Case alternation impairs word identification*

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Smith (1969) and Smith, Lott, & Cronnell (1969) claimed that word identification was not impaired by printing the characters making up a word in a mixture of cases. If this were so, it would rule out such word-identification models as the "more-features" model of Wheeler (1970) and Rumelhart & Siple (1972). The experimental methods used by Smith et al are criticized. A straightforward word-identification experiment revealed that case alternation does, in fact, lead to a large impairment of word identification, as would be predicted by models of word identification based on multiletter visual features.

Much recent work on word recognition has centered around the findings of Reicher (1969) and Wheeler (1970), who showed that report of an alphabetic display in superior when the display forms a word than when it forms a meaningless sequence of letters or when it is a single letter. The effect cannot have been due to a redundancy or guessing effect operating during the S's response, because the response was a two-alternative forced choice, and, in the case of words, both response alternatives (e.g., D or K in WOR–) made up a word. Thompson & Massaro (1973) have claimed that this technique does not adequately eliminate possible redundancy effects. They give the example of a S who perceives WOR– plus a curved feature in the last position. This S knows the last letter would have to be D, O, or Q, and, since only D makes a word, he can respond "WORD," even though he did not identify all four letters. If, on the other hand, only the letter D were presented and only the curved feature detected, the S could only guess at random from the three alternatives D, O, and Q. Thus, redundancy assists words and not letters, and so, according to Thompson and Massaro, Reicher's and Wheeler's results may be due to redundancy. It is difficult to see how this view can explain why single letters are reported less well than words. Before the redundancy mechanism can begin to operate, the S must first have identified at least one letter in a word without the assistance of redundancy; so how can word performance be *better* than single-letter performance? We maintain, then, that redundancy cannot be the explanation of the superiority of words over single letters.

One explanation of this effect which was proposed by Wheeler (1970), and which has subsequently been taken up by Rumelhart & Siple (1972), is that there exist multiletter visual features such as word shape (in the case of lowercase displays) or trigram or digram properties such as the roundness of CO or the squareness of NI; "with multiletter stimuli there could be additional features extracted from the various combinations of letters, independent of the specific letter features. Any feature extracted from a letter combination including the tested letter might be relevant to the choice between the two alternatives. The additional information available from these features would enable the S to perform better on words than on letters [Wheeler, 1970]."

This seems an attractive possibility. In fact, however, data relevant to this theory had already been published by Smith (1969) and Smith, Lott, & Cronnell (1969). These data came from experiments on the identification of words presented in mixed uppercase and lowercase characters. A word which was made up of alternating uppercase and lowercase characters would be visually quite unfamiliar and would not yield the kinds of multiletter visual features which readers might have learned to extract from all-uppercase or all-lowercase words. Therefore, if such multiletter features are important for word identification, case alternation should impair word identification.

Smith found, indeed, that when uppercase characters were larger than lowercase characters, performance was worse with case alternation than when case was the same throughout the word. However, when he used uppercase characters which were the same height as lowercase characters (ignoring ascenders and descenders), performance was the same for words with case alternation as for words with the same case throughout.

This very surprising result was shown with two different paradigms. Firstly, Smith (1969) used the technique of having Ss read aloud 150-word prose passages. The time taken to complete such a passage was the same for all-upper-, all-lower-, and mixed-case passages, provided that the letters in the mixed-case condition were all the same size (neglecting ascenders and descenders). This result by no means indicates that case alternation has no effect on word identification. When Ss read aloud, there exists an eye-voice span (Morton, 1964); while the S is uttering a particular word, he is looking at and identifying words further on in the passage. Since utterance rate in Smith's experiment (about 3 words/sec) was vastly slower than the rate at which words can be identified, only very gross differences in processing rates could possibly show up as differences in rate of utterance.

Secondly, Smith, Lott, & Cronnell (1969) had Ss search a 150-word prose passage for 20 target words.

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Fig. 1.

The prose passage was on the left page of a booklet, in upper case, lower case, or alternating case. The 20 target words were on the facing right page of the booklet printed in uppercase, lowercase, or mixed-case italics. The number of target words found in the prose passage was the same for uppercase, lowercase, or alternating-case prose passages if size of characters was equated between upper and lower cases in the alternating-case situation. Smith et al concluded (p. 252) that "disruption of 'total word form' does not interfere with the identification of words."

If what is being studied is the effect of case alternation on word identification, it seems quite unnecessary to use such a complex multiple visual search task as this. If there is an effect of case alternation, it is likely to be rather small in magnitude compared to the effects introduced by having continually to consult the list of target words and to keep as many of them as possible in memory while scanning the prose passage. It seems clear that the appropriate experiment is to present Ss with single words under conditions in which identification performance is less than perfect, and to measure the effect of case alternation on probability of identification. It is this experiment that we report.

METHOD

From the word-count of Kucera & Francis (1967), 48 words were chosen. All words were 8 letters in length, were disyllables, and consisted of two morphemes, and had a frequency of between 4 and 7 in the word count. No word contained any letter whose uppercase form differed from its lowercase form only with respect to size. Each word was presented three times to each S: once in uppercase characters, once in lowercase characters, and once with case alternating from character to character. The uppercase characters were the same height as the lowercase characters (ignoring ascenders or descenders). Examples of the three display modes are given in Fig. 1.

The 48 words were first presented in one block, 16 words in each display mode, with display mode in a random order. The words were then presented again in the same order but in a different display mode from the one first used. Then the words were presented again in the same order, using the previously unused display mode for each word. An experimental session thus consisted of 144 trials, after a short practice session.

The apparatus consisted of a VR12 CRT display slaved to a PDP-12 computer, which ran the experiment. Each trial began with the presentation of a fixation point (a small cross). The S fixated this point and, when ready, pressed an initiate button. The fixation point disappeared, and 500 msec later a word was presented for 50 msec, symmetrically about the location of the fixation point. Then a mask (a crosshatched pattern of oblique lines covering the area previously occupied by the word) was

Table 1
Number of Correct and Incorrect Responses and Omissions Under Conditions U (Uppercase), L (Lowercase), and A (Alternating Case) for Each Subject

	Number of Correct Responses			Number of Incorrect Responses			Number of Omissions		
Condition	U	L	A	U	L	A	U	L	A
S 1	35	41	24	9	5	20	4	2	4
S 2	44	46	36	3	2	10	1	0	2
S 3	6	5	0	20	22	21	22	21	27
S 4	13	15	12	31	28	28	4	5	8
S 5	45	48	38	3	0	10	0	0	0
S 6	36	35	25	6	9	13	6	4	10
S 7	17	22	12	18	16	16	13	10	20
S 8	27	24	24	19	20	18	2	4	6
S 9	25	30	20	22	15	25	1	3	3
S 10	42	45	39	6	3	8	0	0	1
Mean Percentage	60.4	64.8	47.9	28.5	25.0	35.2	11.0	10.2	16.9

presented for 2 sec; after this, the fixation point reappeared.

The S's task was simply to say what word had been presented. The 10 Ss were all undergraduates at the University of Reading. None were familiar with the aims of the experiment.

RESULTS AND DISCUSSION

The number of correct responses, incorrect responses, and omissions are shown in Table 1 for each S and each display mode. Every S gave more correct responses in the uppercase mode than in the alternating mode; nine Ss gave more correct responses in the lower-case than in the alternating mode, with a tie occurring for the 10th S.

This experiment, then, has shown that the alternating-case condition does, in fact, lead to impaired word identification, even when character size is the same for upper- and lowercase characters. Consequently, it seems reasonable to conclude that the failure of Smith (1969) and Smith, Lott, & Cronnell (1969) to find such an effect was due, as was suggested above, to the insensitivity of the experimental paradigms they used. Theories of word identification which depend upon multiletter visual features are supported by our data, since such theories would predict deleterious effect of case alternation.

When asked after the experiment what kinds of letters had been presented, six of our Ss claimed that all the words had been in lower case, two claimed that all the words had been in upper case, and two claimed that, although most of the words had been in lower case, some were in upper case. No S reported awareness of the alternating case condition, even after some questioning about this. This finding in itself would seem to merit further study.

REFERENCES

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

Morton, J. The effects of content upon speed of reading, eye movements and eye-voice span. Quarterly Journal of Experimental Psychology, 1964, 16, 340-355.

Reicher, G. M. Perceptual recognition as a function of meaningfulness of stimulus material. Journal of Experimental Psychology, 1969, 81, 275-280.

Rumelhart, D. E., & Siple, P. The process of recognizing tachistoscopically presented words. Center for Human Information Processing Technical Report No. 27, University of California, San Diego, 1972.

Smith, F. Familiarity of configuration vs discriminability of features in the visual identification of words. Psychonomic Science, 1969, 14, 261-262.

Smith, F., Lott, D., & Cronnell, B. The effect of type size and case alternation on word identification. American Journal of Psychology, 1969, 82, 248-253.

Thompson, M. C., & Massaro, D. W. Visual information and redundancy in reading. Journal of Experimental Psychology, 1973, 98, 49-54.

Wheeler, D. D. Processes in word recognition. Cognitive Psychology, 1970, 1, 59-85.

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Noncontingent reward magnitude effects on reaction time: A replication and extension*

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Stillings, Allen, & Estes (1968) have demonstrated a facilitating effect of reward magnitude upon reaction time even if the reward was not contingent upon the reaction time. Their study showed anomalous results for the control group, however. They suggested that these anomalous results were due to their experimental group having a cognitive task to perform while the control group did not. Our study added a control group which did have a cognitive task (remembering a number) to perform. We replicated Stillings et al's noncontingent reward magnitude effect, but did not replicate the anomalous control group results. In addition, we found that the magnitude of a number to be remembered retards reaction time. Several explanations for this latter result are examined and discarded.

Stillings, Allen, & Estes (1968) demonstrated that magnitude of reward, even though the reward was strictly noncontingent upon performance, had a measurable effect upon simple reaction time (RT) latencies. In their experiment, they measured a simple RT to a go signal (green lights). All Ss were paid cash according to the number of points amassed over the entire session, with different point values assigned to each RT trial. The optimum strategy was to respond as rapidly as possible on every trial so as to maximize the total number of points, regardless of the value of any one trial. One group of Ss was informed before each trial as to the point value of that trial. A second group was

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