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A New Teletext Character Set with Enhanced Legibility

FLORIS L. VAN NES

Abstract—**Teletext is difficult to read, partly because of the letter fonts employed. Present fonts are contained in a matrix of 6 (horizontal) × 10 (vertical) elements. Research on matrix characters of optimum legibility started in 1969 at the Institute for Perception Research. Criteria resulting from this research have now been used to design alphanumeric characters in a matrix of 12 × 10 elements for use in Teletext. Several versions of each character were designed and their legibility tested in recognition experiments. The legibility of the best new version for each letter was compared with and shown generally to be greater than that of the presently used version.**

I. Introduction

DOT-MATRIX characters are used for text display on conventional TV receivers in an increasing number of consumer-electronics applications, such as Teletext, videotex, electronic games, and personal computing. The resolution of a TV display is rather limited because of bandwidth limitations of the TV channel and the video amplifier, etc. Therefore, the dot matrix of which the characters are composed is relatively coarse, implying that they can only be schematic approximations of the elaborate detailed fonts used in print. In order to ensure good legibility of such schematic letters and digits, they should be designed with three criteria in mind [1]: acceptability, identifiability, and discriminability. A character has high acceptability when its shape closely corresponds to a concept that observers have of this shape; it is highly identifiable when its parts stand out clearly against the character background; it has high discriminability when the chances of it being confused with a similar character are low. Such confusion may occur under difficult observation conditions, such as low contrast between character and background or reading from a distance. A luminous contrast that is too low occurs, for instance, when red or blue letters are used on a black background, or yellow letters on a white background. With respect to viewing distance, applications such as Teletext are commonly viewed from the same distance as normal TV programs. However, this distance is too large for the size of Teletext characters, which means that, especially for viewers with a reduced visual acuity, Teletext is inherently difficult to read. The following may illustrate this point: the height of the row of capital letters on a Snellen chart, which can be read by somebody with an average visual acuity, i.e., 1.0 (equivalent to 20/20), subtends 5 min of arc. To avoid letters with a similar configuration being confused during reading a text, it should be made up of letters that are considerably higher, for example 12 min of arc to quote a figure from a human-factors handbook [2].

For a large-screen TV display with Teletext letters of the regular size, this value corresponds to a viewing distance of 1.6 m, i.e., less than half of that which is typical for viewing TV. Therefore, it is worth optimizing character discriminability.

We designed alphanumeric characters and punctuation marks on a matrix of 12 × 10 elements (horizontal × vertical, including gaps between letters and rows). Such a matrix allows more refined as well as more acceptable configurations, compared to the 6 × 10 matrix now mostly in use. The latter format presents minimal possibilities for designing upper- and lower-case letters. The resulting character configurations were judged by viewers as being too square with too thin diagonal strokes. To counteract such effects, "character rounding" was introduced by adding half dots at the appropriate positions, close to the diagonal strokes [3]. The rounding rules are based on an interlaced scan pattern; however, the use of two interlaced fields in one TV frame creates an annoying "line flicker" effect when watching Teletext. Most present-day European TV sets therefore do not interlace in the Teletext mode thus, unfortunately, obliterating character rounding. In view of this outcome and, on the other hand, developments in the German "Bildschermtext" (viewdata) service, a 12 × 10 matrix format has been recently adopted as the new videotex matrix standard by the European Conference of Posts and Telecommunications Administrations (CEPT).

II. Design and Tests of Lower-Case Letters

The first phase of this project consisted of designing four configurations for each lower-case character using the results of previous experiments on the acceptability as well as discriminability of another comparable character set as guidelines [1]. The new characters were designed on a terminal screen by assembling matrix "dots" in a graphical representation of the character matrix that was magnified approximately 15 times compared to the normal size. The resulting configuration could subsequently be observed on a TV screen at normal display size. In this way, a stimulus set of 4 × 26 = 104 characters was ob-

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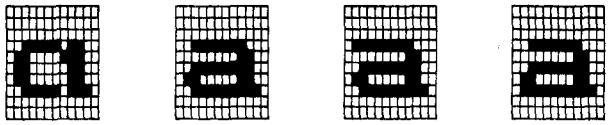

(a) (b) (c) (d)

Fig. 1. Four configurations for the letter *a* that were used in the first two experiments.

tained. Fig. 1(a) to (d) shows the four different versions of the letter *a*.

These 104 characters were presented in random order to two groups of 12 subjects each in two experiments. In the first experiment the characters were presented foveally for 2 s, on a 25-in color TV set (maximum horizontal screen dimension 53 cm, frame rate 50 Hz) at an observation distance of 8 m. At this distance the character box of 12 × 10 dot-matrix elements, as shown in Fig. 1, subtended a viewing angle of 4.5 min of arc horizontally and 6.5 min of arc vertically. In the second experiment, the characters were presented peripherally for 0.1 s to the left or right (in random order) of a fixation cross that was generated in the center of the screen from the same TV set. In this experiment an observation distance of 4 m was used, and the stimuli were presented at an eccentricity of plus or minus 2 degrees; the character box then subtending a viewing angle of 9 min of arc horizontally and 13 min of arc vertically.

The viewing distance in the first experiment and retinal eccentricity in the second one were chosen so that the average recognition score was around 50 percent. This method allows a clear separation between characters of high discriminability, which then score considerably higher than 50 percent, and characters of low discriminability, which then score much lower.

Some of the results of the second experiment, in which each stimulus of the set was presented three times to each subject, are shown in Figs. 2 and 3. Fig. 2 represents a confusion matrix for the worst, i.e., least discriminable versions (e.g., the *a* of Fig. 1(a)); and Fig. 3 is for the best, i.e., most discriminable configurations (e.g., the *a* of Fig. 1(d)).

The main diagonals of Figs. 2 and 3 represent the correct recognition scores. A comparison of these two diagonals clearly shows that the differences between the best and worst versions are not the same for all letters. With respect to the confusion, it appears that the errors are more concentrated in particular cells for the least legible letter versions than for the most legible ones: there are 12 cells with a content of 10 or more in Fig. 2, and only two such cells in Fig. 3.

The first experiment had yielded similar results. The correct scores from both experiments were added for each letter configuration. Generally, the configuration with the highest combined score was then taken for the final character set. However, if there was only a small difference between the combined scores for two configurations, acceptability criteria were taken into account to choose the configuration that 1) corresponded most to the internal

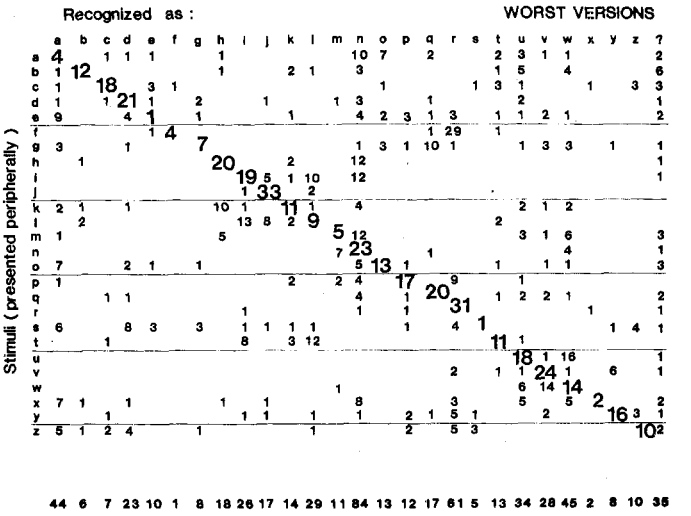

Fig. 2. Confusion matrix for the worst versions of the investigated lower-case letter configurations in a discriminability experiment with peripheral stimulus presentation.

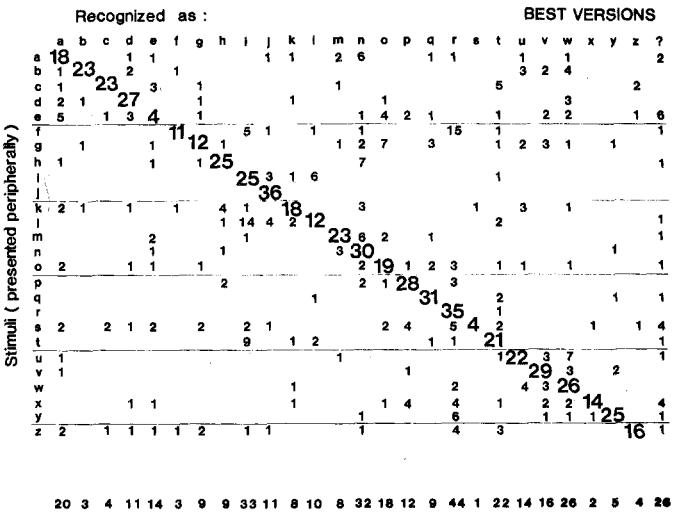

Fig. 3. Confusion matrix for the best versions of the investigated lower-case letter configurations in a discriminability experiment with peripheral stimulus presentation.

representation of the character concerned and 2) fitted best in the complete alphabet, in the opinion of a few observers. Such a situation was obtained for the two letter *a* configurations shown in Fig. 1(c) and (d); that from Fig. 1(c) was considered to be more acceptable, so it was selected for the final set of optimally discriminable and acceptable characters, named "IPO-Normal," and as such appears in Fig. 5.

III. Comparative Evaluation of Lower-Case Letters

In the second phase of the project, the discriminability of the IPO-Normal set was compared with that of three other sets in a new experiment. The other sets were:

1) "IPO-Bold," with bold versions of the "IPO-Normal" lower-case letters;

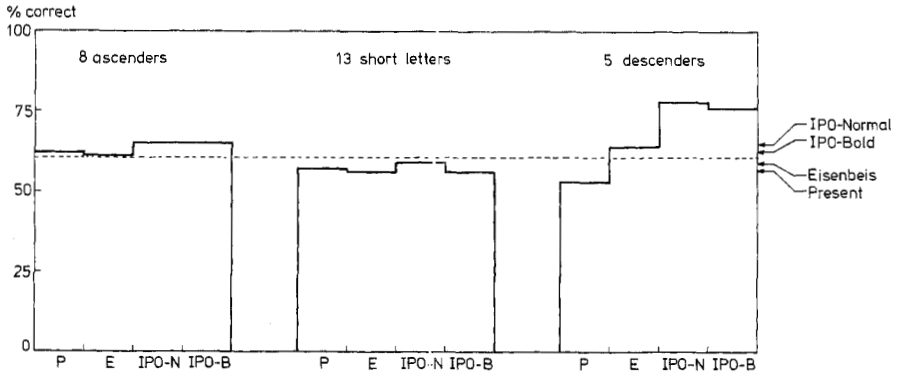

Fig. 4. The recognition scores of ascenders, short letters, and descenders in a distance-reading experiment with lower-case letters from four alphabets: *P*resently used, i.e., 6 × 10, *E*isenbeis, *IPO-N*ormal, and *IPO-B*old. The dashed line refers to the average recognition score for all lower-case letters from all four alphabets: 61 percent.

2) a German set of lower-case letters [4]; and
3) the lower-case letters presently used in most teletext decoders, but without "character rounding."

In this experiment, lower-case letters from the four alphabets were presented centrally (at the same viewing distance as previously used, i.e., 8 m) in random order; 12 subjects participated. Fig. 4 shows the results of the comparative experiment, separately for the three types of lower-case letters: ascenders, short letters, and descenders. Averaged over all the lower-case letters, the recognition score of the "IPO-Normal" letters was 65 percent, that of "IPO-Bold" 63 percent, that of the German letters 59 percent, and that of the present set 57 percent.

In judging the practical significance of these results it should be realized that when the characters of such sets are used for representing nonredundant alphanumeric strings, as may occur in codes of all sorts, the probability that the whole string is correctly recognized equals the *product* of the recognition probabilities for the symbols that constitute the string. Therefore, a difference in recognition probability of a few percent at the level of single symbols can become quite significant at the level of complete codes. Bouwhuis [5] has shown that, in principle, the same multiplication rule holds for the recognition of three-letter words when the recognition probabilities of the component letters are known.

IV. Capitals and Numerals

Essentially the same two-phase procedure was used for upper-case letters. For numerals, however, a somewhat different route was followed. Three sets of numerals were designed: one set in which the numerals had the same stroke width as that of the upper- and lower-case letters and two sets of boldface numerals with a larger stroke width. The discriminability of these numerals was tested in an experiment, with the numerals from the three sets as stimuli. The boldface numerals scored as high as the others. It was then decided to use boldface numerals in the final character set because the increased stroke width might facilitate the distinction between numerals and capitals in alphanumeric strings. The discriminability of the boldface numerals with the highest correct recognition scores was tested in a new experiment using only such bold digits as stimuli. Some numerals that had an unsatisfactorily low recognition score, viz. *5* and *6*, were then redesigned, taking account of the particular confusion errors of the subjects. The resulting set of numerals was again tested; this time the correct recognition scores were more uniformly distributed among the numerals.

V. Discussion and Conclusions

Finally, a complete set of 196 characters—alphanumerics, punctuation marks, and supplementary symbols—was obtained on a 12 × 10 dot matrix. The most important characters are shown in Fig. 5. All alphanumeric characters of the set have a width of 9 or 10 matrix elements, so the capital size is (9 or 10) × 7.

The character design procedure described may be employed in a variety of other applications. With its emphasis on discriminability, it is especially suited for the design of characters to be read under poor observation conditions.

Comparisons of the IPO-Normal character set with alphabets designed in other dot-matrix formats, for instance the ubiquitous VDT font with a capital size of 7 × 9, are difficult, at least as far as the respective mutual discriminations are concerned, because small differences in dot configurations may entail substantial differences in recognition and confusion scores. For example: a horizontal displacement of the ascending part of the numeral *6* over a distance of one matrix element in the present experiments caused a difference in correct score of more than 30 percent, viz. 47 versus 11 percent for the two different configurations, because the perceptual difference with the other numerals, especially the *4*, had been increased considerably by the displacement.

One feature of the described character set, bold numeral strokes, three elements wide—compared with two for the upper-case letters—is not found in the widely used 7 × 9 fonts.

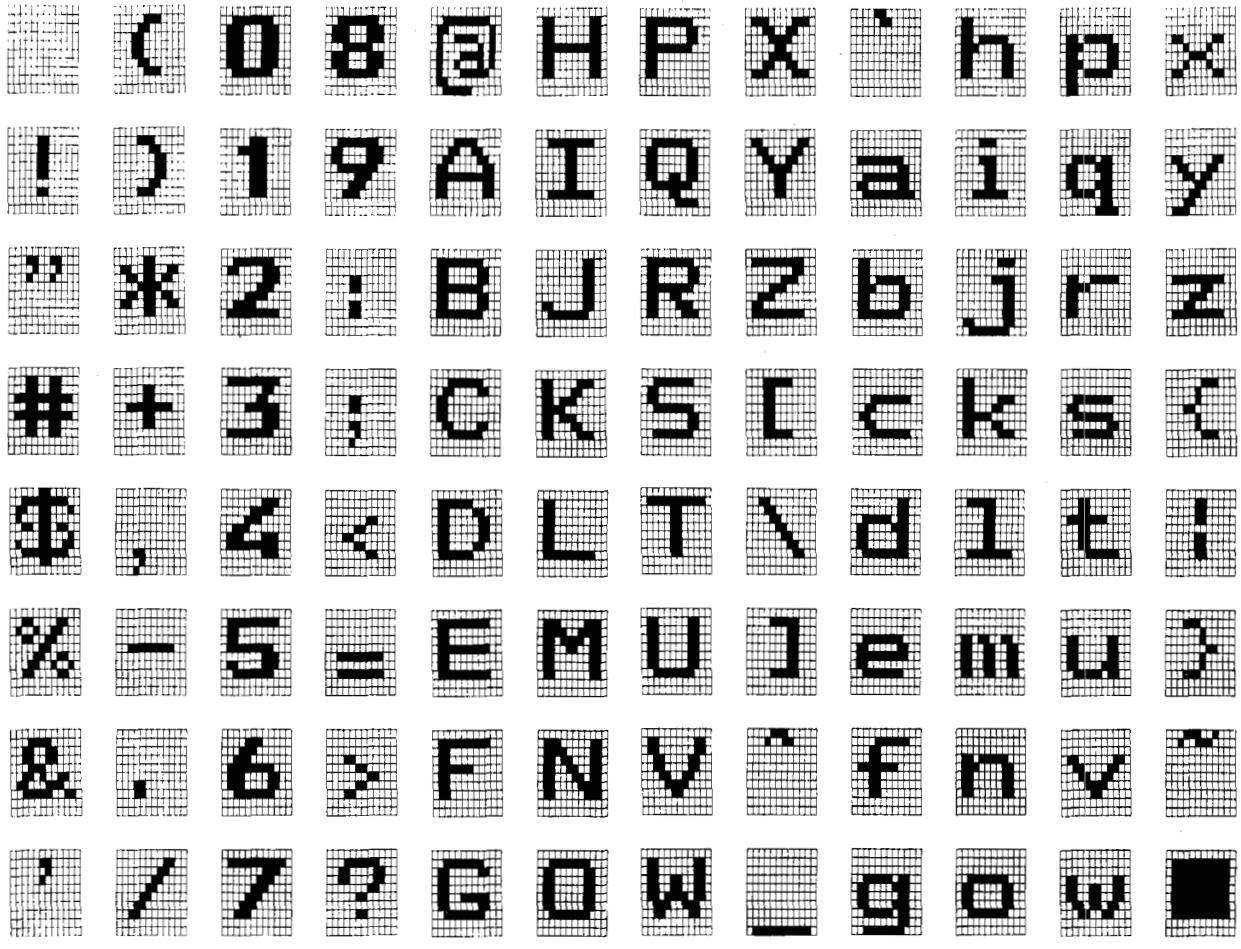

Fig. 5. The basic set of IPO-Normal 12 × 10 dot-matrix characters (copyrighted). The complete IPO-Normal set is now protected under the rules of the International Design Registration effected under the Geneva Protocol of 1975.

It facilitates the distinction between numeral-capital pairs such as 5-S, 0-O, 8-B in the IPO-Normal set. In passing, it may be remarked that there appear to be few published research results, if any, on the legibility of lower-case dot-matrix letters, whereas there are at least some on the legibility of upper-case letters and numerals [6], [7].

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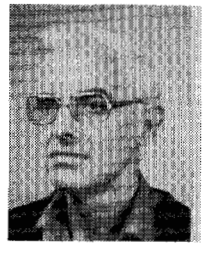

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