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STUDIES IN DISPLAY SYMBOL LEGIBILITY

Part XVIII. The Relative Legibility of Uppercase and Lower Case Typewritten Words

JUNE 1967

G. C. Kinney

D. J. Showman

Prepared for

DEPUTY FOR COMMAND SYSTEMS
COMPUTER AND DISPLAY DIVISION
ELECTRONIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
L. G. Hanscom Field, Bedford, Massachusetts

Project 512C
Prepared by
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FOREWORD

This report is one of a series describing symbol legibility for television display. Additional information on this topic may be found in the following reports: "Studies of Display Symbol Legibility: The Effects of Line Construction, Exposure Time, and Stroke Width," by B. Botha and D. Shurtleff, The MITRE Corp., Bedford, Mass., ESD-TR-63-249, February 1963; "Studies of Display Symbol Legibility, II: The Effects of the Ratio of Width of Inactive to Active Elements Within a TV Scan Line and the Scan Pattern Used in Symbol Construction," by B. Botha and D. Shurtleff, The MITRE Corp., Bedford, Mass., ESD-TR-63-440, July 1963; "Studies of Display Symbol Legibility, III: Line Scan Orientation Effects," by B. Botha, D. Shurtleff, and M. Young, The MITRE Corp., Bedford, Mass., ESD-TR-65-138, May 1966; "Studies of Display Symbol Legibility, IV: The Effects of Brightness, Letter Spacing, Symbol Background Relation, and Surround Brightness on the Legibility of Capitol Letters," by D. Shurtleff, B. Botha, and M. Young, The MITRE Corp., Bedford, Mass., ESD-TR-65-134, May 1966; "Studies of Display Symbol Legibility, V: The Effects of Television Transmission on the Legibility of the Common Five-Letter Words," by G. Kosmider, The MITRE Corp., Bedford, Mass., ESD-TR-65-135, May 1966; "Studies of Display Symbol Legibility, VI: Leroy and Courtney Symbols," by D. Shurtleff, and D. Owen, The MITRE Corp., Bedford, Mass., ESD-TR-65-136, May 1966; "Studies of Display Symbol Legibility, VII: Comparison of Displays at 945- and 525-Line Resolutions," by D. Shurtleff and D. Owen, The MITRE Corp., Bedford, Mass., ESD-TR-65-137, May 1966; "Studies of Display Symbol Legibility, VIII: Legibility of Common Five-Letter Words," by G. Kosmider, M. Young, and G. Kinney, The MITRE Corp., Bedford, Mass., ESD-TR-65-385, May 1966; "Studies of Display Symbol Legibility, IX: The Effects of Resolution, Size and Viewing Angle of Legibility," by D. Shurtleff, M. Marsetta, and D. Showman, The MITRE Corp., Bedford, Mass., ESD-TR-65-411, May 1966; "Studies of Display Symbol Legibility, X: The Relative Legibility of Leroy and Lincoln/MITRE Alphanumeric Symbols," by D. Showman, The MITRE Corp., Bedford, Mass., ESD-TR-66-115, August 1966; "Studies of Display Symbol Legibility, XI: The Relative Legibility of Selected Alphanumerics in Two Fonts," by G. Kinney and D. Showman, The MITRE Corp., Bedford, Mass., ESD-TR-66-116, August 1966; "Studies of Display Legibility, XII: The Legibility of Alphanumeric Symbols for Digitalized Television," by G. Kinney, M. Marsetta, and D. Showman, The MITRE Corp., Bedford, Mass., ESD-TR-66-117, August 1966; "Studies of Display Symbol Legibility, XIII: Studies of the Legibility of Alphanumeric Symbols in the BUIC Symbol," by G. Kinney and D. Showman, The MITRE Corp., Bedford, Mass., ESD-TR-66-302, August 1966; "Studies in Display Symbol Legibility, XIV: The Legibility of Military Map

Symbols on Television" by M. Marsetta and D. Shurtleff, The MITRE Corp., Bedford, Mass., ESD-TR-66-315, September 1966; "Studies of Display Legibility, XV: Relative Legibility of Leroy and Teletypewriter Symbols," by G. L. Bell, The MITRE Corp., Bedford, Mass., ESD-TR-66-316, September 1966; "Studies of Display Legibility, XVI: The Legibility of Teletypewriter Symbols on Television," by G. L. Bell, The MITRE Corp., Bedford, Mass., ESD-TR-67-104, April 1967; and "Studies in Display Symbol Legibility, XVII: The Legibility of the Lincoln/MITRE Font on Television," by D. Shurtleff, The MITRE Corp., Bedford, Mass., ESD-TR-67-105, April 1967.

REVIEW AND APPROVAL

This report has been reviewed and is approved.

CHARLES A. LAUSTRUP, Colonel, USAF
Chief, Computer and Display Division

ABSTRACT

The relative legibilities of common words typewritten in all-uppercase and all-lowercase letters were studied in three experiments. Human subjects identified the words shown one at a time for a short period. All-uppercase printing was found to be significantly more legible than all-lowercase in all three experiments. The "word-form" of all-lowercase words was not found to to influence word identification. The use of uppercase letters is recommended for displays.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

SECTION I

INTRODUCTION AND BACKGROUND

The relative legibility of lowercase and uppercase (capital) letters is of interest in the design of visual displays for military systems just as it is in the fields of printing, advertising, product labeling, and entertainment. The designer of system displays has a special problem in legibility whenever his application does not provide the ordinary contextual meaning, spacing and punctuation, and the high resolution of the printing press to help the viewer read his displays. The display designer needs every advantage he can get, and any reasonably attainable increase in legibility is worth having.* Many displays use all capital letters, but since the average reader is trained to read lowercase printing, it may be possible to make gains in display legibility by using lowercase symbols. Therefore, it is worthwhile to determine whether lowercase letters are more legible than uppercase letters for reading tasks like those found with system displays.

There are several reasons for suspecting that lowercase symbols are better. Several investigators have reported that lowercase printing is read faster and more accurately than is all-uppercase printing.[1,2,3,4,5] Tinker has repeatedly drawn attention to the effects of lowercase word-form in making words more legible.[3,6,7,8] The difference in word-form

*See Ref. 10 for a discussion of current problems.

between a lowercase and uppercase word is shown in Figure 1, in the manner of Tinker. Since lowercase letters are more varied in design than the capitals, (having two large sizes, with one protruding above the line and the second below, and a small size), it is conceivable that lowercase letters would retain superior discriminability when seen alone or out of the context of common words and phrases.

However, there are several experiments in which the uppercase letters and words were found more legible. In the references cited,* all authors found that capital letters and words in all capitals were correctly identified farther from the eye than were lowercase letters or words. Hodge also found that words in all capitals were of superior legibility to words printed with an initial capital and the rest of the letters in lowercase.(9) Berger disagrees with Tinker on the benefits of lowercase word-form; "Form of words as such due to differences in grouping of constituent letters appears to have no specific influence upon [the distance threshold of recognition] of words."** These findings support the contention that uppercase letters would be better for use in systems wherever unusual reading tasks are involved.

It is not surprising to find, also, those experiments which support neither uppercase nor lowercase printing. Crook, Hanson and Weisz, in an elaborate study of several typographical variables, found that, "Capitals could be read more readily than lowercase when occupying the same printing

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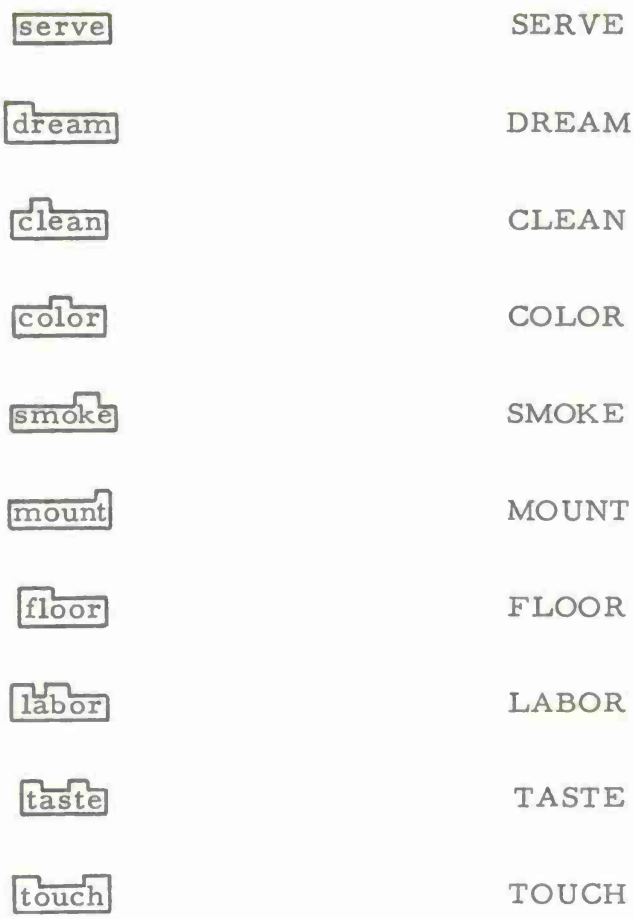
* Tinker,(3,8, p. 59) Paterson and Tinker,(7) Berger,(10) Hodge,(9,11) and Forbes, Moscowitz and Morgan.(15)

** See Reference 10, p. 222, (italics his).



This figure illustrates word-form after Tinker, of words in all-lowercase letters, and their counterparts in all-uppercase letters. The ten word-forms were those of Experiment 3, and the words were taken from the lists used and are shown here with the same type face.

Figure 1. Word-Form After Tinker

area" (see their Abstract and Figure 1).[12] Unfortunately, they use a cross-out task for lowercase and an oral reading task for uppercase, which makes a direct comparison depend upon their "legibility score." Fox compared lowercase printing with all-capital printing in which the capitals were of the same size, and occupied the same line distance, as the smaller lowercase.[13] He found no significant differences between the two letter cases in speed and accuracy of reading when the subjects were instructed to read for comprehension alone. He also found no differences in comprehension when the subjects were instructed to read as rapidly as possible, and no differences in average rate of reading. Paterson and Tinker showed headlines to subjects with the exposure held constant at 180 milliseconds.[7] They reported no difference between uppercase and lowercase letters. Tinker studied the rate of eye blinking while reading text printed either in all-uppercase or in all-lowercase letters.[14] His data show more blinks when reading the lowercase letters, but the differences were reported not to be statistically significant. This result lead Tinker to reject blink rate as a measure of legibility.

Hodge found no difference in the distance threshold of confusion between the large and small lowercase letters, concluding that the legibility of lowercase letters depends largely upon the smaller details of their construction.[11] Since his conclusion in this regard is probably applicable to the uppercase letters, one is left to guess about the relative perceptibility of detail in uppercase letters.

In addition to differences in experimental results, there are differences of opinion. The two extremes are represented by Tinker and Hodge.[3,9] Tinker wrote, "The use of all capitals should be dispensed with in every printing situation."* Hodge wrote, "The data were interpreted as indicating that, for optimal performance, single-word instrument panel labels should be printed in all uppercase letters ...", and he noted "The lack of agreement between these findings and a large portion of the legibility research literature ..."** There are opinions between these extremes all of which make it clear that the issue is not resolved.

Part of the confusion has arisen because different writers use the term "legibility" with different meanings. As Cornog, Rose and Walkowicz point out, "In the legibility literature, there is much confusion and overlap in the usage of the terms legibility, readability, perceptibility and visibility." "In general, legibility refers to the characteristics of printed, written or other displayed meaningful symbolic material which determine the speed and accuracy with which the material may be read or identified."*** (Their bibliography contains approximately 300 items.) Obviously, if more legible means superior performance in all reading situations, then the argument will go on forever.

Yet, the data of the literature are in agreement on at least two counts. First, there seems to be no doubt that standard text is read

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* See Reference 3, p. 65.

** See Reference 9, p. 66.

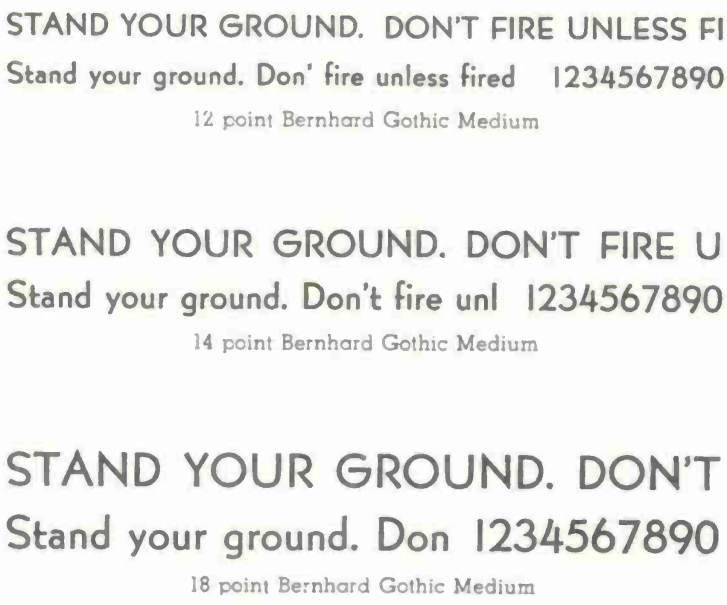
*** See Reference 15, pp. 1-2.

more rapidly and accurately in lowercase than in uppercase printing; second, that capital letters and words are read at a greater distance than lowercase of the same point size.

Point size is a term for the size of a set of uppercase and lowercase symbols as shown in Figure 2. A point is an arbitrary unit of length usually given in reference works as approximately 1/72 (0.0139) inch, but being closer to 0.0135 inch for letters up to 14 points. (The unit applies to the thickness of the lead bar on which the letters are embossed, but the letter height is less than this thickness.) It is clear from inspection of Figure 2 that the letters within a given point size are of different heights and various widths (see Figure 3 for other type faces).

Since the distance at which a letter can be correctly perceived is proportional to the size of the letter (within rather narrow limits), it is clear why the capital letters are seen farther from the eye, on the average, than are the lowercase letters. Indeed, a comparison of uppercase and lowercase letters or words using a given point size and the distance of correct perception as the measurement of legibility is biased in favor of the uppercase letters. Thus, it is easy to understand the results of experiments like those of Hodge.[9,11]

It is also easy to understand why the lowercase letters are found to be more legible when the measure is speed of reading. One reason is that all, or nearly all, reader subjects have more vast experience reading lowercase printing than they have with uppercase printing. A second reason is that the letter widths in lowercase are smaller, and the denser



The relative heights of the uppercase and lowercase letters for three different point sizes may be compared in this figure. (From A Specimen Book of Types, Lexington Press, Inc., Lexington, Massachusetts.)

Figure 2. Relative Heights of The Uppercase and Lowercase Letters for Three Different Point Sizes

s m i l e	S M I L E
B E C O M E	b e c o m e
C H I E F	c h i e f
a c c e p t	A C C E P T
r a t h e r	R A T H E R
F I F T Y	f i f t y
K N O W N	k n o w n
o u g h t	O U G H T
R E P O R T	r e p o r t
e i g h t	E I G H T

Figure 3. Showing The First Ten Words From The Two Lists, and With The Type Face of Experiment 1

printing puts more words to the inch and requires less inches of visual scan per word or phrase. Furthermore, many experiments on speed of reading use a standard English text, such as newspaper articles or common sentences. In this circumstance, the redundancy of words and phrases enhances ease of scanning lowercase printing more than uppercase because more print is scanned per inch with the smaller lowercase printing, and the more print scanned, the more likely is the seeing of a redundant word or phrase. Thus, these experiments find that lowercase printing is more legible than uppercase in precisely those situations best suited to give lowercase printing the advantage.

What about the reading situation of a visual display in a military system? Which form of printing has the advantage there? The materials to be read are not common text and are not being viewed at maximum distance. The criteria of legibility are the speed and accuracy of recognition of letters and words seen at viewing distances from which the letter height subtends a visual angle of approximately 10 to 20 minutes of arc. In many display devices, such as cathode ray tubes, symbol matrices (Nixie tubes are an example), status boards and many high speed printers, the space allotted for a letter or numeral is fixed in height and width. In these situations, the small lowercase letters (a, c, e, i, m, n, o, r, s, u, v, w, x, and z, comprising half plus one of the alphabet) would be much smaller than the fixed space. To make the space for these letters larger would waste the display area, and to use these letters at normal size would risk losses in legibility when the number of required symbol spaces

is large and the size of each space smaller. To make the small lowercase letters as large as the allotted space allows would require keeping the large lowercase letters in the same space, and the display's resemblance to ordinary lowercase printing would nearly vanish, along with any related advantage. There seems to be no immediately obvious way either to decide which type form to use, or to modify the symbol shapes to better advantage.

The question of interest may be answered in part by experimenting on the speed and accuracy of word recognition under reading and viewing conditions similar to those found in displays. Subjects could be shown common words, either in all-lowercase or all-capitals, for brief exposure periods, and the speed and accuracy of word identification measured. This report discusses two such experiments. The effects of word-form on speed and accuracy of identification of lowercase words were examined in a third experiment. The experiments and their results are described briefly below, and in more detail in the sections which follow.

In the first experiment, 30 subjects saw common five-letter and six-letter words typed in all-lowercase or all-uppercase letters with an extra space between letters to compensate for the closer spacing of all capital printing on the typewriter. The words were exposed for 100 milliseconds and reading time was recorded for each word. The average reading time for all capitals was significantly faster than for words in all lowercase; the values are shown in Table I.

The second experiment repeated the first experiment, but there were 27 subjects and there was no extra space between letters. In addition,

TABLE I

Mean Response Times and Errors for Both Letter Cases in Experiment 1.

	Mean Response Time in Seconds	Number of Errors	Percentage Error
Uppercase	.552	21	1.5%
Lowercase	.576	23	1.5%

the words were typed on a different machine whose output is closer in appearance to standard print. Again, the all-uppercase words were read faster than the all-lowercase words, and the difference was statistically significant (see Table I).

From these two experiments it was concluded that speed and accuracy of recognition of words in all-uppercase letters is superior to that with all-lowercase letters.

The third experiment examined the effect of word-form on the recognition of words in all-lowercase, and at the same time made a third comparison of all-uppercase and all-lowercase printing using a different method. The results lead to the conclusions that word-form has no significant effect on the recognition of all-lowercase words seen in isolation, and that words in all-uppercase printing are recognized more quickly than are words in all-lowercase printing.

All three experiments gave results in favor of all-uppercase printing, and it was concluded that such printing is suitable and probably preferable for those displays in which standard textual features do not occur. Details of the experiments follow.

SECTION II

EXPERIMENT 1

PURPOSE

The purpose of this experiment was to compare the recognition time of subjects reading common words typed in uppercase letters with the time for the same words in lowercase letters. Since each word was seen in isolation and in a random sequence, there was no redundancy between words, as there would be in a normal sentence, but there was redundancy between letters, of course. It was assumed that the amount of redundancy in the word stimuli approximated the redundancy found in many system displays, and that the results of the comparison would apply to these system situations.

The words were shown at random in two lengths (five-letters and six-letters), and the two letter cases also appeared in a random sequence. Thus, the subject did not know in advance which word, nor which letter case, would be shown next. Furthermore, in an attempt to control the effects of letter case preference and reading habits (such as eye movement and visual scanning habits), each word was shown for 100 milliseconds. In addition, the subjects were told that the experiment was a study in perception time; the real interest in letter case was not mentioned. This latter precaution seemed wise even if its success in avoiding the effects of reader preferences is unknown.

APPARATUS

Sixty common five-letter and six-letter words were taken from Thorndike and Lorge's Teacher's Word Book of 30,000 Words, and all occurred 100 or more times per million words in their count. The sixty words were typed on a length of white adding machine tape with an IBM standard electric typewriter which had Prestige Elite type and a new carbon ribbon. The words were typed one above the other; each was centered about a line parallel to the edge of the tape, and typed with one space between each letter. The sixty words included ten practice words and fifty test words. Half of the test words were typed in lowercase and half in uppercase. Of the twenty-five test words in lowercase, 12 had five letters and 13 had six letters; of the twenty-five uppercase words, 13 had five letters and 12 had six letters. The ten practice words similarly were composed of five uppercase (three five-letter and two six-letter) words and five lowercase (two five-letter and three six-letter) words. The practice words and the test words were arranged in an order random with respect to word length, letter case, or alphabetical order.

A second list (List 2) containing the same sixty words as the first list (List 1), and in the same order, was typed on a length of white adding machine tape in the same manner as List 1; in List 2 the words which were in lowercase in List 1 were in capitals, and the words which were in capitals in List 1 were in lowercase (see Figure 3).

Because the strokes of each letter were variable in width, a wide stroke and a narrow stroke were measured for each letter in addition to

letter height and width. The average height-to-width ratio was 1.2 for both lowercase and uppercase letters. The average ratio of height to narrow stroke-width was 6.1 for lowercase and 6.5 for uppercase; the average ratio of height to wide stroke-width was 10.0 for lowercase and 10.2 for uppercase.

The words were shown in a Gerbrands tachistoscope to each subject. The tachistoscope (Model T-2B-1) is L-shaped with square cross-section (approximately 7-1/2 inches by 7-1/2 inches). The subject's eyepiece is at the intersection of the two arms, with the area at the end of one arm (Field S, the stimulus field) 26 inches away in a straight line from the eyepiece. A partially reflecting mirror at the intersection of the two arms, at a 45^{o} angle to each arm, transmits the image of Field S and reflects the image at the end of the other arm (Field B, the background field, also 26 inches away).

Each field, when turned on, was illuminated from the front by two fluorescent lamps masked from the subject's view. The two fields were painted flat white. A small rectangle drawn in the center of Field B allowed the subject to fix his eyes where the words would appear. The tape containing the words was passed behind a small rectangular slot in the center of Field S, the same size (just large enough to expose one word at a time) and in the same visual position as the rectangle in Field B. Each field could be illuminated independently of the other by means of an electronic timer; the subject saw one field at a time, with the other in darkness. Field B, the pre-exposure field, was lighted

continuously except for the time that Field S was lighted. When the subject pressed the button, Field S was illuminated after a 500 ms delay, just as Field B shut off, so that there was no noticeable break in the brightness; Field S, with the word in the center, was lighted for 100 ms, after which it shut off and Field B again was lighted.

Thus, the subject saw a lighted field all the time, with a brief exposure of the word in the center of a white field preceded and followed by a plain white field with a rectangle in the center. The brightness of each field was measured through the eyepiece of the tachistoscope with a Spectra Brightness Spot Meter. The brightness of the pre-exposure field was approximately 7.5 fL where the words appeared, and the white part of the tape surrounding the words was approximately 9 fL.

A timer started when the subject pressed the button, and stopped when the subject spoke into a microphone. The clock indicated the subject's response time plus the 500 ms delay before the word exposure; equipment delays were measured and found to be negligible, and the time indicated minus 500 ms was taken as the subject's response time.

The height of uppercase letters subtended 13 minutes of arc at the subject's eyes. The height of the tall lowercase letters (b, d, f, g, h, i, j, k, l, p, q, t, y) subtended approximately 13.5 minutes of arc, and the thirteen small lowercase letters subtended approximately 9.5 minutes of arc.

PROCEDURE

The subjects were 30 MITRE employees. All scored at least 20/20, either corrected or uncorrected, for both near acuity and far acuity in the Bausch and Lomb Ortho-Rater, and had normal color vision, phoria, and depth perception.

Subjects were tested one at a time. Each subject was told that the experiment was a test of perception time; he was instructed to call out each word as quickly as possible, and to guess if he was not sure of a word. The subject looked into the tachistoscope, and when his eyes were fixated on the rectangle and he was ready to see the word, he pressed his button. The experimenter recorded the reaction time to each word and whether the response was correct or incorrect, and advanced the tape to the next word, after which the subject again pressed the button when he was ready to see the next word. After the subject was shown the practice words and twenty-five test words, he was given a brief rest, after which he was shown the last twenty-five test words. Half of the subjects were shown List 1 and the other half List 2; assignments of subjects to lists were made at random.

RESULTS AND CONCLUSIONS

The mean response times and errors are shown in Table I. The difference between the means is statistically significant (correlated $t = 4.44$, $p < .005$), but the difference in frequency of error is not, though there were more errors made with lowercase.

Conclusion: Common words typed with one space between adjacent letters are recognized more quickly when printed with all uppercase letters than with all lowercase letters, there being no difference in accuracy.

The results and conclusions are discussed after the description of the third experiment.

SECTION III

EXPERIMENT 2

PURPOSE

The second experiment was done to see if the results of the first experiment, namely that words in all-uppercase letters were read faster, depended upon the inter-letter spacing, which may have favored the upper-case words. Therefore, for the second experiment, the words were typed on a different typewriter with variable inter-letter spacing whose typed output looks more like regular printing. In all other respects, this experiment repeated the first one.

APPARATUS AND PROCEDURE

The apparatus and the procedure were the same as in Experiment 1 except that a new list of 60 five-letter and six-letter words was compiled; the words occurred 100 or more times per million in the Thorndike and Lorge count. The list was typed twice on lengths of white adding machine tape with an IBM executive typewriter having Modern type. One list was the opposite of the other with respect to letter case, as before. The words were typed with no extra spacing between the letters. Thus, the words in this experiment appeared more as they do in most printed matter. In general, the capitals were wider than the lowercase letters, so that a word typed in capitals was wider than the same word typed in lowercase (see Figure 4).

enough	ENOUGH
dance	DANCE
PRESS	press
change	CHANGE
MOMENT	moment
STRIKE	strike
HONOR	honor
watch	WATCH
THING	thing
voice	VOICE

Figure 4. Showing The First Ten Words From The Two Lists, and With The Type Face of Experiment 2.

Twenty-seven of the 30 subjects in Experiment 1 served as subjects in Experiment 2. Fourteen subjects saw one list and thirteen saw the other, again being assigned at random.

RESULTS AND CONCLUSIONS

The mean response times and errors are shown in Table II. The difference between the means is statistically significant (correlated $t = 2.00$, $p < 0.05$). The error frequencies were too small to permit statistical analysis. If the errors in Experiments 1 and 2 are pooled (uppercase = 24, lowercase = 34) the difference is not statistically significant ($\chi^2 = 1.72$, $0.10 < p < 0.20$).

Conclusion: Common words typed with style and spacing similar to ordinary print are recognized more quickly when printed in all uppercase letters than in all lowercase letters.

The results and conclusions are discussed after the description of the third experiment.

TABLE II

Mean Response Times and Errors for Both Letter Cases In Experiment 2

	Mean Response Time in Seconds	Number of Errors	Percentage Error
Uppercase	.525	3	0.4%
Lowercase	.534	11	1.7%

SECTION IV

EXPERIMENT 3

PURPOSE

The purpose of the third experiment was to investigate the effects of word-form on the recognition of words typed in all-lowercase letters. This experiment was suggested to the authors by some of Tinker's comments. In discussing some of his results he wrote, "... total word-form is more important in perceiving words in lowercase than in all capitals where perception occurs largely by letters. This conclusion is supported by the fact that words in lowercase yielded more misreadings than words in capitals. In the lowercase print, the incorrect word frequently had a total configuration or form similar to that of the stimulus word."* Also, "... word-form is absent when printed in all capitals."** It follows that the influence of word-form can be studied by examining the distribution of errors made when subjects read words in lowercase.

This is to say that if words in lowercase are of, say, 10 different word-forms (see Figure 1), and are shown to subjects who make errors in reading the words, then the words which were given in error should be words whose form is the same as the form of the word that was actually shown when the error was made. At least, the errors made should be distributed proportionately more to the same form than to different forms.

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* See Reference 16, pp. 59 and 60.

** See Reference 11, p. 25.

The scheme of the experiment is to give the subject a printed list of words in lowercase from which he must choose his guess when a word is shown to him. The list would contain some words of the same form and other words of different form. The subject is made to guess from the list by showing him a word at such a short exposure time that he would be so uncertain of his identification as to refer to the list. If the subject is allowed to examine the list and choose his response without hurrying, the hypothesis is that if he chose wrongly, he would choose a word whose form is the same as that of the word shown.

Furthermore, if the subject was shown words in both uppercase and lowercase in random sequence, and the same guessing procedure was followed for both cases, and each word appeared in both cases, then his responses to uppercase words could be used as an indicator of his guessing preferences. Since each word would be in both uppercase and lowercase letters, the uppercase words fall into two classes, those whose lowercase counterparts are of the same word-form as the word shown, and those whose lowercase counterparts are of different word-form. Therefore, the subject's distribution of errors made for uppercase words (which lack word-form) is the best estimate of his guessing preferences <u>in the absence of word-form</u>. This distribution is thus the distribution expected to occur, without the effects of word-form, and it may be compared directly to the distribution which occurred with the lowercase words where the effects of word-form should appear.

If each word was shown to the subject at an exposure time too short for ready recognition, and the time was increased by small steps until correct identification occurred, a sample of erroneous responses would be generated. Finally, the exposure time required for correct recognition of uppercase words could be compared to that for lowercase words as another way of examining their comparative legibilities. The details of Experiment 3 follow.

APPARATUS AND PROCEDURE

Twenty-four common five-letter words (twenty test words and four practice words) were selected from Thorndike and Lorge's lists; all occurred between 50 and 100 times per million words in their count. To make up the twenty test words, two words of each of ten word shapes were chosen. The term "word shape" here refers to the distribution of tall letters (b, d, f, h, k, l, and t) and small letters (a, c, e, m, n, o, r, s, u, v, w, x, z) within a word typed or printed in lowercase, which give the word a characteristic outline, after Tinker.[16] For example, the words floor and there were considered to have the same word shape. The ten word shapes used in this experiment are shown in Figure 1, and were as follows: one shape with five small letters, five shapes with one tall letter in one of the five letter positions within the word with the other four letters being small, and four shapes with a tall letter as the first letter of the word and one other tall letter at one of the four remaining letter positions. The practice words had shapes different from any of the test words.

The list was typed on white adding machine tape with an IBM Executive typewriter, as was done for Experiment 2 (see Figure 1). On the typed list each word appeared once in lowercase and once in capitals, the order of words on the list being random with respect to letter case, word shape, or alphabetical order.

Two additional lists for the subject to choose from in responding were prepared. The two lists contained the same words; all the words were typed in capitals on one list, and all were in lowercase on the other list. Each list had forty words, the twenty test words and twenty words not appearing on the test list. The additional twenty words included two words of each of the ten word shapes listed above. Thus, the lists contained four words (two test words and two extra words) of each of the ten word shapes. Each list was typed with the same IBM Executive typewriter on a sheet of white bond paper, and the words were listed in alphabetical order.

The words were shown in the tachistoscope described previously. As before, the delay between the time the subject pressed his button and the exposure of the word was 500 ms. Seven subjects, all screened for 20/20 visual acuity, were tested. Each subject was told that the experiment was a test of guessing preferences, and not to worry about making errors. Each word was shown several times in succession, with each exposure of the word 2 ms longer than the last exposure, until the subject guessed the word correctly one or more times. The subject was required to guess at each exposure of a word, choosing a word from the two lists before him.

Since the errors were of interest, the experimenter selected a time for the first exposure of each word which would probably produce an error; the practice words gave the experimenter an idea of what exposure time would produce errors. The time at which each word was first shown could vary within a session, and was different for different subjects. Each word was shown at least two times and not more than eight times. A brief rest was given after half the words. The subject's response was recorded for each word at each exposure time it was shown.

RESULTS AND CONCLUSIONS

The errors made by all subjects were pooled. The distribution of all errors made in the experiment is shown in Table III. The errors made with uppercase words were assigned to the same or different word-form according to whether their counterparts in lowercase were of the same or different word-form, as discussed earlier. With the distribution for uppercase errors as the expected frequencies, the distribution of lowercase errors to same or different word-form was not significantly different from chance ($\chi^2 = 2.52$, $0.10 < p < 0.20$).

Another, and similar test of the same hypothesis was made for those errors which immediately preceded a correct word identification (see Table IV). Again, the distribution of lowercase errors to same or different word-form was not significantly different from chance ($\chi^2 = 3.34$, $0.05 < p < 0.10$).

Conclusion: Word-form, as defined here, has no significant effect on the recognition of lowercase words seen in isolation.

TABLE III

Total Errors Made by All Subjects in Experiment 3

	Same Word-Form	Different Word-Form
Lowercase	46	239
Uppercase	28	187

Total errors made by all subjects in Experiment 3 when the words were of the same or different word-form than the word actually shown. The errors made with uppercase were taken as the correction for guessing preferences.

TABLE IV

Errors by All Subjects During Experiment 3 Trial

	Same Word-Form	Different Word-Form
Lowercase	26	102
Uppercase	18	105

Errors made by all subjects in Experiment 3 on the trial immediately before a correct word identification when the words were of the same or different word-form than the word actually shown. The errors made with uppercase were taken as the correction for guessing preferences.

The frequencies of occurrence of the first correct word identifications for both uppercase and lowercase words are shown for different exposure times in Table V. The data for 4 and 6 milliseconds, and for 12 and 14 milliseconds, were each pooled as shown because the frequencies for 4 and 14 milliseconds were too small for a Chi Square analysis. The distribution shown in Table IV is significantly different from chance expectancies ($\chi^2 = 29.77$, $p < 0.01$), and indicates that words in all-uppercase letters were recognized correctly at shorter exposure times than were words in all lowercase letters.

Conclusion: Common words seen in isolation are recognized more quickly when printed in all uppercase letters than when printed in all lowercase letters.

TABLE V

Occurrence of First Correct Word Identifications

	Exposure Time in Milliseconds			
	4 and 6	8	10	12 and 14
Lowercase	22	48	33	19
Uppercase	59	39	12	11

Frequency of occurrence of first correct word identifications for each exposure time for both letter cases, all subjects summed for Experiment 3.

SECTION V

DISCUSSION AND RECOMMENDATION

The time required by subjects to recognize words and speak them correctly is shown by the first two experiments to be shorter for uppercase than for lowercase printing. The third experiment substantiates these two findings by showing that correct word identification occurs at a shorter exposure time when the words are printed in all-uppercase letters. These findings were made when the words were seen free of the usual textual cues and visual scanning habits. It appears that for applications other than ordinary printing, the all-uppercase letters are to be preferred.

Since the actual differences in response times are all small, it might be argued on the basis of the literature that lowercase is to be preferred because of the advantages of word-form. This argument is unsound in view of the results of the third experiment. Here, not only was there no significant effect of word-form, but the uppercase words were seen at shorter exposure times.

Finally, since the occurrence of errors in all three experiments was in favor of the all-uppercase printing, the superior legibility of all-uppercase words in this study seems unambiguous.

It is recommended that uppercase letters be used in those applications other than ordinary printing. Such applications are found in military, government, and commercial displays.

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13. ABSTRACT

The relative legibilities of common words typewritten in all uppercase and all lowercase letters were studied in three experiments. Human subjects identified the words shown one at a time for a short period. All uppercase printing was found to be significantly more legible than all lowercase in all three experiments. The "word-form" of all lowercase words was not found to influence word identification. The use of uppercase letters is recommended for displays.

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