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Preliminary Letter Identification in the Perception of Words and Nonwords

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Words with mixed uppercase and lowercase letters (e.g., fAdE) were perceived more accurately than mixed-case pseudowords (e.g., gAdE), and mixed-case pseudowords were perceived more accurately than mixed-case unrelated letter strings (e.g., eFdT). In addition, same-case words were perceived more accurately than their mixed-case counterparts. The same held true for pseudowords but not for unrelated letter strings. The results are compatible with the view that both letter identity and visual form information are used in word perception.

Does word recognition involve preliminary letter identification? Ever since Cattell (1885) showed that subjects could report words from presentations too brief for reports of all the letters in equally long nonwords, the answer has appeared to be no. Students of the reading process from Cattell himself to Neisser (1967) and Smith (1971) have argued that letter identification could hardly mediate word recognition if a word is recognizable under conditions in which all the letters in a sequence as long as the word are not.

Cattell's word superiority effect does seem to rule out the possibility that word recognition is mediated by a sequential letter recognition process which must be completed before word identification can begin (cf. Johnson, 1975). However, the word superiority effect is compatible with a parallel letter identification process (itself based on parallel feature analysis) which need not letter identification process which need not necessarily be complete or conclusive before word identification can take place. To see this, consider what might happen if a subject viewed a presentation of the word READ that was too brief or too degraded to permit complete extraction of visual feature information. Preliminary letter analysis might still determine that only R or P were possible in the first position, E or F in the second, A or H in the third, and D or B in the fourth. Since READ is the only word compatible with one of the available possibilities in each position, the word could be correctly identified from the results of the letter analysis process, even though only about half the letters would be identified correctly if considered separately.

A word recognition process based on preliminary letter identification would also give words an advantage over nonwords if identified letters were subject to loss unless a word was recognized from the letters (Huey, 1908). For example, a translation of the results of preliminary letter identification into an accessible form might require sequential processing of each recognized unit (cf. Sperling, 1967) and hence might not always be complete before letter identity information began to decay. If word recognition occurred before this transfer proc-

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ess, a word could be transferred as a single unit before decay set in.

Under conditions of poststimulus patterned masking, there is a third way word superiority effects could be obtained. Under these patterned-mask conditions, we assume that letter analyzers read the feature information present in the patterned mask as well as the feature information present in the stimulus. Thus, letter identity information established by the stimulus will be subject to disruption by the mask. By hypothesis, the letter analyzers are interposed between the feature analyzers and the word analyzers, so any information that passes the letter level and establishes a pattern of activity at the word level will be relatively safe from the mask's disruptive effects. Hence, we expect superior retention of information about the letters in a word than about the letters in a nonword or even about a single letter alone.

This last account makes a preliminary letter identification model compatible with forced-choice superiority of words over nonwords and single letters (Johnston & McClelland, 1973; Reicher, 1969; Smith & Haviland, 1972; Wheeler, 1970). It is worth noting that this account depends on the patterned mask. Without it, there would be nothing to disrupt letter identity information and no reason to suppose that a word advantage over single letters should be obtained. In accord with this reasoning, two investigations report no advantage when a blank post-exposure field is used (Johnston & McClelland, 1973; Juola, Leavitt, & Choe, 1974).

This paper reports some experimental evidence on the viability of the preliminary letter recognition hypothesis. If word perception is mediated by preliminary letter identification, accurate word perception should depend on the familiarity of the arrangement of the letters in a word and not the familiarity of the visual configuration of the word. It follows that the word superiority effect should still be obtained with words presented in mixed uppercase and lowercase type; mixing cases would disrupt the visual configuration but would not change the arrangement of letters.

Thus far, we have treated the word superiority effect as though it were a single effect. In fact, it appears that the effect can be divided into a *word familiarity effect* and an *orthographic structure effect*. Effects apparently due to the familiarity of the stimulus as an actual English word have been reported by several investigators. Manelis (1974), Juola, Leavitt, and Choe (1974), and Spoehr and Smith (1975, Experiment 1) found that words have a forced-choice advantage over matched orthographically regular pseudowords (e.g., BUNE). Failures to obtain this effect have been reported (Baron & Thurston, 1973; Spoehr & Smith, 1975, Experiment 2), but there do not appear to be compelling reasons to suppose that the effect is artifactual when it is obtained. The orthographic structure effect has also been reported several times. Baron and Thurston (1973), Spoehr and Smith (1975), and many others have found that pseudowords have a forced-choice advantage over unrelated letter strings which violate the orthographic structure of English.

The present experiment tested tachistoscopic perception of mixed case words, pseudowords, and unrelated letter strings. If preliminary letter identification plays a role in both of the superiority effects, they should be obtained in stimuli presented in mixed-case type.

The preliminary letter identification hypothesis would lead us to expect no advantage for same- over mixed-case stimuli. However, there is evidence that same-case stimuli are easier to perceive than their mixed-case counterparts. Smith (1969) and Smith, Lott, and Cronnel (1969) found that subjects read prose passages presented in mixed cases more slowly than all uppercase passages (see also Fisher, 1975). It can be argued that alternating letters of different sizes (as in RaGe) disrupts preliminary letter identification. However, Coltheart and Freeman (1974) reduced their uppercase letters to the height of lowercase letters such as *a*, *e*, and *c*, and still found that word identification was impaired by mixing cases. Even with these data, it remains possible that it is the letter identification process and not the process of word identification per se that is disrupted by mixing cases. For example, decisions about letter identity may be based in part on relative size; if so, the T in FdTg would have one strike against it and might be identified erroneously as an r.

If mixing cases interferes with letter identification and not with word recognition, any difference between same- and mixed-case words should extend to both pseudowords and unrelated letter strings as well. The present experiment tested this prediction by including both same- and mixed-case stimuli in all three lexical categories.

To assess tachistoscopic perception of same- and mixed-case stimuli, free reports of all four letters presented were obtained in addition to forced choices following the Reicher (1969) procedure. Inclusion of free reports does not appear to have much effect on forced-choice performance and permits assessment of the probability of reporting an item completely correctly, providing a more sensitive index of actual word recognition than forced choice on just one letter (McClelland & Johnston, Note 2). The free reports also permit separate assessment of the effects of the nature of the stimulus on arrangement of letters (probability of reporting letters in the correct position) and correct identification independent of arrangement (probability of correct report regardless of position).

The experiment also assessed the nature of representations of briefly presented letter strings. According to the preliminary letter identification approach, representations of briefly presented words might specify the identity of the letters presented without specifying their actual form. If the representations specify the form of the stimulus, subjects should be able to report whether an item is uppercase, lowercase, or mixed whenever they can report all of the letters. However, if the representations only specify letter identity, case reports would not necessarily be correct, even with identification of all four letters. To obtain evidence on this issue, subjects gave case reports between free reports and forced choices.

Experiment 1

Method

Design

The experiment used 576 separate test stimuli. There were 48 four-letter word, pseudoword, and unrelated letter items. Each item came in four different calligraphies, two same-case (all uppercase or all lowercase) and two mixed-case (upper-lower-upper-lower or lower-upper-lower-upper). Stimuli were blocked by lexical category and randomized with respect to calligraphy.

The 48 items in each lexical category were made up in pairs differing by a single letter (e.g., FARE–FADE). The differing letter is the one tested in the forced choice (see dependent measures section) and is called the critical letter. Within each category, six pairs had the critical letter in each position. Each word pair was matched to a pseudoword pair and an unrelated letter pair with the same critical letters in the same position (e.g., matched to FARE–FADE were GARE–GADE and EFRT–EFDT).

The stimuli were sorted into four 144-stimulus lists. Each list contained one same- and one mixed-case stimulus from each pair with three stimuli at each joint level of lexical category, calligraphy, and critical letter position. The two stimuli from half of the pairs were exemplars of the same item and were exemplars of the two different items from the remaining pairs. The 48 stimuli from each lexical category formed two 24-trial blocks containing one token of each pair of items, six in each of the four calligraphies. The six blocks were arranged into two cycles containing one block from each lexical category. Twelve subjects received each of the four lists. Order of cycles within the list was crossed with the six permutations of lexical categories within cycles to give a different sequence of blocks for each subject receiving each list.

Stimuli

Calligraphic properties. All of the items were made up only of the letters A, B, D, E, F, G, H, N, R, and T. These letters were selected because their upper- and lowercase versions were different in form. The Prestype fonts used were 10-point Futura Bold for the uppercase letters, 12-point Eurostyle Medium for lowercase *f*, *r*, and *t*, and 14-point Helvetica Medium for the remaining lowercase letters. The cast of characters and some example stimuli are presented in Figure 1.

Lexical and orthographic properties. All of the items in the word category were monosyllabic words familiar to the author (see McClelland, Note 1, for list), and all occurred at least once in the Lorge magazine count (Thorndike & Lorge, 1944) with the exception of TEND. All of the items in the pseudoword category were pronounceable monosyllables judged by the author to be accept-

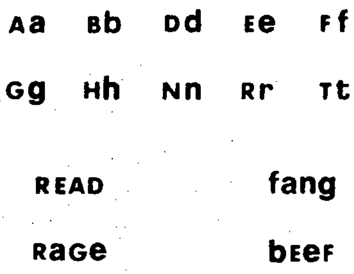

FIGURE 1. The characters used in the experiments and some example stimuli.

able candidates for words if a new word were needed. Only one, the archaic word BATE, occurred in the Lorge magazine count. Three undergraduates read through the list of pseudowords and confirmed that they were not familiar with any of the items on the list, and they agreed that the items were candidates for words. The word and pseudoword stimuli were matched for position specific and word length specific single letter and bigram frequency, as indexed by a token count for letters and bigrams in words occurring in running text (Mayzner & Tresselt, 1965). To match these orthographic properties it was necessary to allow individual letters to occur more or less frequently (plus or minus at most two occurrences) in each of the two categories.

The unrelated letter items were all judged not to be candidates for words by the author, and three undergraduates read through the list and agreed with this assessment. Furthermore, all unrelated letter items were unpronounceable according to common spelling-to-sound correspondence rules (Venesky, 1970). The 10 different letters occurred the same number of times in the unrelated letter items as in the pseudowords.

Visual Conditions

The visual conditions were the same as the patterned mask conditions of Johnston and McClelland (1973) and several other studies of these investigators. The only difference was that the letters used in the present study had a wider stroke (cf. Figure 1). Each 1.4° stimulus was preceded and followed by a black-on-white mask consisting of a 1.9° by 3.2° pattern of jagged and wavy lines, with a grid indicating the location of the stimulus display. Subjects had to look outside the apparatus to view the choice alternatives.

Subjects

The design called for 48 subjects. To avoid floor and ceiling effects, a subject's results were discarded if he averaged more than 60% or less than 40% correct in correct-position scoring of free reports. Due to the stringency of the criterion, 64 subjects were required. All were University of Pennsylvania undergraduates, and all received $3 for participating in the 2-hour experiment.

Dependent Measures

After each stimulus presentation, the subject gave a free report, a case report, and a forced-choice response. For the free reports, the subject was instructed to report four and only four letters which best characterized what he had seen. He was told not to force his reports to be items of the type expected; for example, he was told he did not have to report four letters which made a word on trials in word blocks. Immediately after the free report, the subject gave a case report. The options for the case report were "upper," "lower," and "mixed." "Unsure" was permitted when the subject felt he had no idea of the correct response. Five seconds after the stimulus presentation, a click signaled the subject to look out at the forced-choice alternatives. The alternatives were the critical letter from the stimulus and the critical letter from the other member of the pair, with dashes indicating the position being tested. For example, for the stimuli BAND and BEND, the choice alternatives were –A–– and –E––. A forced-choice response was required on every trial. No feedback was given.

Practice

The experiment began with 120 practice stimuli, divided into two cycles of three 20-trial blocks, one block from each lexical category per cycle. Practice blocks were presented in the same order as test blocks. Exposure durations were adjusted during practice to find a duration at which the subject could report 50% of the letters correctly in the correct position.

To ensure that the subjects had some practice viewing all of the letters to be used in the test stimuli but no practice viewing any mixed-case combinations of these letters, all of the letters used in the test stimuli occurred in some practice items, but at most one of these letters occurred in any given item.

Results

Case Reports

The probability of correctly identifying the form of the stimulus as upper-, lower-, or mixed-case averaged only .39 over the whole experiment. Even when all four letters were reported correctly, the probability of correct case report was only .52 (see Table 1).

There was a strong bias to report the item shown as one of the two same-case

TABLE 1

Proportion of Upper, Lower, Mixed, and Unsure Responses Given Completely Correct Free Report

Stimulus	Response				*n*
	Upper	Lower	Mixed	Unsure	
Words					
Same-upper	*.68*	.09	.16	.06	315
Same-lower	.03	*.75*	.18	.04	307
Mixed-ULUL	.29	.34	*.30*	.08	247
Mixed-LULU	.13	.49	*.31*	.07	212
Pseudowords					
Same-upper	*.64*	.09	.16	.10	140
Same-lower	.03	*.68*	.16	.14	139
Mixed-ULUL	.25	.23	*.42*	.10	79
Mixed-LULU	.12	.50	*.35*	.03	58
Unrelated letters					
Same-upper	*.68*	.07	.16	.10	32
Same-lower	.00	*.63*	.22	.15	27
Mixed-ULUL	.28	.33	*.22*	.17	18
Mixed-LULU	.00	.45	*.35*	.20	20

Note. Proportions of correct responses are italicized (U = uppercase; L = lowercase).

forms, but even within the same-case items, the probability that the form would be identified correctly was only about .70. This pattern held up over all three material types.

Free Reports

The probabilities of completely correct report, of reporting letters in the correct position, and of reporting letters correctly regardless of position are all presented in Table 2. Inspection reveals that mixed words had an advantage over mixed pseudowords, and mixed pseudowords had an advantage over mixed unrelated letters by all three measures. Same-case words and pseudowords had an advantage over their mixed counterparts by all three measures. In unrelated letters, a same–mixed difference only appeared in free reports scored regardless of position.

The results obtained by each method of scoring were subjected to analyses of variance over subjects (subjects [random] × lexical category × case) and over items

TABLE 2

Free Report Results, Experiment 1

Stimulus	Lexical category		
	Word	Pseudoword	Unrelated letter
Probability of completely correct report			
Same-case	.533	.237	.032
Mixed-case	.391	.114	.021
Probability of reporting letters in the correct position			
Same-case	.714	.566	.308
Mixed-case	.641	.471	.287
Probability of reporting letters regardless of position			
Same-case	.770	.650	.507
Mixed-case	.716	.571	.473

(items [random] within lexical category × case). The results of the analyses were pooled following Clark (1973).

Only words and pseudowords were included in the analysis of probability of reporting items completely correctly. Highly reliable main effects of lexical category, $\min F'(1, 140) = 120.48$, $p < .001$, and case, $\min F'(1, 127) = 53.50$, $p < .001$, emerged. However, there was no hint of an interaction, $\min F'(1, 107) = .21$, $p > .5$.

The analysis of probability of reporting letters correctly in the correct position included all three lexical categories. The effects of lexical category, $\min F'(2, 235) = 178.33$, $p < .001$, and case, $\min F'(1, 129) = 24.81$, $p < .001$, were highly reliable, as was the smaller interaction, $\min F'(2, 223) = 3.94$, $p < .025$. The six cell means were compared using Tukey's test, with the critical range adjusted so that the probability that any one of the possible comparisons between the six cell means would exceed the critical range by chance was .05 (Keppel, 1973, p. 245). The word—pseudoword and pseudoword—unrelated letter differences exceeded the critical range in both same and mixed stimuli, using either subject or item error terms. The same–mixed difference was reliable in words and pseudowords. The minuscule difference in the unrelated letter category did reach significance in a one-tailed t test over items, $t_D(47) = 2.13$, $p < .05$, but was marginal over subjects, $t_D(47) = 1.59$, $.1 < p < .05$.

Analysis of free reports scored regardless of position revealed effects of lexical category, $\min F'(2, 233) = 117.24$, $p < .001$, and case, $\min F'(1, 128) = 32.03$, $p < .001$. The interaction was marginal, $\min F'(2, 234) = 2.17$, $p = .12$. Tukey's test revealed that the differences between lexical categories were all reliable in same and mixed stimuli, and the advantage of same over mixed showed up in all three lexical categories.

Differences between calligraphies within same and mixed stimuli. No differences were found between all uppercase and all lowercase stimuli. Table 3 presents the results for the correct position scoring of free reports (the pattern of results was similar for the other measures as well). An effect of lexical category emerged, $\min F'(2, 232) = 129.19$, $p < .001$, but no main effect of upper versus lower, $\min F'(1, 218) = .22$, $p > .5$, or of the interaction, $\min F'(2, 232) = .88$, $p = .42$, was obtained.

TABLE 3

MEAN PROBABILITY OF CORRECT POSITION FREE REPORTS, BROKEN DOWN BY VERSION WITHIN SAME- AND MIXED-CASE STIMULI, FOR EXPERIMENT 1

	Lexical category		
Stimulus	Word	Pseudo-word	Unrelated letter
Same-case			
Upper (U)	.722	.563	.290
Lower (L)	.706	.569	.326
Mixed-case			
ULUL	.672	.493	.285
LULU	.609	.449	.289

Within the mixed stimuli, items beginning in uppercase had an advantage over items beginning in lowercase. Analyses of variance revealed reliable lexical category, $\min F'(2, 234) = 118.77$, $p < .001$, and version, $\min F'(2, 234) = 4.63$, $p < .025$, effects. The interaction, $\min F'(2, 235) = 1.47$, $p = .23$, escaped reliability.

Forced-Choice Results

The pattern of forced-choice results (see Table 4) matched the pattern of free report results in all major respects except one: The difference between mixed pseudowords and unrelated letters was small and of dubious reliability. Analyses of variance treating the critical letter pairs as the units of analysis (critical letter pairs [random] × lexical category × case) and treating sub-

TABLE 4

FORCED-CHOICE RESULTS FOR EXPERIMENT 1

	Lexical category		
Stimulus	Word	Pseudo-word	Unrelated letter
Same-case	.846	.779	.694
Mixed-case	.802	.726	.694

jects as the units (subjects [random] × lexical category × case) were combined as before. The effects of lexical category, $\min F'(2, 113) = 20.63$, $p < .001$, and case, $\min F'(1, 118) = 5.36$, $p < .025$, were reliable, but the interaction, $\min F'(2, 136) = 1.70$, $p = .19$, was not. The differences between lexical categories were reliable for same-case stimuli, and the word–pseudoword difference was reliable for mixed-case stimuli using Tukey's test with either subject or critical-letter-pair error terms. The 3.2% difference between mixed pseudowords and unrelated letters only tottered on the edge of significance in one-tailed t tests over critical letter pairs, $t_D(23) = 1.72$, $p < .05$, and subjects, $t_D(47) = 1.79$, $p < .05$.

Discussion

Experiment 1 has demonstrated that the disruptive effect of mixing cases in word stimuli, previously reported by Coltheart and Freeman (1974) can be extended to pseudowords but not to unrelated letters. This finding suggests that it is neither word identification per se nor preliminary letter identification which is disrupted by mixing cases but some stage or aspect of processing which words and pseudowords share. Just what this might be will be considered in the general discussion below.

Perhaps more importantly, from a preliminary letter identification point of view, the experiment has demonstrated that the word familiarity effect previously obtained in same-case stimuli can be obtained with mixed case stimuli as well. The effect was about the same magnitude in mixed-case stimuli as in same-case stimuli, by four dependent measures. The results suggest, therefore, that the identity of the letters in a stimulus is the primary determinant of the word familiarity effect.

Experiment 1 does not clearly demonstrate that the orthographic structure effect can be obtained with mixed-case stimuli. Although large pseudoword-unrelated letter differences were obtained in free reports, the difference was small and of dubious reliability in the forced choice. Further analysis revealed a possible reason for this discrepancy. In unrelated letter strings, letters occurring in orthographically regular positions had a reliable advantage over letters occurring in irregular positions (see McClelland, Note 1, for details). Because the same critical letters were kept in the same positions in all three material types, the critical letter always occurred in an orthographically regular position. To make the unrelated letter strings irregular, the context letters were usually placed in positions which were irregular. Hence, the small size of the orthographic structure effect obtained in forced choices may simply reflect failure to tap the extremes of orthographic structure, especially for the critical letter. It therefore seemed likely that the orthographic structure effect could be obtained in mixed-case stimuli if the extremes of orthographic structure were sampled.

Experiment 2

Experiment 2 tests the conclusion just reached by comparing forced-choice performance on pseudowords and unrelated letter strings constructed to differ as widely as possible in the extent of their conformity to several different aspects of English orthography, including position-specific letter frequency of the critical letter.

The design of Experiment 2 permits us to eliminate two possible difficulties with Experiment 1. First, it is possible that the free reports and case reports and the accompanying delay of testing introduced retention problems which would not have been operative with more immediate testing. This possibility seems remote since McClelland and Johnston (Note 2) did not obtain any support for this possibility in an explicit test. To remove any remaining doubt, the subject's only task in Experiment 2 was to make a forced-choice response to each stimulus. There was a delay of 1 to 2 seconds, in the range found to be optimal by Wheeler (1970). Second, in Experiment 1, stimuli were blocked by lexical category. It is conceivable that the small difference between mixed-case pseudowords and unrelated letters was due to reduced motivation with unrelated letters because they were more difficult than the other material types. To preclude this possibility, pseudoword and unrelated letter stimuli were mixed within the same block.

Method

Design

A total of 192 different test stimuli were used. Forty-eight pseudoword and 48 unrelated letter items were constructed in pairs differing by a single letter such that six pairs in each category had the critical letter in each position (see stimuli). There was one same- and one mixed-case version of each item. The mixed version was always lower-upper-lower-upper because this is less like familiar visual configurations than upper-lower-upper-lower. The same-case version was in the case of the critical letter in the mixed version of that item. Thus, same-case stimuli with first and third position forced choices were lowercase; the remaining same-case stimuli were uppercase.

The stimuli were divided into two 96-stimulus lists. Each list contained one same- and one mixed-case stimulus from each item pair, with three exemplars of each joint level of lexical category, case, and critical letter position. The lists were subdivided into four 24-trial blocks each containing six same-case and six mixed-case items in each category, with the critical letter occurring equally often in each position. Sixteen subjects received each list of items. Order of pairs of blocks, blocks within pairs, and trials within blocks (forward or backward order) was counterbalanced separately for each list.

Stimuli

The same letters and fonts were used as in Experiment 1. Stimuli were built around a set of critical letters: For pseudowords, each of the 10 letters (A, B, D, E, F, G, H, N, R, T) was assigned as the critical letter in one or two positions to maximize position-specific letter frequency. Critical letters were assigned to minimize this variable in unrelated letter strings. For both lexical categories four letters were assigned to each serial position, and all possible pairs of these letters were formed to give six critical letter pairs at each position.

Once the assignment of critical letters was established, the experimenter filled in context letters for pseudowords so that (a) all items were pronounceable monosyllables, (b) the context letters fit together with both critical letters without actually forming words, (c) no two items were identical, and (d) whenever there was freedom within these constraints, position-specific single letter and bigram frequencies were maximized.

For the unrelated letters, context letters were chosen so that (a) none of the items were pronounceable without adding vowel sounds not indicated in the orthography, (b) all context letters were consonants, thus minimizing the likelihood that the subject could reorganize his perceptual representation of the letters presented and produce a pronounceable or orthographically regular item, (c) no two items were identical, and (d) within these constraints, position-specific letter and bigram frequencies were kept as low as possible. A full list of the stimuli is given in McClelland (Note 1).

Subjects

The design called for 32 subjects. To avoid floor and ceiling effects, a subject's results were replaced if the overall percentage of correct forced choices fell outside 65% to 85%. Two subjects had to be replaced, so that 34 were tested. All were undergraduates at the University of California, San Diego, and all participated as part of a course requirement.

Practice

The practice phase of the experiment was like the practice phase of Experiment 1, except that stimuli were mixed across all factors as in the test phase. There were 80 trials in four 20-trial blocks. Exposure durations were adjusted in an attempt to obtain 75% correct forced-choice performance.

Results and Discussion

Large orthographic structure effects were obtained with both same- and mixed-case stimuli (see Table 5). There was a small difference between same- and mixed-case pseudowords and no difference between same- and mixed-case unrelated letters. A combined analysis of variance over critical letter pairs (critical letter pair [random] × case within lexical category) and subjects (subjects [random] × case × lexical category) yielded a reliable effect of lexical category, $\min F'(1, 75) = 21.74$, $p < .001$. Although the effects of case, $\min F'(1, 64) =$

TABLE 5
PROBABILITY OF CORRECT FORCED CHOICE FOR EXPERIMENT 2

Stimulus	Lexical category: Pseudoword	Lexical category: Unrelated letter
Same-case	.825	.686
Mixed-case	.780	.690

.80, $p = .37$, and interaction, $\min F'(1,70) = 1.91$, $p = .17$, were not reliable, the difference between same- and mixed-case pseudowords showed up in one-tailed t tests over stimuli, $t_D(23) = 2.56$, $p < .01$, and subjects, $t_D(31) = 2.57$, $p < .01$.

Experiment 2 demonstrates that orthographic structure has a reliable effect on forced-choice performance with mixed-case letter strings. Since there was no interpolated free report or case report, the difference does not appear to depend on processes uniquely involved in retention of information over several seconds. Furthermore, because all of the items were presented in one mixed list, the effect cannot be attributed to differences in attentiveness to the different material types.

General Discussion

Several aspects of the reported findings have important implications for models of word perception. Each of these aspects is considered in turn.

Mixed-Case Superiority Effects

Mixed-case stimuli produced a reliable word familiarity effect in Experiment 1 and a reliable orthographic structure effect in Experiment 2. These findings were predicted by the preliminary letter identification hypothesis and thus provide some support for it. However, it is worth considering whether accounts which have no provision for preliminary letter analysis could produce mixed-case superiority effects. Two accounts are considered.

Superletter features. Wheeler (1970) has noted that word superiority effects might be produced by recognition of familiar superletter features. Such features provide a source of information about the identity of letters in words and pseudowords not available in unrelated letter stimuli, where at least most of the superletter features would be unfamiliar.

While recognition of superletter features might be responsible for the same-case advantage in words and pseudowords, it is difficult to see how recognition of superletter features alone could be responsible for mixed-case superiority effects, unless mixing cases failed to eliminate these superletter features. Although this possibility exists with some mixed-case stimuli, several items in each lexical category were made up using only the letters *a, d, e, g,* and *r* for which the upper- and lowercase forms seem to have little in common (see Figure 1 above). Therefore, mixed-case items made up only of these letters should contain few, if any, familiar superletter features. Yet such items showed superiority effects just as strong as the other items (see Table 6), and pair-wise differences between categories were reliable over stimuli, even for these small samples ($p < .05$ in one-tailed t tests). Surely these differences cannot be accounted for by recognition of superletter features.

Direct recognition. On their face, mixed-case superiority effects also cast doubt on the view that words are recognized directly from the results of feature analysis as familiar configurations of features (Smith, 1971). It could be argued that the features of a mixed-case word are sufficiently like the features of at least one of its same-case counterparts that recognition of the correct word should still occur, at least some of the time. Mixed-case superiority effects, even with stimuli made up only of the letters *a, d, e, g,* and *r*, would seem to strain this interpretation; but in the absence of a specific formulation of the exact features involved, it cannot be ruled out. This possibility aside, Smith has suggested an adaptation of his model which is extremely difficult to differentiate from a preliminary

TABLE 6

Probability of Reporting All Four Letters Correctly in the Correct Position for Mixed-Case Stimuli

Stimulus	Lexical category		
	Word	Pseudo-word	Unrelated letter
A,E,D,G,R items	.38 (6)	.12 (7)	.02 (7)
All items	.39 (48)	.11 (48)	.02 (48)

Note. Number of items is given in parentheses. Number of trials equals the number of items times 24.

letter identification model. By this account, mixed-case words are recognized by determining that features extracted from the input match up with nonoverlapping subsets of the "criterial features sets" for the upper- and lowercase versions of the same word. That letters are the smallest reasonable candidates for nonoverlapping subsets indicates the difficulty of a test of this view.

Accuracy Differences Between Same- and Mixed-Case Stimuli

The accuracy difference between same- and mixed-case words and pseudowords did not extend to unrelated letter strings. Evidently, then, mixing cases disrupts processes which only affect accuracy of performance with words and pseudowords. Possible candidates for disruption are utilization of superletter features in recognizing higher-order units and direct recognition of multiletter configurations from the results of feature analysis. Either process could operate in conjunction with preliminary letter identification (cf. LaBerge & Samuels, 1974).

The data are also compatible with the possibility that preliminary letter identification is case-specific and that a letter's case, in addition to its identity, plays a part in perception. For example, a word-recognition mechanism might use preliminary letter identification to determine which case-specific letters were compatible with the visual information extracted at each letter position in a word. Then, a word compatible with the possibilities left open by letter analysis could be selected, subject to the additional constraint that all letters be of the same case if possible. This system could easily result in superior perception of same- over mixed-case words. Suppose the mixed item tHaT were shown and that sufficient information about the H, a, and final T had been extracted to permit correct case-specific identification. Suppose further that only the curved segment of the initial t were extracted during feature analysis. This segment would be compatible with either uppercase or lowercase c or lowercase t but not uppercase T. Since there would be more uppercase letters in the context, a bias to perceive the item as all one case could lead to the choice of uppercase C over either lowercase c or t, and hence to the erroneous perception of CHAT. Such a mechanism would not necessarily produce a same-case advantage in unrelated letter strings; it is possible that case constraints are not used in perception of letter strings consisting of otherwise unrelated elements.

There are clearly several ways to account for the same-mixed difference in words and pseudowords, and the present experiment provides little basis for a choice among them. What is important to note is that it is not necessary to invoke either superletter features or direct recognition of words as familiar visual configurations to account for the advantage of same- over mixed-case stimuli. Case-specific preliminary letter identification remains a possibility.

The Size of Superiority Effects in Same- and Mixed-Case Stimuli

The effect of word familiarity was the same size in same- and mixed-case stimuli by all four measures used, whereas the effect of orthographic structure was smaller in mixed-case stimuli than in same-case stimuli. This pattern of results seems to suggest that mixing cases affects stages or aspects of processing common to words and pseudowords rather than those responsible for the word–pseudoword difference. However, it is possible that same-case words would have a greater advantage over their pseudoword counterparts than mixed-case words would have over their counterparts, if the advantage were measured at the same point along the accuracy scale in both same- and mixed-case stimuli. Thus, a firm determination of whether mixing cases has any effect on processes which are responsible for the word advantage over pseudowords awaits further research.

Case Reports

Even when all four letters were reported correctly, the case reports were only correct about 50% of the time. These results suggest that subjects often retain the identity of the letters in the stimulus in some rather abstract form. More immediate case reports would help to determine whether the subjects had available and then lost the information about the form of the stimulus or whether they sometimes failed to perceive the form, though they did perceive the letters.

It should be noted that the form of the stimulus was reported correctly some of the time. Indeed, the form of the stimulus appears to have been encoded more accurately if the stimulus was all upper- or all lowercase, and there was a marked tendency to report mixed-case items as either all upper- or all lowercase. This pattern of results suggests that when subjects do form a representation which corresponds to some actual physical form, that representation tends to conform to the structural regularities of English calligraphy, that is, it is either exclusively upper- or lowercase. It remains to determine whether subjects actually misperceive mixed-case words as all upper- or all lowercase or simply report them as such due to response biases.

Conclusion

It seems likely that preliminary letter identification does mediate word superiority effects obtained with mixed-case stimuli, but the role of preliminary letter identification in word recognition under normal circumstances, when all the letters in a word are in the same case, remains to be resolved. It is possible that preliminary letter identity information in conjunction with form-specific information jointly provide the basis of word recognition. It is also possible that preliminary letter identification plays no role in the normal word identification processes of the fluent reader and is brought into play only when the normal channels fail. In either case, the mixed-case word familiarity and orthographic structure effects suggest that knowledge of the abstract properties of familiar stimuli can influence the process of perception.

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