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Letter case and text legibility in normal and low vision

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Abstract

It is thought by cognitive scientists and typographers alike, that lower-case text is more legible than upper-case. Yet lower-case letters are, on average, smaller in height and width than upper-case characters, which suggests an upper-case advantage. Using a single unaltered font and all upper-, all lower-, and mixed-case text, we assessed size thresholds for words and random strings, and reading speeds for text with normal and visually impaired participants. Lower-case thresholds were roughly 0.1 log unit higher than upper. Reading speeds were higher for upper- than for mixed-case text at sizes twice acuity size; at larger sizes, the upper-case advantage disappeared. Results suggest that upper-case is more legible than the other case styles, especially for visually-impaired readers, because smaller letter sizes can be used than with the other case styles, with no diminution of legibility.

Keywords: Low vision; Legibility; Typography; Visual acuity; Reading speed

1. Introduction

There is conventional wisdom, supported by some evidence and logic within the fields of typography and cognitive science, that asserts that text set in mixed upper- and lower-case is more legible than all upper-case (all capital letters). Typographers generally point to the fact that word shape is more distinctive with mixed- and lower-case than it is with all upper-case, a virtue that results from the fact that all upper-case characters are the same height and have no ascenders and descenders, whereas lower-case characters, which have both ascenders and descenders vary in both height and average position, arguably making words constructed with them more distinctive due to more variation in the height of word contours (see Fig. 1).

Miles Tinker, an authority on legibility and typography said ''Lower-case letters have more 'character' in terms of variation in shape and the contrasting of ascenders and descenders with short letters. This leads to characteristic word forms that are much easier to read than words in all capitals'' (Tinker, 1963; p. 34). Tinker found that while upper-case text was perceived at a greater distance, it had a 'retarding effect' on reading speed, especially for long intervals of reading, and was preferred by only 10% of readers, compared with 90% for lower-case text (Tinker, 1932; Tinker & Patterson, 1929).

The evidence from cognitive science comes from tachistoscopic experiments that suggest that letter identification follows word identification rather than preceding it. Cattell (1886) early on showed that with tachistiscopic presentation, words are recognized more accurately than letters, a phenomenon that in various guises and variations, has come to be known as the ''word superiority effect.'' While there are alternate explanations of this and related effects, such as the greater ease with which letters are recognized within words than in isolation, it has been taken as evidence for a dominant role of word shape in word recognition, relative to letter recognition. Since lower-case words appear to have more distinct shapes than upper-case, there is the common belief that the word superiority effect is responsible for what is assumed to be the greater legibility of lower-case text.

There is a very sensible competing idea, however: that all upper-case text should be more legible since the letters are in general larger than in lower-case text. Enlarging nearly

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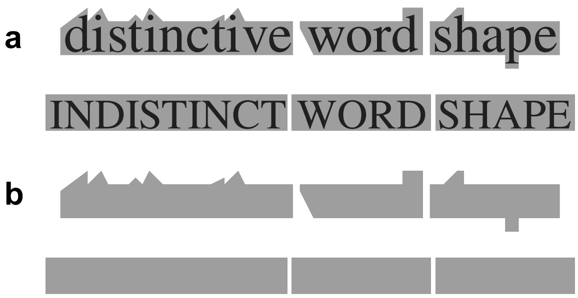

Fig. 1. Shapes of words in (a), outlined in (b), are more distinctive in mixed-case and lower-case than all upper-case text.

any small object makes it more visible, of course, and indeed nearly all optical vision aids rely on the enhanced visibility of magnified objects to achieve better visibility. Text set in visually small sizes in general, and low vision reading in particular, might be expected to benefit from the larger letter sizes of upper-case letters.

The issue of size complicates matters considerably in studies of legibiliity, however, since there does not seem to be any method for characterizing letter size that properly accounts for both upper- and lower-case letters. One may equate upper-case and lower-case character size by equating cap height (the height of a capital letter) to the x-height of lower-case letters. This generally results in findings of lower-case being more legibile than upper-case (Smith, Lott, & Cronnell, 1969). Since 12 of the 26 lower-case letters have ascenders and descenders that extend well above the x-height or below the baseline, respectively, this method of specifying letter size gives an unfair size advantage to lower-case letters. Characterizing letter size by overall font size (conventionally equal to cap height plus descent, at least for computer fonts), similarly, gives a size advantage to upper-case letters since 14 of the lower-case letters (those without ascenders or descenders) are smaller than virtually all the upper-case letters, in both breadth and height.

In this paper, we adopt the latter convention, of specifying letter size by font size, i.e. by the sum of cap height plus descent, which is usually specified in points. We do so because font size is usually specified in this fashion in typography and graphic design, without distinguishing between upper- and lower-case character size. This decision will allow us to make very practical conclusions that can be applied by any graphic designer. In the discussion, of course, we will consider the inherent size difference between letter cases, and weigh the potential advantage of enhanced word shape information in lower-case words against the letter size advantage of words set in upper-case.

2. Methods

We assessed relative legibility of different case conditions using three different criteria for legibility:

1. Size thresholds (visual acuity) for letter identification, measured with 5-letter, strings presented on a video monitor, using an up–down staircase (Levitt, 1971) with 0.05 log unit size steps. Size (or, inversely, distance) thresholds are probably the most common method for assessing text legibility (Tinker, 1963), and are widely used in applied settings such as highway signage, with lower size thresholds indicating higher legibility. We used two kinds of stimuli: random strings of all lower-, all-upper, and randomly selected case and 5-letter words, all upper- or all lower-case, randomly selected from the 2110 most frequent 5-letter words in English (Francis & Kucera, 1982).
2. Reading speeds using rapid serial visual presentation (RSVP). Higher legibility, by this criterion, allows faster reading. We measured reading speed using RSVP with small (two times acuity size) and large letters (roughly 10 times acuity size), using both all upper-case and conventional mixed-case text from an expanded MNREAD (Legge, Ross, Luebker, & LaMay, 1989) corpus. Reading speed is a less common measure of legibility but it is perhaps more representative of ordinary reading than is size threshold. And because RSVP can support extremely high rates of reading (Rubin & Turano, 1992), it has the potential to be more sensitive to subtle differences in legibility. RSVP reading was tested with individual sentences, whose speed was varied to determine the speed that supported a 50% correct (of words) reading rate.
3. Reading speeds using continuous reading of text passages taken from standardized tests (9th grade level). We included this condition to address possible differences between reading speeds with RSVP with those more commonly observed with continuous reading.

We also characterized participants' degree of vision loss with by assessing visual acuity with a transilluminated Lighthouse/ETDRS distance acuity chart. These measurements were also used in the computation of acuity reserve (see below).

2.1. Stimuli

2.1.1. Size thresholds: (Experiment 1)

In this experiment, random 5-letter strings were presented centered on a SONY Multiscan 520GS monitor, as black (3.6 cd/m^2) letters on a white (129 cd/m^2) background. Normally-sighted subjects viewed the screen optically folded through a front-surface mirror at an optical distance of 788.4 cm, so that letters were at least 100 pixels in height (from the top of an upper-case letter to bottom of the descent), or equivalently, for these fonts, 66.66 pixels in cap height. For these subjects, the letters were rendered in reverse on the screen to compensate for the mirror reversal. Subjects with low vision viewed the screen directly (i.e. with no mirror) at a viewing distance of 100 cm. Participants were seated comfortably in a chair, with head position fixed with a head and chin rest.

The random letter strings were constructed by sampling (with replacement) from the 26 letters of the English alphabet, and for the random case condition, then selecting the upper- or lower-case version of the letter randomly with probability 0.5.

2.1.2. RSVP reading (Experiment 2)

We used custom software to present each word of a sentence centered vertically and horizontally on the computer monitor, for a constant time interval. Text was black on white, as with the size thresholds. The participant read aloud each sentence as it was presented, prior to presentation of the next sentence.

2.1.3. Continuous reading (Experiment 3)

Four text passages of ninth grade-level reading difficulty, and approximately 400 words in length, were used. The subject read the text aloud continuously, while the experimenter timed the reading of the entire passage and recorded errors.

2.1.4. Font

We used TrueType Arial as the display font for the entire study. Arial was selected because it is found on most computers used for desktop publishing today, and because it has a large x-height, making it relatively less likely to produce legibility differences based on differences in relative size