The role of configuration in the identification of visually degraded words

W. R. GARNER

Yale University, New Haven, Connecticut 06520

Two experiments were carried out in which reaction time for identification of words in sets of four was measured. The words were of three letters, with dichotomous variation of the first and third letters, in either upper- or lowercase, with letters chosen to give maximum variation in word configuration in lowercase. Four types of display were used, differing in size and masking. In Experiment 1, the words were easy to identify in uppercase as well as in lowercase, because the letters were easily discriminable in either case, and the results showed no advantage to lowercase words at any level of degradation. In Experiment 2, the letters were more difficult to discriminate in uppercase, and with the most severe degradation, the words in lowercase were identified more rapidly than those in uppercase. Thus the reaction time results showed an advantage of the configural properties available in lowercase only with words difficult to identify in uppercase and with extreme amounts of degradation. Error analyses of both experiments showed that errors were made to individual letters, not on the basis of the configuration, for words in both cases. It is concluded that letter processing occurs even when there is evidence for the use of configural information, thus implying a predominant role of letter perception in word identification. Some reservation is expressed whether whole-word configuration is the only pertinent configural property and whether the results from such simple identification tasks are appropriate to an understanding of natural reading.

Is a word perceived as a series of individual letters or as a total configuration? This question has been the subject of much research in recent years (see reviews on this question by Baron, 1978; Estes, 1975; Kolers, 1970; LaBerge & Samuels, 1974; Massaro & Schumacher, 1975; Smith & Spoehr, 1974), although the question has an older history as well (see Huey, 1908; Woodworth, 1938). Much of this research has addressed the question in an all-or-none fashion, as though words are always perceived as configural wholes or as individual letters, regardless of the task or the specific nature of the stimuli. The results of the many experiments provide a very mixed answer to the question, giving the impression that the problem is simply intractable or that the concepts that are being tested are inadequately specified.

It is self-evident, however, that there can be no single answer to this question, since there are circumstances in which only single-letter information can be available or in which only configural information can be available. (See Garner, 1981, on this issue; but see also Kinchla & Wolfe, 1979, on the related topic of part-whole perception with nonwords.) If, to illustrate, a word is printed with widely spaced letters, it is unlikely that a total configuration will be perceived, even though in a

strict definitional sense there might be a configuration for the entire group of letters making up the word. On the other hand, if the letters are spaced close together and the size of the total word is very small, it will be possible to perceive the outline of the total word even though no individual letter can be perceived. Or a word that is defocused may be perceived as a configuration even when the defocusing prevents identification of any single letter. It would seem useful, therefore, to investigate this question by establishing some of the conditions under which configural properties of words are used rather than properties of individual letters.

A factor that makes such an experimental task difficult, just as it has made all research on word perception difficult, is that a word configuration does not exist without there being components to form the configuration (see Garner, 1978a, 1981). Thus it is not possible to arrange experimental conditions with words having configurations but no component letters or letters but no configuration. It is perhaps reasonable to assume that if letters are spaced far enough apart there can be component letters without configuration or that if letters are close enough together and are small size there can be configuration but not components. In either case, however, properties both of component letters and whole-word configuration in fact coexist, and differences between the cases can only be differences in whether a human observer can be expected to use one or the other type of property.

Since configural properties are redundant to component properties, it is reasonable to consider that the

This research was supported by Grant MH 14229 from the National Institute of Mental Health to Yale University. Carolyn Paul acted as experimenter, did much of the data analysis, and aided in many other ways in the carrying out of these experiments. Requests for reprints should be sent to W. R. Garner, Department of Psychology, Box 11-A Yale Station, New Haven, Connecticut 06520.

redundant configural properties will be used to a greater extent when there is a more serious need for the redundancy (Garner, 1962). If a perceptual task can be carried out efficiently with the use of component properties, it is less likely that the configural properties will be used. If, however, the component properties are degraded, then the redundant configural properties will be more necessary, and there is ample evidence that masking or other forms of degradation do influence how words or letters are perceived (e.g., Estes, 1972; Garner & Haun, 1978; Johnston & McClelland, 1973). For these reasons, the major purpose of the present experiments is to investigate the perceptual use of configural properties of words under conditions of stimulus degradation, conditions in which the components will possibly be inadequate to provide the necessary information for word identification.

Another consideration in research on word perception is that in the use of real words formed from real letters, there are constraints on stimulus generation that often give inadequate experimental control over the nature of the properties of both the components and the configurations. One kind of word set has been used to maximize control over the nature of the stimulus properties: word sets formed from combinations of first and last letters with a fixed vowel in the middle, such as "bat, rat, bag, rag." Such word sets, formed from orthogonal combinations of two first and two last letters, give some of the kind of experimental control to the production of words that we ordinarily use in the production of nonmeaningful stimulus materials.

Chang and Shepard (1964) used two such word sets (including the illustrative set) in an association and a classification learning task. Analysis of errors showed no tendency for the words to be used holistically, since when errors were made, they tended to be made with responses differing only in a single letter position. Later, Silverman (1976, 1977) used such three-letter words and found some evidence for holistic perception with discrimination tasks of the sort used by Garner (1974, 1978b) to investigate integrality and separability of stimulus dimensions. Specifically, he found some increased speed of discrimination to pairs of words differing in both the first and third letter positions compared with pairs differing in only a single letter position; in condensation classification tasks requiring two words to be put into each class, but with neither the first nor the third letter being the same for a given class, words were classified faster than nonwords. Silverman's results were, on the whole, somewhat equivocal as to whether such words are perceived and processed holistically, and specific attempts to vary the configuration of the words were not made.

In an attempt to extend Silverman's (1976, 1977) work, Garner (1981) used words that varied the amount of configural information available and added a focusing task to those used by Silverman, a task in which one word is classified against the other three. Several word

sets were used, words that when reversed produced nonwords (but having, of course, the same component letters) and words that when used in lowercase could give maximum variation in configurations of the whole words, even though giving little variation in configuration when used in uppercase. The words "sum, sun, rum, run" form a set not differing in amount of configuration between upper- and lowercase, whereas the words "beg, bet, peg, pet" form a set that, in lowercase, produce whole words varying maximally in configuration. Garner's results showed almost complete evidence for use of letter components in the various discrimination and classification tasks, for words or nonwords, upper- or lowercase. The only slight exception was that the two lowercase words in the set that slope down or up ("beg" and "pet") were very slightly faster in the focusing task and almost as fast as the discrimination tasks. Overall, however, the evidence clearly favored the conclusion that such words in these tasks are processed by their component letters.

Purpose of Experiments

The present experiments differ in two major ways from the previous research: (1) Four types of stimulus display were used in which the words differed in size and in amount and type of masking. These variations were used in order to determine whether the increased need for redundant information would increase the use of configural properties. (2) The task was one of word identification in which each word in the set was actually pronounced. In the previous work of both Garner (1981) and Silverman (1976, 1977), subjects were never required to use the actual word as a response, but they used either a manual response or a card classification. The use of word identification in the present experiments was intended to increase the likelihood that whole-word properties would be used by requiring a whole-word response.

As in Garner's (1981) previous research with words of this type, the amount of configural information available in a word set was varied by using the same words in either upper- or lowercase and by using words with letters that in lowercase were ascenders or descenders. While there is a configural property in such words even in uppercase, the extent to which the words in a set differ in configural property is clearly greater in lower- than in uppercase.

The specific question being investigated was whether the greater differences in configural properties of the words in lowercase would lead to better performance with those types of displays that were more difficult. Thus an interaction was anticipated between letter case and type of display, with words in lowercase being relatively easier to identify with the more difficult types of display.

It might be good to emphasize that the logic of this experimental design requires acceptance of the assumption that there are greater configural differences of the

whole-word type when these words are used in lower- rather than uppercase. As already noted, words in uppercase also have whole-word configurations, and words in both cases have component configurations as well. Despite these inherent difficulties of separating component from holistic properties, it is not unreasonable to argue that there are greater differences in whole-word configurations with lowercase rather than uppercase words and, thus, that this manipulation provides a reasonable attempt to understand the role of configuration in word identification.

EXPERIMENT 1: BEG, BET, PEG, PET

The set of words used was that which Garner (1981) had shown to provide some slight evidence that configurational properties were used, with the lowercase words "beg, bet, peg, pet" having maximum up-and-down variation.

Method

Stimuli. The stimuli were presented in a Scientific Prototype three-field tachistoscope, for which 12.7 by 17.8 cm cards are used to display the stimuli. For the largest stimuli, Letraset 1450, Futura demibold letters were used. These letters, uppercase, are 7.5 mm high with a line thickness of 1.0 mm. When arranged into words, the space between adjacent letters was 1.0 mm. The letter width varies slightly with the particular letter, but the maximum word width (slightly greater with G than with T) was 17.5 mm. The words were viewed at 127 cm, and with these dimensions, the visual angle for word height was .34 deg and that for word width was a maximum of .79 deg. Purcell, Stanovich, and Spector (1978) showed that word-superiority effects in letter detection were better at visual angles under 1.0 deg. These words, even at maximum size, were small enough to be well under this size, while also allowing clear identification of the individual letters. These letters in lowercase give the same basic dimensions, except that the letter height pertains to the total height for the consonant letters that begin and end the words. Thus the words "bet" and "peg" have the same height in lower- and uppercase, whereas the words "beg" and "pet," which go both below and above the main line of the words, have a greater total height in lowercase. The effect of these arrangements is that the upper- and lowercase words were of about the same total area. One word was printed on a single display card, centered. The words were black on a white background.

Types of display. There were four different types of display, which, when combined with upper and lower cases, produced eight different experimental conditions: (1) Large, high contrast—These words were as described in the preceding section and were displayed with the maximum contrast possible of the white background to the black letters. The white background had a luminance of 5.0 fL. (2) Small, high contrast—The letter sizes for this type of display were reduced to .53 that of the large letters, and all other size factors were reduced proportionately. Letraset 2066, Futura demibold letters were used. Luminance and contrast were as above. (3) Small, low contrast—The small letters were used, but an additional field of the tachistoscope was exposed simultaneously with the primary field. The additional field had a luminance of 10 fL, producing an effective background luminance of 15 fL and a luminance of the letters of 10 fL, with a contrast ratio of 1.5. (4) Small, masked—The small letters were used, with high contrast, but with a grid of dots overlying the display to act as a mask. The mask was Letratone 916 and consisted of small black squares, six per

centimeter, both horizontally and vertically, with the black squares being approximately .5 mm in width.

The low contrast and the mask were chosen on the basis of pilot work to provide approximately equal degradation. The two types were used because of some prior evidence that a "pattern" mask would affect word perception differently from the way a mask of light would (Garner & Haun, 1978; Johnston & McClelland, 1973).

Procedure. The experiment was run in blocks of trials, a block consisting of 20 trials for each of the four words in one of the eight conditions, for a total of 80 trials/block. A trial was initiated by the subject's pressing a switch held in either hand, at which time the word appeared immediately. The subject identified the word aloud, thus activating a Gerbrands voice key. The stimulus remained on for 1.0 sec, regardless of the subject's response. Between trials, a fixation dot was visible from one of the fields of the tachistoscope. Total time per trial was approximately 10 sec, so that a block of trials lasted about 13 min. The subject was always shown the words as they would appear at the beginning of each block.

A computer randomized the trials in a block. These were displayed on a terminal at the side of the experimenter, who then inserted the appropriate stimulus into the tachistoscope. Both the initiation of a trial by the subject and the output of the voice key activated the computer that measured the reaction time (RT) with 1-msec accuracy. The actual response was typed into the terminal by the experimenter. Thus both RT and error data were available for analysis.

Subjects. A total of 16 subjects were used, consisting of undergraduate and graduate students and staff members at Yale University, and all were paid for their participation. All had normal vision, although some with correction. No formal visual test was used, since in experiments of this sort it becomes readily apparent if there are any visual difficulties.

Many of the subjects had participated in the pilot research and were thus experienced with the stimulus materials and the procedures. If they had not had such experience, they were given an initial 1 h practice.

Experimental design. As mentioned, a block of trials consisted of 80 trials with a single condition defined by type of display and letter case. A session of about 1 h consisted of four blocks of trials, separated by brief rest periods as requested by the subject. In a session, a subject received each of the four types of display and alternated case across blocks, half of the subjects starting with lowercase and half with uppercase. Two sessions were required for one subject to complete all eight conditions, and in the second session, a subject started with the case not started in the first session. After completing all eight conditions, the subject was run for two more sessions, duplicating the sequence of conditions used in the first two sessions. A group of eight subjects formed a Latin square balancing conditions and orders. This Latin square was repeated for the same subjects in the last two sessions, and it was duplicated for a second group of eight subjects. Within the Latin square, four subjects formed an additional Latin square balancing the four types of display and order, disregarding the letter case. This Latin square was completed in the first session and was repeated for the same four subjects in the second session. One such Latin square was used for the four subjects starting with the lowercase, and another Latin square was used for the four subjects starting with the uppercase. This experimental design insures that effects of both type of display and letter case are fully counterbalanced in order of use across subjects, both as separate and as combined experimental factors.

Analyses. Analyses were carried out for both RTs and errors. For RT analyses, a median was computed for all correct trials for each word in each block, a maximum of 20 trials. All further RT analyses used means of these medians. Error analyses were carried out with total or mean errors. For both measures, analyses of variance were used for overall effects and *t* tests were used for specific analyses. In addition, many nonparametric

tests were used, ordinarily the sign test, as appropriate. Statements about significant effects are made for a p of .01 unless otherwise specified.

Results

Reaction times. Initial analyses established that the average RT was lower by 17.9 msec on the second time through the experiment, but this decrease in RT did not interact with any of the experimental variables. Therefore, all further analyses were carried out with data averaged over the two halves of the experiment.

Case and type of display. The two experimental factors that were the main concern of the experiments were the case of the words and the type of display. Data for these eight experimental conditions are shown in Table 1, along with the difference between upper- and lowercase for each type of display, averaged across subjects and words. There were strong effects of type of display, with large, high-contrast words being easiest and small, low-contrast words being most difficult. These effects were very robust, with 14 of the 16 subjects having exactly the ordering of difficulty shown in Table 1 and the other 2 subjects showing a reversal only for the two most difficult conditions. These two conditions, small with either low contrast or masked, had been intended from pilot work to be equally difficult, but they were in fact significantly different in this experiment. Since this result did not occur in the second experiment, and since this difference did not interact with case, it is of little concern.

There were no significant differences between the two cases. Of greater importance is the fact that there was no significant interaction between type of display and case. Thus the greater difficulty of word identification that the low contrast and masking produced did not give an advantage to the lowercase words, an advantage that might have occurred if the greater difference in configuration of the lowercase words was an advantage.

Word effects. There were significant differences in RT between the four words, in both uppercase and lowercase, and within each type of display. These differences did not interact with either case or type of display. Averaged over the four types of display and both cases, mean RT in milliseconds was 449.3 for "beg," 449.1 for "bet," 471.3 for "peg," and 463.3 for "pet." Most of the difference is between words beginning with *b* and those beginning with *p*. This factor

Table 2
Mean Error Rates for Upper- and Lowercase Words
and Types of Display: Experiment 1

Display	Case		Difference
	Upper	Lower	
Large, High Contrast	.018	.027	-.009
Small, High Contrast	.032	.025	.007
Small, Low Contrast	.044	.043	.001
Small, Masked	.034	.034	.000
Mean	.032	.032	.000

alone accounted for 86% of the variance of words in uppercase and 94% for words in lowercase. There was no other significant source of variance between words, either between words differing in the last letter or words differing in both letters. This effect was also very robust with respect to subjects, with 14 of the 16 subjects being faster on words beginning with *b* than on those beginning with *p*, in both cases. The effect was also present in every type of display. Since the letter *b* is vocalized and the letter *p* is unvocalized, even though both are plosives, these differences due to words can be interpreted as differences due to vocalization of the initial letter. In other words, the effect of particular words is not a perceptual effect but is a response artifact, one commonly found with the use of voice keys to measure RT.

Errors. Overall errors were small, totaling 655 on 20,480 trials, a mean error rate of .032 per trial. For this reason, analyses of errors could not be carried out at small levels of analysis, but larger analyses are quite possible and support the results based on the analyses of RTs.

Case and type of display. Table 2 shows mean error rates for upper- and lowercase words for each type of display, averaged across subjects and words. There was a significant effect of type of display, with more errors occurring with displays of smaller size and of lower contrast or masked. This effect occurred with both upper- and lowercase words, and there was no interaction between type of display and case. There was no difference between the two cases. These results completely parallel those obtained with RTs and indicate that there was no speed-accuracy tradeoff across types of displays and that RTs were not maintained equally between lower- and uppercase at a differential cost in errors.

Word effects. Averaged over the four types of display and both cases, mean error rates were .036 for "beg," .042 for "bet," .028 for "peg," and .023 for "pet." The largest, and only significant, effect was that words beginning with *b* produced more errors than those beginning with *p*, and this effect did not interact with case or with type of display. Since the effect occurred with both upper- and lowercase letters, it seems unlikely that the explanation resides in perceptual properties of the letters, but rather, it is best interpreted as a response artifact, as with RT data for individual words.

Table 1
Mean Reaction Times (in Milliseconds) for Upper- and
Lowercase Words and Types of Display: Experiment 1

Display	Case		Difference
	Upper	Lower	
Large, High Contrast	423.3	427.4	-4.1
Small, High Contrast	445.2	452.1	-6.9
Small, Low Contrast	488.2	485.6	2.6
Small, Masked	473.3	470.6	2.7
Mean	457.5	458.9	-1.4

The pattern of actual error responses was the same for upper- and lowercase words: Of all errors, .55 were due to a b being pronounced as a p and .34 were due to a p being pronounced as a b, these two errors thus accounting for .89 of the total. Errors involving changes in the third letter (g to t or t to g) accounted for .10 of the errors, and those involving changes in both letters accounted for only .01 of all errors. Thus the great majority of the errors were simply mispronunciations of the first letter, and the majority of these were failures to vocalize the initial b.

Discussion

This experiment was intended to determine whether the redundant configural properties more available with lowercase words would maintain better performance when the word identification task was made more difficult by decreasing size and otherwise degrading the stimuli. The results, either in RTs or in errors, showed no evidence of such better performance, even though the effect of the degradation was strong with both measures. Thus it would appear that configural properties are not important in this type of task.

Further evidence that word identification in this task is carried out with component letters rather than with whole-word configurations comes from the analysis of the particular errors. The vast majority of errors were made by substituting one of the two possible first letters for the other; a few errors were made by substituting one of the two possible last letters for the other. Hardly any errors involved substitutions of both letters, even in lowercase, and yet these are the types of errors most likely to occur if configurations are perceptually important; that is, "beg" and "pet" would be mistaken, as would "bet" and "peg," since the first two words share an up-down configuration and the latter two have a horizontal appearance, albeit one with upward items and the other with downward items. The pattern of errors also makes it clear that errors were not made by random choice of whole words as errors, since in that case, errors in two letter positions would be as likely as errors involving either single-letter position.

Thus this type of simple word identification task is carried out with the use of letters as the primary perceptual components. However, even words made with uppercase letters do have configurations, and possibly the choice of stimuli did not provide a sufficient differentiation between the configural (or component letter) properties of the two types of words. Experiment 2 was therefore carried out to push the distinction even further.

EXPERIMENT 2: FAT, FAY, PAT, PAY

Method

This experiment was identical to Experiment 1 in all respects except two: (1) A different set of words was used. As contrasted with the Experiment 1 words, the first and last letters of the new words were more difficult to discriminate in uppercase, although

approximately the same letter discrimination and overall configural differences existed when in lowercase, "fat, fay, pat, pay." (2) Eight subjects were used, with a single Latin square arrangement in the experimental design. One subject without previous experience was given an extra 1 h of trials before beginning the experiment proper. The other seven subjects had been used in either Experiment 1 or some of the pilot research.

Results

Reaction times. Initial analyses established that the average RT was lower by 10.9 msec on the second half of the experiment, and this difference was just marginally significant ($p < .05$). There was no interaction of this effect with any of the experimental conditions, however, so all further analyses were carried out with data averaged over the two halves of the experiment.

Case and type of display. RTs for the eight main experimental conditions, averaged across subjects and words, are shown in Table 3. There were, in this experiment, significant differences between types of display and between upper- and lowercase, and a significant interaction between case and type of display. Once again, the effects of type of display were robust, with six of the eight subjects showing exactly the same rank ordering as the average and the other two subjects showing a reversal only for the two most difficult conditions. The difference between the small, low-contrast display and the small, masked display was not significant, for either case or averaged for both cases.

While there was a significant difference between cases, the existence and nature of the interaction is more pertinent to the question being asked in the experiment. The interaction was due to the fact that there was no significant difference between words in upper- and lowercase for the two easiest conditions, large and small with high contrast, but there was a significant difference between the two cases for the two most difficult conditions, with words in lowercase being easier to identify. The advantage for the lowercase was not significantly different for these two most difficult types of display; that is, there was no significant interaction between case and type of display when just these two types of display are considered.

Word effects. The range of differences in RT for individual words was about half that obtained in Experiment 1, and these differences were not significant in

Table 3
Mean Reaction Times (in Milliseconds) for Upper- and Lowercase Words and Types of Display; Experiment 2

Display	Case		Difference
	Upper	Lower	
Large, High Contrast	412.5	411.6	.9
Small, High Contrast	438.0	444.7	-6.7
Small, Low Contrast	494.6	466.8	27.8
Small, Masked	508.0	482.9	25.1
Mean	463.3	451.5	11.8

either upper- or lowercase. To emphasize this lack of significance, and to contrast the results with those of Experiment 1, in uppercase .52 of the variance due to words (averaged across types of display) was due to the T-Y difference and only .34 was related to the initial F-P difference, neither of the specific effects being significant. In lowercase, .29 of the variance was due to third-letter differences and .66 to the interaction between letter positions. The latter effect, which was only marginally significant ($p < .05$), occurs because the words "fat" and "pay" had a mean RT of 447.5, whereas the words "pat" and "fay" had a mean RT of 455.5. This very slight advantage for words having a uniform configuration over those having an up-down configuration is the only evidence of any kind from individual word data that word configuration plays some role in identification RT with these sets of four words, and this evidence is only of marginal significance.

Errors. Overall, errors were small, totaling 320 on 10,240 trials, a mean rate of .031 per trial. Therefore, as in Experiment 1, only larger levels of analysis were carried out.

Case and type of display. Mean error rates for upper- and lowercase words for each type of display, averaged across words and subjects, are shown in Table 4. The effects of type of display and case and the interaction between them were all significant. Furthermore, the effect of type of display was significant within lowercase, although the effect is substantially reduced with words in lowercase. The interaction was due primarily to the fact that the two easier conditions showed no substantial difference between upper- and lowercase words, but the two more difficult conditions did. There was a substantially greater difference between cases with masked than with low-contrast stimuli, and this difference of the differences was marginally significant ($p < .05$). Except for this marginal effect, the error data of Table 4 completely parallel the RT data of Table 3 and indicate that there was no speed-accuracy tradeoff with respect either to letter case or type of display.

Word effects. Averaged over the four types of display and two cases, mean error rates were .032 for "fat," .026 for "fay," .048 for "pat," and .019 for "pay." The largest effect was that words ending in t produced

more errors than those ending in y, and although this effect was significant for both cases averaged and uppercase alone, the effect was only marginally significant ($p < .05$) for lowercase alone, due to the very small total number of errors made with the lowercase words. These effects, however, although statistically significant, were of small magnitude.

Despite the fact that the largest difference in error rates was due to the third letter, the actual errors made showed many more errors in the first letter position. These patterns of errors will be reported separately for each case because of the large difference in number of errors in the two cases, but also because, if there is any evidence at all of the use of configural properties in the error data, they should occur with lowercase words. In uppercase, .33 of all errors involved changing F to P and .32, P to F, for a total of .65 errors of letter changes in the first position only. For letters in the third position, T was changed to Y .24 of the times and Y to T .07 of the times, for a total of .31 errors in the third position only. Only .04 of the errors involved changes in both the first and third letters. In lowercase, .30 errors were f to p and .46 were p to f, for a total of .76 errors in the first letter only. For letters in the third position, .08 were t to y and .15 y to t, for a total of .23 errors in the third letter only. Only 1 error (of a total of 99) was made involving letter changes in both positions. Averaged over both upper- and lowercase, .69 of the errors were changes in the first letter position only, .28 were changes in the third letter position only, and only .03 involved changes in both letter positions. As in Experiment 1, the very small number of errors involving changes in both first and last letter positions makes it clear that error responses were not randomly distributed across words.

Discussion

This experiment was intended to push further the possibility that the redundant configural properties more available with lowercase words would show better identification performance for lowercase words than for the same words in uppercase if the stimuli were sufficiently difficult to discriminate on a component-letter basis in uppercase and if the stimuli were sufficiently degraded for the redundant configural property to be necessary. Both overall RT and error analyses showed the lowercase words to be easier to identify with the two conditions of greatest degradation. Thus we can conclude that configural properties are of some importance when they are sufficiently needed.

Despite this evidence of the use of configural properties, there is also evidence from the error data that individual letters are perceived even when configural properties are contributing to performance. Thus there is little evidence that configural properties are used instead of component properties; rather, the configural properties seem to add information useful in the task but not to substitute for letter information.

Table 4
Mean Error Rate for Upper- and Lowercase Words
and Types of Display: Experiment 2

Display	Case		Difference
	Upper	Lower	
Large, High Contrast	.011	.013	-.002
Small, High Contrast	.023	.015	.008
Small, Low Contrast	.048	.022	.026
Small, Masked	.091	.027	.064
Mean	.043	.019	.024

GENERAL DISCUSSION

These two experiments have shown that if words are sufficiently difficult to discriminate in uppercase and if the stimulus words are sufficiently degraded, then performance is improved in word identification when the words are in lowercase, at least when there are ascending and descending letters in lowercase. Thus, in line with the premise stated in the introduction that there is greater configural differentiation when the words are in lowercase rather than in uppercase, it can be concluded that the redundant configural information is useful in word identification when viewing conditions are sufficiently poor to make the redundant configural information of value.

Overall, however, the results of these experiments clearly indicate the predominant role of letters as contrasted to configurations in a simple word identification task. The RT data show there to be no advantage to the greater variation in configuration with the lowercase words except with the word set most difficult to discriminate, and then only with the two most severe amounts of degradation. As such, these data conform well to those models of word identification and recognition that emphasize the perception of letters prior to word perception. Word perception models of Bouwhuis and Bouma (1979), Estes (1977), LaBerge and Samuels (1974), and Massaro (1975) are to a greater or lesser extent of this type, and the present data support the attitude expressed by Estes (1977, p. 3): "It is conceivable that words are classified and encoded primarily in terms of a limited number of attributes or features having to do with overall shape and the like, but . . . this suggestion . . . has not yet adduced any substantial empirical support."

As pointed out above, configural information is always redundant to letter information, since it exists as a consequence of the interrelations of the letters. The results, especially of Experiment 2, are in line with this idea of configural information's being redundant to letter information, therefore facilitating identification of words when there is sufficient degradation to require the redundant information, but not totally substituting for the letter information itself. Thus in Experiment 2, with the words difficult to discriminate and, therefore, to identify in uppercase, degradation still had an effect on word identification with words in lowercase, although not as severe an effect as with words in uppercase. Even with this evidence of the perceptual use of configural information, the error data showed unequivocally that letters were still operative as perceptual units. This result showing configural information to be used in addition to letter information rather than instead of it is consistent with the conclusion of McClelland (1977) in an experiment using uppercase and script versions of words. As pointed out in the introduction, there are obvious limiting conditions, such as very small sizes or defocused words, in which only configural information can (and would) be used. Thus any

conclusion that configural information is used only in addition to, rather than instead of, letter information has to be limited to those circumstances in which letter information, at some level, is clearly perceptually available, and that circumstance did hold in these experiments.

As indicated earlier, establishing general conclusions about the role of configuration is difficult, and therefore conclusions drawn from any single set of experiments must be limited. There are in particular two reservations that must be maintained concerning the conclusion that letter information rather than configural information predominated in these experiments. The first reservation concerns whether overall word configuration is the only type of configural information to be considered and, indeed, whether there were differences in whole-word configuration only with words in lowercase. As pointed out earlier, even words in uppercase do have configural properties, and it may be that the use of lower- rather than uppercase letters did not give sufficiently greater whole-word configural differences. Still further, there can be configural differences within words, either within letters or within pairs of adjacent letters. Certainly, it is possible that the necessary change of the middle vowel from E to A in the second experiment also changed configural relations within parts of the uppercase words. To illustrate, the final Y or T in Experiment 2 was responsible for more errors than the final G or T in Experiment 1. This difference may have been due to the configural interaction between the middle vowel and the final consonant. Such a supposition is at least reasonable with the AY or AT format of the words in Experiment 2, in which the slope of the A could easily interact in a configurally meaningful way with the slope of the Y. Our data are insufficient to make these kinds of distinctions.

The second reservation is about the generality of the conclusion concerning the primary role of letters for normal reading. The task used in these experiments was simple identification of short words, with only four words in a set; similarly, simple tasks and constrained sets of words have been used in most other research showing the primary (or at least preliminary) use of letter information in word perception. With more complicated tasks or word sets, such as Brooks (1977) has used, there appears to be greater evidence that word configuration is important in reading. Configurations of words might well be the primary source of word (or even phrase) information in more realistic reading tasks.

REFERENCES

- BARON, J. The word-superiority effect: Perceptual learning from reading. In W. K. Estes (Ed.), *Handbook of learning and cognitive processes* (Vol. 6). Hillsdale, N.J.: Erlbaum, 1978.
- BOUWHUIS, D., & BOUMA, H. Visual word recognition of three-letter words as derived from the recognition of the constituent letters. *Perception & Psychophysics*, 1979, 25, 12-22.
- BROOKS, L. Visual pattern in fluent word identification. In A. S.

- Reber & D. L. Scarborough (Eds.), *Toward a psychology of reading*. Hillsdale, N.J.: Erlbaum, 1977.
- CHANG, J. -J., & SHEPARD, R. N. Meaningfulness in classification learning with pronounceable trigrams. *Journal of Verbal Learning and Verbal Behavior*, 1964, 3, 85-90.
- ESTES, W. K. Interactions of signal and background variables in visual processing. *Perception & Psychophysics*, 1972, 12, 278-286.
- ESTES, W. K. Memory, perception and decision in letter identification. In R. L. Solso (Ed.), *Information processing and cognition: The Loyola symposium*. Hillsdale, N.J.: Erlbaum, 1975.
- ESTES, W. K. On the interaction of perception and memory in reading. In D. LaBerge & S. J. Samuels (Eds.), *Basic processes in reading: Perception and comprehension*. Hillsdale, N.J.: Erlbaum, 1977.
- GARNER, W. R. *Uncertainty and structure as psychological concepts*. New York: Wiley, 1962.
- GARNER, W. R. *The processing of information and structure*. Potomac, Md: Erlbaum, 1974.
- GARNER, W. R. Aspects of a stimulus: Features, dimensions, and configurations. In E. H. Rosch & B. B. Lloyd (Eds.), *Cognition and categorization*. Hillsdale, N.J.: Erlbaum, 1978. (a)
- GARNER, W. R. Selective attention to attributes and to stimuli. *Journal of Experimental Psychology: General*, 1978, 107, 287-308. (b)
- GARNER, W. R. The analysis of unanalyzed perceptions. In M. Kubovy & J. R. Pomerantz (Eds.), *Perceptual organization*. Hillsdale, N.J.: Erlbaum, 1981.
- GARNER, W. R., & HAUN, F. Letter identification as a function of type of perceptual limitation and type of attribute. *Journal of Experimental Psychology: Human Perception and Performance*, 1978, 4, 199-209.
- HUEY, E. B. *The psychology and pedagogy of reading*. New York: Macmillan, 1908.
- JOHNSTON, J. C., & McCLELLAND, J. L. Visual factors in word perception. *Perception & Psychophysics*, 1973, 14, 365-370.
- KINCHLA, R. A., & WOLFE, J. M. The order of visual processing: "Top-down," "bottom-up," or "middle-out." *Perception & Psychophysics*, 1979, 25, 225-231.
- KOLERS, P. A. Three stages of reading. In H. Levin & J. P. Williams (Eds.), *Basic studies on reading*. New York: Basic Books, 1970.
- LABERGE, D., & SAMUELS, S. J. Toward a theory of automatic information processing in reading. *Cognitive Psychology*, 1974, 6, 293-323.
- MASSARO, D. W. Primary and secondary recognition in reading. In D. W. Massaro (Ed.), *Understanding language*. New York: Academic Press, 1975.
- MASSARO, D. W., & SCHMULLER, J. Visual features, preperceptual storage, and processing time in reading. In D. W. Massaro (Ed.), *Understanding language*. New York: Academic Press, 1975.
- McCLELLAND, J. L. Letter and configuration information in word identification. *Journal of Verbal Learning and Verbal Behavior*, 1977, 16, 137-150.
- PURCELL, D. G., STANOVICH, K. E., & SPECTOR, A. Visual angle and the word superiority effect. *Memory & Cognition*, 1978, 6, 3-8.
- SILVERMAN, W. P. Can "words" be processed as integrated units? *Perception & Psychophysics*, 1976, 20, 143-152.
- SILVERMAN, W. P. Are visually presented one-syllable words integral stimuli? *Bulletin of the Psychonomic Society*, 1977, 9, 103-105.
- SMITH, E. E., & SPOEHR, K. T. The perception of printed English: A theoretical perspective. In B. Kantowitz (Ed.), *Human information processing: Tutorials in performance and cognition*. Hillsdale, N.J.: Erlbaum, 1974.
- WOODWORTH, R. S. *Experimental psychology*. New York: Holt, 1938.

(Received for publication November 7, 1980;
revision accepted February 23, 1981.)