because forward masking could operate between word primes and targets. The solution requires that a neutral prime, which is physically similar to a word, be used in the control condition to equate forward masking effects (cf. Hellige, Walsh, Lawrence and Prasse, 1979; Schiller, 1966). The control used for this purpose in Experiment I was an orthographically regular nonword as a prime to target words.

Method

Subjects

The subjects were 14 volunteers from the Psychology Department of Bristol University. All participants had normal or corrected-to-normal vision, and each was run individually in one session lasting about 30 min.

Materials and design

A pool of 80 word pairs was created in which the second member of each pair was the primary associate of the first. Seventy-six pairs were drawn from Postman and Keppel (1970) and four other pairs were selected by two independent judges. The target words (the second members of each pair) were divided into four groups of 20 each, balanced for word frequency (Kučera and Francis, 1967) and word length. A complete list of the stimuli for all experiments is reported in the Appendix. Treatments were defined by type of prime paired with the target.

Each subject received four treatments:

(a) the prime and target had the same identity;
(b) the prime and target were associated;
(c) the prime and target were unassociated;
(d) the prime was a nonword.

There were two groups of subjects (Groups 1 and 2), and the targets in the same identity and associated conditions for Group 1 became targets in the nonword-prime and unassociated conditions respectively for Group 2, and vice versa. As far as the constraints of pair selection would allow, the associative strength between pair members was equated for Groups 1 and 2. There were 20 trials in each condition, and no subject saw the same target twice. The order of the trials for each subject was randomised using a computer.

Letter strings were 4 to 6 letters long, and the relative lengths of primes to targets were balanced across conditions. Each nonword was orthographically regular and pronounceable (Venezky, 1970) and was formed by changing one letter in a word which was unrelated to the paired target word.

Stimulus presentation, timing and data collection were controlled by a PDP 11/10 computer. Displays were plotted on a Tektronix 602 oscilloscope equipped with a P-31 phosphor, with the characteristic that removing a character leads to a drop to 1% of maximum brightness in 0·25 ms. The targets were always in upper case and primes in lower case. This ensured that targets always overlapped primes. Each character covered approximately 0·5° of visual angle from the viewing distance of 50 cm, so the largest words (six letters) subtended about 3° of visual angle. The character set used is shown in Figure 1.

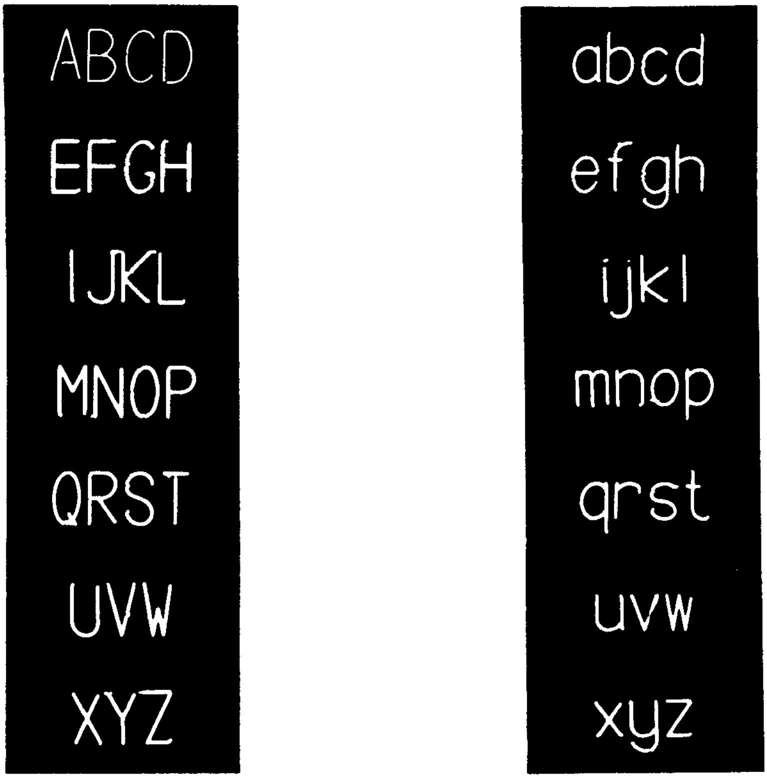

FIGURE 1. The character set used in Experiments I to III.

Procedure

Subjects were told that they would be presented with pattern masked words, and they were asked to identify any words they thought had been presented. They were asked to guess if unsure, and responses were required on every trial. The pattern mask was constructed from randomly oriented letter fragments. The mask covered the same spatial area as words and subtended a visual angle of about 2° vertically by 3° horizontally. Subjects were instructed to fixate a dot on the oscilloscope which was at the mid-point directly underneath the letter strings. When fixated, subjects initiated a display by pressing a key on the computer terminal. Displays were presented immediately after the keypress. Responses were entered on a Decscope keyboard. Subjects were encouraged to type in more than one word if they thought more than one stimulus had been presented.

Subjects were initially presented with a series of threshold trials using the descending method of limits to determine the duration at which they would perform at approximately 30 to 40% correct target identification. On these trials orthographically regular nonword primes were used. Threshold trials were run in blocks of eight, starting with field durations (equal for each stimulus in the display) at which targets were fairly easy to identify. Keeping the durations of the four fields equal, exposure times were then covaried between the start durations and durations at which targets could not be identified until the required level of performance was maintained over 32 trials. After the threshold trials, the experimental trials were run at the established durations. Over subjects, the mean duration of each field in the display was 33 ms, with a range from 24 to 45 ms inclusive.

Following the experimental trials, subjects were encouraged to comment on their impressions of the task. Specifically, they were asked to report whether or not they had been aware of more than one letter string on any of the trials, and in what case they thought letter strings were presented. They were then debriefed on the nature of the experiment.

Results and discussion

Mean correct target identification scores (%) over subjects are presented in Table I. The data were submitted to an analysis of variance for a mixed design with one within-subjects factor (conditions) and one between-subjects factor (subject groups).* There was a statistically significant main effect for conditions ($F(3,36)=1.19$, $P<0.001$), but not for groups ($F<1.0$). Nor was the conditions × groups interaction statistically significant ($F(3,36=1.19$, $P>0.05$).

TABLE I

Mean correct target identification (%) in Experiment I

Conditions		Percentage correct
Same identity	smoke – SMOKE	67·86
Associated	salt – PEPPER	52·14
Unassociated	card – LIGHT	42·14
Nonword prime	deet – CLEAN	40·36

The differences between the conditions were examined in more detail using the Newman–Keuls test. There was a significant facilitation effect in the same identity condition relative to all the other conditions ($P<0.01$), and a facilitation effect in the associated condition relative to the unassociated word and nonword prime conditions ($P<0.01$). There were no other differences between the conditions. These results demonstrate significant priming effects based upon the semantic and/or the structural relationship between primes and targets.

Only five subjects reported that they thought more than one stimulus was present on some occasions.† When two responses were made, one was either the target or an error containing a majority of target letters; the other usually bore no relation to either the prime or target, and for each subject it tended to be the same or a very similar response on each trial. Since such responses were made consistently across different primes and targets, they were interpreted as responses to letter fragments in the mask. No subjects reported seeing any lower case letters, even though some target identification errors were produced by transposing letters from primes to targets (Allport, 1977; Shallice and McGill, 1978).

* In all the analyses for individual experiments in this paper, only statistical generalisations over subjects are presented. It was held to be inappropriate to treat stimuli as a random factor (Clark, 1973) because there were unavoidable restrictions in selecting stimuli so as to manipulate semantic and graphemic similarity between word pairs. Instead, we replicated the results over different pools of word pairs, which may be a more valid approach to the problem of generalising the findings over stimuli (Wike and Church, 1976).

† Although subjects were encouraged to produce two responses on every trial, this proved difficult to enforce. Since target identification was itself relatively difficult, many subjects were both unable and unwilling to generate another response. This was true also of Experiments II and III.

Nevertheless, a small proportion of correct prime identifications did occur. Pooling over subjects, there were five correct prime identifications out of 280 trials in the associated treatment, and one correct prime identification in the unassociated condition. The slightly higher number in the associated condition relative to the unassociated condition could be due to a number of factors. One possibility is that the masking of the prime by the target was attenuated when the target was an associate (Jacobson, 1974, 1976; Jacobson and Rhinelander, 1978). However, even in the unassociated condition and even when the target was not identified, about 5·7% of responses could be classified as target associates. It seems likely that such responses reflect guesses based on knowledge of the types of words used as targets (Ellis and Marshall, 1978; Williams and Parkin, 1980). Since such guesses would have a relatively high probability of being classified as correct prime identifications in the associated condition, the increase in identifications in this treatment can be attributed to this strategy. Even then though, only 1·8% of the primes were correctly identified. This is well within the guessing levels of 8·9 and 11·5% for masked words established by Ellis and Marshall (1978) and Williams and Parkin (1980) respectively. It therefore seems appropriate to claim that primes were not explicitly identified, and, accordingly, that any priming effects occurred automatically. Further empirical support for this proposition is provided by the equivalence of performance in the nonword control condition and the unassociated word condition. Previous work by Neely (1977) and Posner (1978) suggests that the incorrect priming of the target's identity (in the unassociated condition) should only inhibit performance relative to a neutral priming condition (with a nonword prime) when subjects intentionally use the prime.

The results were obtained using a four-field masking paradigm. At present, the parameters of four-field masking are not well understood, and caution must be used in generalising interpretations from the more common two-field masking paradigm. However, we may suspect that one factor making primes more difficult to identify than targets is that primes were backward masked by another letter string (the target), while targets were backward masked by random letter fragments. Masking should be more severe in the former than in the latter situation (Johnston and McClelland, 1980; Taylor and Chabot, 1978). Nevertheless, the semantic priming effect (the difference between the associated and unassociated conditions) demonstrates that primes gained access to the internal lexicon. In this respect, the result is similar to the semantic priming effects reported by Allport (1977) and Marcel (Marcel, in press; Marcel and Patterson, 1978). They used a two-field masking procedure, in which primes were backward pattern masked, to prevent prime identification. Along with these studies, the present experiment indicates that masking can limit the explicit identification of stimuli rather than their lexical encoding, and, thus, that lexical access occurs before an identification response becomes available.

Same identity priming facilitated target identification over and above the benefit from priming by an associate. This may have been either because semantic priming was greater in the same identity than the associated condition (due to the complete overlap of semantic information), or because of structural activation of the target representation by the prime. Structural priming could stem from the activation of common visual features in lower case prime and upper case target representations, from the activation of a common abstract (case independent) representation, or from the activation of a common phonemic representation. Experiment II was designed to examine these possibilities in more detail.

Experiment II

The logic of the second experiment was based on a study conducted by Meyer *et al.* (1974), and is equivalent to that used in other studies of structural priming effects (Hillinger, 1980; Shulman *et al.*, 1978). There were two main experimental conditions. In the phonemic experimental condition, targets were primed by words which were phonemically and graphemically similar (e.g., bribe – TRIBE, hence – FENCE). In the graphemic experimental condition, targets were primed by words which were graphemically similar but phonemically different (break – FREAK, couch – TOUCH). Each of these experimental conditions had its own control formed by interchanging word-pair members to produce pairs in which the words were graphemically and phonemically different (e.g., fence – BRIBE, tribe – HENCE in the phonemic control condition; freak – COUCH, touch – BREAK in the graphemic control condition). These aspects of the design match exactly the above studies of structural priming.

If graphemic priming occurs, target recognition in both experimental conditions should be facilitated relative to their respective controls. If phonemic priming also occurs, the size of the facilitation effect in the phonemic experimental condition should be larger than the facilitation effect in the graphemic experimental condition. Previous studies have found evidence for both phonemic (Hillinger, 1980; Meyer *et al.*, 1974) and graphemic priming (Shulman *et al.*, 1978), using conditions in which subjects can identify both primes and targets, The present experiment tested whether graphemic or phonemic priming occurs when the intentional use of primes is prohibited by the masking procedure validated in Experiment I.

In addition to the graphemic and phonemic conditions, the same identity treatment was again included, along with a control in which target words, balanced over subjects, were paired with unrelated primes. The identity facilitation effect (the difference between the latter conditions) should serve as a baseline against which to assess the effectiveness of graphemic or phonemic priming.

Method

Unless otherwise stated, the apparatus design and procedure were the same as in the previous study.

The subjects were 28 paid volunteers from the Birkbeck College subject-pool, 14 males and 14 females. Each had either normal or corrected-to-normal sight and participated in one session lasting about 45 min.

The six prime-target conditions were manipulated within subjects. No subject saw the same target twice, and the targets which appeared in each condition were counter-balanced over subjects. This was achieved for the phonemic and graphemic experimental and control conditions by reversing the prime-target pairs for half the subjects. For the same identity experimental and control conditions, this was achieved by presenting targets which were in the experimental condition for half the subjects as targets in the control condition for the other subjects (the same set of primes were used in the control condition for all subjects); while targets in the control became targets in the experimental condition.

Each subject was presented with 30 word-pairs in each condition. Words were between four and six letters long, and the conditions were balanced for mean word length and frequency (Kučera and Francis, 1967). Primes were always the same length as targets. In the phonemic and graphemic experimental conditions primes and targets differed by a single letter. As far as possible in all the control conditions no letter occurred in the same position in primes and targets. Also, since a large number of the words could be changed into other words by altering one of the letters into another letter (i.e., the words tended to have high N values, where N is defined as the number of different English words which can be produced by changing one letter in a letter string; see Coltheart *et al.*, 1977), the targets in the conditions were also matched for their N values (see Appendix). The nonword-prime control condition used in Experiment I was not included in Experiment II since performance in that condition had been shown to be equivalent to that in the unrelated word treatment (i.e., there was no inhibitory effect of incorrect word priming). Any difference between the experimental and control conditions here should reflect the facilitatory effects of priming.

Stimulus displays were again controlled by a PDP 11/10 computer, but were plotted on an Advance Instrument oscilloscope (05 250), equipped with a P-31 rapid decay phospher. Written responses were made and subjects were asked to report any words they thought had been presented. They were also instructed to write their responses in the case in which words had been presented.

A series of threshold trials, during which primes were words unrelated to target words, again preceded the experimental trials. The mean field duration over subjects was 35 ms and a range between 30 and 50 ms was required. Following the threshold procedure, 180 experimental trials were given at the duration established for each subject. The order of presentation of the conditions for each subject was randomised using the computer.

Results and discussion

The mean percentage correct target identifications in each condition are shown in Table II.

TABLE II

Mean correct target identifications (%) in Experiment II

Conditions		*Percentage* correct
Same identity experimental	hand – HAND	76·57
Same identity control	city – HOPE	49·96
Phonemic experimental	file – TILE	54·86
Phonemic control	loft – FILE	40·43
Graphemic experimental	couch – TOUCH	56·11
Graphemic control	flown – COUCH	41·07

A preliminary analysis of variance established that there was no statistically significant main effect of sex of subject, nor did this variable interact with the experimental conditions (both $F < 1 \cdot 0$). Consequently, this variable was excluded from further consideration.

An analysis of variance for a mixed design was performed with two within-subjects factors, pair type (identity, graphemic and phonemic) and condition (experimental and control), and one between-subjects factor, prime-target order.

There was no effect of prime-target order ($F<1\cdot0$), and no interaction between this factor and the other factors. Pair type and condition were both statistically significant ($F(2,52)=41\cdot05$ and $F(1,26)$ 198·60, both $P<0\cdot001$), as was the condition $\times$pair type interaction ($F(2,52)=17\cdot96$, $P<0\cdot001$).

This interaction was further analysed using the Scheffé method. There were reliable facilitation effects for the same identity condition relative to its control ($F(1,52)=172\cdot2$, $P<0\cdot001$), for the phonemic experimental condition relative to its control ($F(1,52)=50\cdot64$, $P<0\cdot01$), and for the graphemic experimental condition relative to its control ($F(1,52)=55\cdot01$, $P<0\cdot01$). Additionally, the size of the facilitation from same identity priming was larger than the facilitation effects in the phonemic and the graphemic conditions ($F(1,52)=24\cdot45$ and $F(1,52)=22\cdot39$, $P<0\cdot05$ respectively). However, there was no difference in the magnitude of the faciltation effects in the latter conditions ($F<1\cdot0$).

Only six observers out of 28 remarked that on some trials they thought two stimuli were presented. Pooling across subjects, there were eight correct prime identifications out of 2520 trials in the three control conditions. Six of these identifications were made by one subject, who correctly reported the prime as being lower case on four occasions, and it is possible that the stimulus duration threshold was too lenient in this one instance (allowing primes as well as targets to be identified). However, omitting this subject's data from the analyses made no difference to the results. No other subjects reported the presence of lower case letters, although transposition errors occurred.

Out of 1680 trials in the graphemic and phonemic experimental conditions, there were 23 (1·3%) correct prime identifications. However, on none of these occasions were targets concurrently reported, and it seems likely that the responses were generated either from substitutions of letters from primes into targets (a transposition effect) or from a sophisticated guessing strategy based on the identification of some of the target letters. In either case, there is a high probability that the response would resemble the prime by chance, since primes differed from targets only by a single letter. As with Experiment I, the results indicate that prime identifications can be attributed to guessing.

The most important result here is that target recognition benefited from priming by a different case word with a high number of letters in the same position. In direct contrast to previous studies of structural priming (e.g., Hillinger, 1980; Meyer *et al.*, 1974), there was no evidence for phonemic priming effects. Performance was facilitated when the prime and target were graphemically similar irrespective of their phonemic relationship. Further, since target recognition in the phonemic and graphemic conditions fell well below the optimal level, the lack of difference between the treatments cannot be attributed to a ceiling effect.

The main procedural difference between Experiment II and the previous studies is that primes were masked to prevent their explicit identification, and intentional usage, here. Two possible reasons for the observed differences in the results follow: (a) phonemic coding may be an optional strategy in visual word recognition (e.g., Carr, Davidson and Hawkins 1978; Davelaar, Coltheart, Besner and Jonasson, 1978; Hawkins, Reicher, Rogers and Peterson, 1976), and, consequently, it is ineffective when priming is based on the automatic activation of the internal lexicon; or (b) the time for automatic access based on a phonemic code may be longer than the time for automatic access based on graphemic information (e.g., Coltheart, 1978; Meyer and Gutschera, unpublished), and, therefore, the phonemic coding of the prime is less likely to influence performance under the present conditions (where the slower access route may be curtailed by masking). Whichever explanation proves to be correct, the data in Experiment II are important, since they demonstrate that lexical access can operate using solely the graphemic route, and that phonemic recoding is not necessary.

The graphemic priming effect could be due to the activation by primes and targets of common, abstract (case independent) letter representations in the internal lexicon, or due to activation based on similar visual features in the stimuli. About half the letters of the alphabet have similar features across cases. It is possible that word pairs which differ in case but have a high number of letters in the same position also have more common visual features than different case word pairs whose letters differ in each position (cf., the experimental and control conditions here).

In order to check for visual priming, two measures of visual similarity between spatially overlapping letters in the graphemic experimental and control conditions were taken. One measure was the amount of physical overlap between the contours of prime and target letters. This measure has been shown to predict the magnitude of visual priming between single alphanumeric characters (Humphreys, 1978). Measures of contour overlap were obtained using a procedure described by Schiller (1966). Each letter was stencilled over a grid to find its area and its overlap with the other letters as assessed independently by two judges who were naive to the experiment. The second measure, related more directly to theories of visual word recognition, was the proportion of visual feature overlap between prime and target letters. Unfortunately, there is no clearly worked out theory of which features might mediate a specifically visual graphemic access route, and the hypothesised features range from line segments (Rumelhart and Siple, 1974) and angled portions of lines (Gibson, 1969) to relational properties of relative size and symmetry (Gibson, 1969; Lindsay and Norman, 1977). Moreover, it is likely that the critical features will differ depending on the character set and the presentation conditions (cf., Bouma, 1971; Geyer, 1977; Townsend, 1971). Nevertheless an attempt was made to measure featural overlap within the present character set using a relatively representative visual feature list, that provided by Lindsay and Norman (1977). There are seven features in this list; namely, vertical lines, horizontal lines, oblique lines, right angles, acute angles, continuous curves and discontinuous curves. The proportion of common features in prime and target letters was assessed independently by the same two judges as used above. The two measures of visual similarity, averaged over the judges and the letters in primes and targets, for each word pair are provided in the Appendix. Because of the difficulty in ascertaining which visual features might be effective even if visual access to the lexicon occurs, it must be accepted that there is unlikely to be a perfect correlation between our measures of physical similarity and the graphemic priming effect. Nevertheless, if priming was based on the visual similarity between the stimuli, the size of the graphemic priming effect should correlate more strongly with measures taking account of visual similarity than with a measure only taking account of abstract, common letter identities between primes and targets.

To test this prediction, the size of the graphemic priming effect was correlated with both measures of physical similarity and with the percentage of common letters in the stimuli, using the Pearson product moment coefficient. There were no correlations between the graphemic priming effect and the contour overlap measure ($r = -0{\cdot}031$, $P > 0{\cdot}05$), or the featural overlap measure ($r = 0{\cdot}008$, $P > 0{\cdot}05$). However, there was a reliable correlation between the size of the graphemic priming effect and the percentage of common letters in primes and targets ($r = 0{\cdot}77$, $P < 0{\cdot}001$).

These results strongly suggest that graphemic priming was not influenced by physical similarity between the stimuli. In contrast, there was a significant positive correlation between the graphemic priming effect and the number of letters in common between primes and targets. This is consistent with the proposal that priming was due to the activation of common abstract (case independent) representations by the stimuli.

In addition to the above graphemic priming effect, there was increased target identification from same identity priming. This increased advantage could be due to the extra common letter in the stimuli in the same identity condition. However, this would only explain the result if such letter priming was non-linear across letter positions, since the advantage in the same identity condition is greater than would be expected from any simple linear accumulation of single letter priming.* Interestingly, numerous studies of word and letter string recognition indicate that the end letters are most informative for identification purposes (e.g., Bruner and O'Dowd, 1958; Merikle and Coltheart, 1972; Merikle and Glick, 1976). From this, it seems that non-linearity of priming across letter positions is likely, with priming being more effective when the end letters of the stimuli are the same (as in the same identity condition) than when the middle letters are the same (as in the graphemic and phonemic experimental conditions).

Experiment III

We have suggested that, in order to explain the same identity facilitation effect in Experiment II in terms of abstract letter priming, such priming must occur non-linearly across letter positions. In order to investigate this possibility more thoroughly, a third experiment was conducted in which graphemically similar primes and targets differed only in their middle letters while the end letters were the same. If end-position effects are important in producing abstract graphemic

* For instance, in the graphemic experimental condition primes and targets differed only by a single letter, and, over word pairs, there was a mean of 3·53 common letters. In the appropriate unrelated word control treatment, there was an average of 0·07 letters with the same identity in the same position in both stimuli. If each letter in common between the prime and target equally benefited performance, we may attribute $0{\cdot}29 \left(\frac{1}{3{\cdot}53 - 0{\cdot}07}\right)$ of the facilitation effect to each common letter. Accordingly, increasing the number of letters in common by one (in the same identity condition) should supplement the benefit to target recognition by 29%. In contrast, the same identity facilitation effect was larger by about a factor of two relative to the effects in the graphemic and phonemic experimental conditions.

priming, the graphemic priming effect in this study should approximate to the same identity effect.

Additionally, graphemic similarity in this study was manipulated both between word pairs and between nonword–word pairs. If the graphemic priming effect is due to the activation of abstract letter representations, it should remain regardless of whether the graphemically similar prime is a word or a nonword.

Method

The same experimental paradigm and equipment as in Experiment I were employed. The subjects were 20 undergraduates from the Psychology Department of Bristol University, who participated as an option on a course requirement. All subjects had normal or corrected-to-normal vision, and each took part in a single session lasting about 40 min. A set of 100 target words, five and six letters in length, were selected with word frequencies ranging between 18 and 808 words/million in the Kučera and Francis (1967) word frequency norms. Treatments were defined by the type of prime paired with the target. Each target item could be preceded by a stimulus which (a) had the same identity; (b) was a graphemically similar word; (c) was a graphemically different word; (d) was a graphemically similar nonword; or (e) was a graphemically different nonword. In the graphemically similar word treatment, the end letters of primes and targets were the same and 1 to 3 middle letters could be altered. Ascenders remained ascenders and descenders remained descenders. As far as possible in the graphemically different word treatment, all letters of primes and targets differed. Ascenders did not remain ascenders and descenders did not remain descenders. The two nonword treatments were formed by altering one letter of primes in the appropriate word-prime treatments to create orthographically regular, pronounceable nonwords (Venezky, 1970). Targets were divided into five groups of 20 each, which were balanced for word frequency and length. These were then combined with five groups of subjects using a latin square design.

Each subject received 100 experimental trials, with the order of presentation of the conditions randomised by computer. Subjects were asked to identify any words they thought were presented, and they responded by typing the word in on the computer keyboard. They were asked to type responses ordinarily if they thought the words were in upper case, and to precede responses by a "hash" symbol (#) if they thought the words were in lower case. Exposure durations for the experimental trials were again individually determined by a series of threshold trials during which unrelated nonwordprimes were employed. The mean duration of each field in the display was 43 ms, and a range between 36 ms and 54 ms was required over subjects.

Results

Mean correct target identification scores (%) are presented in Table III. The data were subjected to an analysis of variance for a mixed design, containing one between-subjects factor (groups) and one within-subjects factor (conditions). There was a statistically reliable effect of conditions ($F(4,15)=19{\cdot}17$, $P<0{\cdot}001$), but no effect for groups ($F(4,15)=1{\cdot}38$, $P>0{\cdot}05$) or for the conditions$\times$groups interaction ($F(16,60)=1{\cdot}56$, $P>0{\cdot}05$).

A Newman–Keuls analysis was used to investigate the precise differences between the conditions. There were reliable facilitation effects in the same identity condition relative to all the other treatments ($P<0{\cdot}01$), and in the graphemically similar conditions relative to the graphemically different conditions ($P<0{\cdot}01$).

Pooled over subjects, out of 400 similar word trials there were 13 (3·3%) correct

TABLE III

Mean correct target identifications (%) in Experiment III

Conditions		*Percentage* correct
Same identity	point – POINT	72·00
Graphemically similar word	while – WHITE	58·16
Graphemically different word	linen – WORLD	42·07
Graphemically similar nonword	stafe – STATE	59·18
Graphemically different nonword	unile – STILL	45·46

prime identifications. On none of these occasions was the target also correctly reported. In the different word condition, there were only 3 (0·8%) correct prime reports. Similarly to Experiments I and II, these results are below the guessing level. The small increase in prime reports in the similar word trials can be attributed either to transpositions of prime letters to targets, or to guesses based on partial target identification.

One subject reported seeing lower case letters in the displays. However, the words so designated were either targets, similar to targets, or differed from both prime and target, and seemed to be based on letter fragments in the mask. No other subject reported the presence of lower case letters. Since prime identification was minimal, we can conclude that the priming effects occurred automatically.

The target identification results show that performance in the graphemically similar and graphemically different conditions did not differ as a function of whether the prime was a word or a nonword. Given that word primes gain automatic access to the lexicon in the present paradigm (Experiment I), the latter effect indicates that lexical access can be achieved using a graphemic access route which operates independently of the lexical, as well as the visual, properties of the stimulus.

The graphemic priming results are consistent with those found in Experiment II. Although target recognition was facilitated when the prime had a high proportion of letters in common, graphemic priming was still inferior to same identity priming. Unlike the previous study, graphemically similar primes and targets differed only in the middle letter positions. It cannot be argued therefore that the extra facilitation in the same identity condition was due to the non-linearity of priming informative end-letter positions. An alternative possibility is that there is a further source of facilitation in the same identity condition. A likely candidate for this is semantic priming, as demonstrated in Experiment I.

General discussion

Three experiments examined case-independent priming effects using a four-field masking paradigm. Subjects were unable to use prime information intentionally since correct prime identifications were minimal, the presence of lower case words was not reported, and performance was not disrupted by inappropriate prime information. In this circumstance, priming should be limited to automatic activation effects between stimuli whose representations are semantically and/or structurally related (Posner, 1978).

In Experiment I, primes were shown to access their lexical representations, since a semantic facilitation effect was found (cf., Meyer and Schvaneveldt, 1971). Further, recognition of targets whose primes had the same identity was facilitated significantly more than that of semantically primed targets. This identity facilitation effect was not due to priming phonemic information, since phonemic similarity between primes and targets did not benefit performance over and above the facilitation from graphemic similarity between the pairs (Experiment II). The graphemic priming effect also occurred regardless of whether the prime was a word or a nonword (Experiment III). These results suggest that processing was facilitated by the activation of graphemic information that is abstract, in that letter identities are specified but not their visual format. Identity priming was still markedly superior to graphemic priming. It was proposed that the extra facilitation occurred because the target representation was activated semantically as well as structurally. This proposal is supported by the demonstration of semantic priming effects in Experiment I.

The most important conclusion to be drawn from this work is that automatic access to the internal lexicon can operate by the activation of abstract graphemic information. This occurs without influence of the phonemic properties of the stimulus. The coding of letter identity information in lexical memory independently of physical format would allow economy of representation, given the infinite variety of formats words can be presented in. Graphemic access to the same lexical entry could then occur irrespective of the physical characteristics of the stimulus on different occasions.

One model which fits closely with the present results is the logogen model of word recognition (Morton, 1969, 1970). In this model, detector mechanisms (logogens) accept evidence relevant to a particular word response from independent sensory and semantic inputs. For instance, they are activated when the appropriate structural information is present in the stimulus, and when the relevant word is preceded by a semantically appropriate context. Facilitatory priming effects occur when a prime which is structurally or semantically related to a target pre-activates the target logogen, thereby requiring less information from the target for a response to be made available. If logogens are activated by the presence of letters in specific positions irrespective of their visual format, case-independent graphemic priming will follow from the structural activation of the target representation by the prime. Such priming will depend solely on the number of letters in common between the stimuli, and will occur equally for word and for nonword primes. Further, it will combine with any effects of semantic priming, when the stimuli are also semantically related.

The notion of abstract graphemic recognition units is supported by a growing body of work on visual word processing. For example, Adams (1979) and McClelland (1976) have both observed word superiority effects (i.e., perceptual advantages for letter recognition in words over letter recognition in nonwords; for reviews, see Henderson, 1976; Krueger, 1975) for stimuli in mixed case types, which ought to disrupt the visual similarity of the stimuli. These findings suggest that letter recognition benefits from the availability of processing mechanisms in word perception which operate independently of visual format.

As well as evidence from skilled readers, clinical evidence from patients with acquired reading disorders is also consistent with the proposal. For example, Coltheart and Wyke (in Coltheart, 1980) report the case of a conduction aphasic who could correctly judge that visually dissimilar, different case nonwords had the same identity (e.g., GREN/gren) even though he could not match stimuli on the basis of their phonemic relationship (i.e., he was equally likely to say that "no" and "new" had the same pronunciation as he was to say that "so" and "sew" had the same pronunciation). Since the former judgment could not have been made using either a semantic code or by making a direct visual match, and since, because of this patient's disability, it could not have been based on a phonemic code, it seems that matching was performed by means of abstract graphemic information.

However, the theory must still explain the essentially veridical nature of word perception (Neisser, 1976). For instance, how do we perceive words as differing in format if lexical access is based on the activation of abstract graphemic information? One possibility is that lexical information is integrated with physical information to provide a coherent, veridical percept (Allport, 1977). This proposition has a number of attractive features. For example, at a descriptive level, it can explain why word recognition involves concurrent knowledge of a word's meaning and of its particular physical appearance, since integration takes place following lexical access. It also concurs with recent work on central visual masking. If central masking disrupts the physical code used in integration, identification of the masked stimulus will be impaired, while the activation of codes in other processing domains (lexical, semantic, etc.) will be unaffected. Consequently, semantic priming effects can occur when primes are centrally masked so that subjects are not aware of their physical components (Marcel, in press). Indeed, it appears that the activation of a lexical code is not sufficient for word recognition, but that lexical information must be integrated with physical information for this to occur.

An interesting observation in this respect is that, under data-limited conditions, subjects quite often report words presented in unfamiliar or unexpected typefaces as being in familiar but non-corresponding format. For instance, in the present studies, subjects occasionally inserted upper case versions of lower case prime letters in their responses to targets (when transposition errors were made). This was so even where the letters involved differed significantly in form in their lower and upper case versions (e.g., as in the response STRING to the prime-target pair yoing – STRIPE). Similarly, other workers have noted that observers may identify briefly presented mixed case words as being in regular block type (e.g., Adams, 1979; Coltheart and Freeman, 1974; McClelland, 1976; Pillsbury, 1897). This suggests that a familiar or expected physical code could be used in perceptual integration when the recovery of the original code is limited by the presentation conditions. More research into this phenomenon is recommended in order to gain a fuller understanding of the integration process and its importance in reading.

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Appendix

Materials for Experiment I

Targets	Associates	Nonassociates	Targets	Associates	Nonassociates
SWEET	bitter	notice	BIRD	robin	class
BUTTER	bread	class	DAGGER	cloak	tray
SMOOTH	rough	court	LIGHT	dark	card
SHORT	long	card	HORSE	pony	pool
SOFT	hard	tray	WHITE	black	court
CHAIR	table	weeds	FAST	slow	book
SAND	dune	book	FISH	tuna	mind
SEEDS	poppy	ruler	PLANE	pilot	weeds
CATS	dogs	pool	SLEEP	dream	ruler
TREE	forest	violin	FEAR	afraid	violin
NEVER	always	tartan	ROUND	square	tartan
COLD	frost	point	NAIL	hammer	wander
PEPPER	salt	post	WATER	bath	peel
UNDER	over	peel	STING	wasp	mask
THREAD	needle	wander	FACE	nose	post
TAKE	give	mask	GRASS	green	point
APPLE	fruit	dress	CHURCH	priest	bridge
BAND	brass	field	FLOOR	carpet	notice
STARS	moon	mind	MOTHER	child	field
NURSE	doctor	bridge	LAMB	sheep	dress

Targets	Same identity	Nonword	Targets	Same identity	Nonword
TOWN	town	thock	FOOD	food	thock
STOP	stop	aheed	LOUD	loud	aheed
QUEEN	queen	thip	GLASS	glass	thip
SMOKE	smoke	deet	CLEAN	clean	deet
FORK	fork	blad	GIRL	girl	blad
THERE	there	femble	HOUSE	house	femble
FLOWER	flower	kerp	SHOW	show	kerp
PEACE	peace	puglic	HAIR	hair	puglic
HILL	hill	rame	HAPPY	happy	rame
SAILOR	sailor	guld	WOMAN	woman	guld
TIGER	tiger	lork	WOOL	wool	lork
GARDEN	garden	palt	TALL	tall	palt
DRINK	drink	oren	ARMY	army	oren
FOOT	foot	ditt	ROAD	road	ditt
WINDOW	window	nethew	SOUND	sound	nethew
SNOW	snow	nost	HEALTH	health	nost
UGLY	ugly	wasm	MOTH	moth	wasm
DOOR	door	yoing	STRIPE	stripe	yoing
SONG	song	wilk	PENCIL	pencil	wilk
ORDER	order	absert	BACON	bacon	absert

Materials for Experiment II

Targets	"N"	Same identity	Unrelated	Targets	"N"	Same identity	Unrelated
Same identity pairs and controls							
MINE	22	mine	just	CULT	3	cult	vine
BUSY	3	busy	wife	MOON	10	moon	wife
SHIP	3	ship	vine	TIDE	10	tide	just
HINT	5	hint	game	KNOW	4	know	game
DIRT	3	dirt	fear	RUIN	1	ruin	like
IRON	0	iron	like	MOLE	17	mole	fear
HAND	9	hand	city	HOPE	13	hope	city
NAME	6	name	hawk	ENVY	0	envy	bath
SIZE	3	size	bath	DRIP	3	drip	rose
RING	9	ring	mist	TOIL	6	toil	hawk
SLOW	12	slow	rose	WORK	6	work	mist
DAWN	3	dawn	song	REAL	12	real	song
STAND	1	stand	white	KNOCK	1	knock	white
SOUND	7	sound	nurse	WIDEN	2	widen	nurse
TRICK	7	trick	plane	MOTOR	1	motor	plane
CHALK	0	chalk	froze	POWER	6	power	froze
CRASH	5	crash	equip	THORN	1	thorn	equip
WITCH	5	witch	abide	TRUCK	3	truck	abide
BROAD	2	broad	sheep	GUIDE	2	guide	sheep
PLACE	3	place	tight	CREST	2	crest	tight
DRIFT	1	drift	shark	HOTEL	2	hotel	shark
CLOCK	8	clock	putty	WAIST	2	waist	putty
GRADE	7	grade	cried	SPINE	7	spine	cried
SCENE	3	scene	shame	DAISY	2	daisy	shame
POND	3	pond	tree	BOOT	13	boot	tree
BARN	13	barn	lash	SEAT	17	seat	lash
SNOB	2	snob	inch	SUCK	15	suck	inch
HOOK	11	hook	axle	FOND	9	fond	axle
DIET	4	diet	brag	NECK	4	neck	brag
GARDEN	1	garden	report	POCKET	3	pocket	report
M	5·37				5·90		

Phonemically and graphemically similar pairs and controls

Targets	"N"	Phonemically similar	"N"	Unrelated
TILE	9	file	8	soft
LOFT	3	soft	3	file
DUMB	1	numb	1	coil
BOIL	4	coil	6	numb
DREAM	3	cream	2	blame
FLAME	3	blame	3	cream
PINK	10	mink	11	rung
SUNG	9	rung	9	mink
WILL	12	hill	12	much
SUCH	1	much	2	hill
WADE	9	made	9	dish
WISH	4	dish	3	made
FIELD	1	yield	1	porch
LARGE	1	barge	1	point
SAIL	11	fail	10	load
TOAD	1	load	2	fail
DITCH	4	pitch	8	might
TIGHT	5	might	5	pitch
JOINT	2	point	2	barge
FLEA	1	plea	1	prim
GRIM	6	prim	5	plea
PAST	7	vast	6	deal
SEAL	9	deal	11	vast
TRACE	3	grace	4	guilt
BUILT	2	guilt	3	grace
WILT	5	tilt	6	mark
BLOT	3	clot	4	zero
DARK	9	mark	8	tilt
TORCH	1	porch	3	yield
HERO	2	zero	1	clot
M	4·70		5·03	

Columns headed "N" give the number of different English words which can be generated by changing one letter to another letter, preserving letter positions, in targets and paired experimental words.

Graphemically similar, phonemically different pairs and controls

Targets	"N"	Graphemically similar primes	"N"	Percentage contour overlap	Percentage feature overlap	Unrelated primes	Percentage contour overlap	Percentage feature overlap
SOME	6	home	6	18·1	44·8	jury	14·5	33·3
CAVE	13	have	9	16·4	44·0	tomb	6·9	23·3
WATCH	7	catch	6	16·0	49·6	horse	9·0	31·0
WORSE	3	horse	4	17·3	55·6	catch	9·1	29·6
BOMB	3	tomb	4	21·2	57·0	have	11·4	25·8
BURY	4	jury	2	19·3	58·7	home	18·7	30·6
SAID	4	paid	5	18·9	52·4	lost	4·4	17·0
MOST	8	lost	9	16·3	73·9	paid	7·2	27·9
WIVES	12	gives	8	22·4	65·8	nasty	5·8	26·6
WEAR	11	dear	14	13·2	31·1	golf	8·9	22·0
SOUTH	3	youth	3	23·3	64·5	grown	14·1	32·7
CROWN	5	grown	7	25·6	67·4	youth	12·3	30·5
PINT	9	mint	8	24·4	70·7	nose	7·8	19·8
TOLL	11	doll	8	9·9	64·4	crow	4·3	10·8
SOUL	2	foul	3	19·6	59·3	gasp	12·7	31·9
BROW	5	crow	5	23·9	65·6	doll	8·7	16·0
WASP	1	gasp	1	13·8	48·3	foul	9·7	20·5
PROVE	4	drove	6	20·6	62·2	diver	7·1	27·8
LIVER	8	diver	8	21·6	59·8	drove	4·9	25·4
HEARD	3	beard	3	15·6	34·6	patio	8·9	30·7
GONE	5	bone	9	19·8	57·1	wash	8·7	15·9
RANGER	7	hanger	5	18·4	42·9	nature	13·7	37·5
LOSE	1	nose	10	17·3	61·8	mint	5·9	15·3
RATIO	1	patio	1	21·5	71·8	beard	8·5	33·0
WOLF	1	golf	2	11·8	57·3	dear	8·8	22·0
MATURE	1	nature	1	18·9	55·0	hanger	15·2	36·9
HASTY	2	nasty	1	19·1	61·4	gives	6·1	26·9
CASH	10	wash	8	15·3	44·0	bone	9·6	19·9
TOUCH	1	couch	1	24·6	67·0	clown	12·5	20·6
FLOWN	3	clown	2	19·9	59·6	couch	13·0	20·6
M	5·23		5·30	18·80	56·92		9·61	25·39

Materials for Experiment III

Targets	Same identity	Similar word	Different word	Similar nonword	Different nonword
BLACK	black	blank	stars	blauk	sters
BOUND	bound	board	plate	boerd	plabe
BREAD	bread	brand	slide	brond	slede
BREAK	break	brink	charm	bronk	chorm
BRICK	brick	brisk	slate	brask	slafe
BROAD	broad	breed	grime	brend	grome
BROWN	brown	brain	least	broin	foast
CHAIR	chair	cheer	brave	cheor	brove
CHEAP	cheap	chimp	water	chisp	waber
CHEEK	cheek	chick	grain	chack	grarn
CHEST	chest	chart	onion	chort	opion
CLAIM	claim	chasm	jaunt	chosm	jarnt
CLOSE	close	chase	wheat	chise	whert
COAST	coast	court	jelly	coert	jeffy
COUNT	count	crest	whale	creot	whabe
CRIME	crime	crave	skirt	crove	skart
FLOOR	floor	flair	glory	fluar	glony
FRUIT	fruit	front	under	fremt	urder
GRAND	grand	guard	photo	guand	pholo
GREEN	green	groan	towel	groon	tonel
GUEST	guest	grant	value	grent	vanue
JOINT	joint	joust	flash	jaust	flosh
MODEL	model	metal	river	mebal	riner
NURSE	nurse	nerve	canal	norve	caval
PAUSE	pause	parse	scold	parne	sceld
PEACE	peace	prone	flood	prome	flond
PENNY	penny	peony	trace	peeny	trame
PHONE	phone	place	ocean	plice	onean
PLANE	plane	plume	adult	plime	adurt
PLANT	plant	pleat	cover	plent	coner
POINT	point	paint	gravy	pairt	grany
PORCH	porch	peach	verge	peash	vorge
PRICE	price	prose	visit	prese	vimit
PRIZE	prize	prime	shell	prine	stell
PUPIL	pupil	papal	blend	payal	blerd
QUICK	quick	quirk	class	quock	closs
QUIET	quiet	quest	sauce	quist	sarce
RANCH	ranch	reach	eager	reash	eaper
RAPID	rapid	rigid	apple	ragid	appte
SERVE	serve	sieve	clock	seeve	closk
SHARP	sharp	stamp	digit	starp	dipit
SHEET	sheet	stoat	belly	stort	bolly
SHIRT	shirt	shoot	verse	stoot	verme
SHOCK	shock	shirk	empty	shink	emply
SHARE	share	shame	think	shime	thirk
SHORE	shore	start	paper	stant	poper
SKILL	skill	stall	tiger	stull	tager
SLAVE	slave	stove	earth	stive	eanth
SMILE	smile	smite	habit	smife	halit
SNAKE	snake	smoke	phial	smike	plisl

Targets	Same identity	Similar word	Different word	Similar nonword	Different nonword
SPARE	spare	spine	child	spone	chald
SPEAK	speak	spark	grass	sperk	gress
STAGE	stage	shape	drink	shope	drenk
STATE	state	stale	brush	stafe	bresh
STILL	still	skull	unite	skall	unile
STONE	stone	stare	girth	stive	ginth
STORM	storm	steam	pound	sheam	paund
SWEET	sweet	sweat	happy	swent	heppy
TEACH	teach	torch	allow	tonch	altow
TOOTH	tooth	tenth	cabin	terth	catin
TRAIL	trail	trawl	party	trewl	parby
TRUTH	truth	teeth	storm	treth	starm
WHITE	white	while	sound	whibe	sornd
WOMAN	woman	woven	shelf	woren	shalf
WORLD	world	wield	linen	wirld	lanen
BULLET	bullet	buffet	ponder	poffet	porder
CANDLE	candle	castle	flower	cantle	flomer
CHANGE	change	charge	forest	charpe	fonest
DINNER	dinner	dancer	sandal	doncer	sardal
DOCTOR	doctor	dealer	combat	deater	corbat
FACTOR	factor	faster	shield	fanter	shirld
FAIRLY	fairly	family	record	farily	renord
HANDLE	handle	hackle	ballet	haskle	bollet
JUNGLE	jungle	jingle	gather	jongle	gatter
LAWYER	lawyer	longer	desire	langer	denire
LEADER	leader	louder	circle	londer	cincle
LOVELY	lovely	lamely	market	larely	marlet
LITTER	litter	lather	church	lother	charch
MARBLE	marble	mantle	asleep	mastle	asteep
MONDAY	monday	monkey	fleece	moskey	flerce
NUMBER	number	neater	friend	nerter	freend
PALACE	palace	police	budget	potice	badget
PATROL	patrol	petrol	farmer	putrol	farner
POCKET	pocket	packet	bridge	pecket	bredge
RATHER	rather	rafter	planet	ralter	plaret
REASON	reason	raisin	trance	raimin	tronce
RESULT	result	revolt	bother	remolt	botter
SAMPLE	sample	simple	carrot	semple	carnot
SOURCE	source	scarce	basket	scance	banket
SPIRIT	spirit	sprint	weight	spront	werght
SQUARE	square	squire	thirst	squore	tharst
STRONG	strong	string	orange	streng	orenge
SUDDEN	sudden	silken	couple	salken	corple
SUFFER	suffer	softer	decide	sotter	demide
SWITCH	switch	snatch	tennis	snotch	ternis
TESTED	tested	tinted	silver	tanted	selver
TIMBER	timber	tinder	resist	tinfer	remist
TREATY	treaty	twenty	profit	twerty	prolit
WANTED	wanted	washed	cradle	wasled	crodle
WONDER	wonder	winter	bottle	wenter	buttle

See text for a description of how the items were combined for each experiment.

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