# Legibility of Numerals Displayed in a 4 x 7 Dot Matrix and Seven-Segment Digits

Bernard Orth, Hans Weckerle, and Dirk Wendt

Conventional and especially designed numerals in 4 x 7 dot matrices and 7-segment displays were tachistoscopically presented to, and identified by, human observers. The number of errors made in this identification task were analyzed as a measure of legibility in terms of information transmission. It is shown that the representation of digits in such matrices can be improved by appropriate design.

Although Nixie cubes and liquid crystal displays are predominantly used for numerical displays on electronic equipment, there are many visual output devices which use lights or dots in a 5 x7, 4 x 7, or 6 x 8 matrix; e.g., time and scores on athletic scoreboards and time and temperature on outdoor signs for banks, etc. For experimentation we chose a 4 x 7 matrix. Although 5 x 7 grids may be more standard in electronic equipment, you can fit a numeral from a 4 x 7 grid into a 5 x 7 or 6 x 8 grid; thus the results from 4 x 7 grids apply to larger grids as well. The more general point in this study is to find possibilities for the improvement of graphic design of numerals as such.

Comparative studies of the legibility of different types of electronic digital displays (including matrix displays) built by light emitting diodes (LEDs) have been performed, for example, by Radl-Koethe and Schubert 1972, and Simpson 1971 (see also Cornog and Rose 1967). With respect to printed numerals, there have been several attempts to design more legible individual characters (see, e.g., Fitts 1951, McCormick 1964, or Murrell 1965). Matrix displays also allow for some variability in the design of individual numerals; i.e., there are several ways (sets of dots) to represent the same numeral. This experimental study was accomplished to find an optimal design for such displays.



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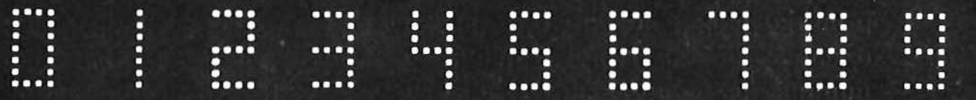
Six sets of 10 numerals (0-9) were designed on a 4 x 7 grid, as shown in Figure 1. Series 1 was designed to simulate the seven-segment numerals in the 4 x 7 grid. Series 2 shows the standard numerals now in use in such displays. Series 3 attempts to increase legibility by increasing the differences or dissimilarities between the numerals within the series. These dissimilarities are still more emphasized in Series 4. In Series 5 we introduced a new dimension (double lines) to base the differences between numerals on more attributes of the characters. In Series 6 we tried to maximize dissimilarities by using elements from all previous series. This was done under the assumption that larger dissimilarities would lead to less confusion, and thus to better legibility.

Out of the numerals within each set, three-digit numbers were composed and displayed by means of light-emitting diodes arranged in a 4 x 7 matrix (size about 6 x 8 mm.) for about 0.275 msec. using a tachistoscope. In addition, similar numbers composed of seven-segment numerals (Series O in Figure 1) were presented for the same exposure time. The distance between subject and display was adjusted for each subject according to his individual threshold. The distances ranged from 50 to 100 cm., with an average of about 90 cm. However, for the seven-segment numerals only about half this distance was appropriate.

Prior to each series of trials, subjects were shown the individual characters (from 0 to 9) to be used in the composition of the three-digit numbers presented in the series of trials. The subjects then initiated each trial by pushing a button, 2.25 sec. after which the three digit stimulus appeared for about 0.275 msec. The subject's task was to name the three-digit number he thought he had seen. This was recorded by the experimenter. Each series of trials consisted of the presentation of 100 stimuli (three-digit numbers) in the random order fixed for each series (set of characters) but systematically rotated over sequences in order to cancel any possible sequential influences. Series 0 and 2 were presented a second time, at a distance of about 270 cm. from the subject, for about 8.665 msec., but only to 41 of the 49 subjects. This was introduced into the experiment in order to compare the seven-segment numerals to a series of 4 x 7 dot display materials under equal conditions. Subjects were run individually in sessions lasting about

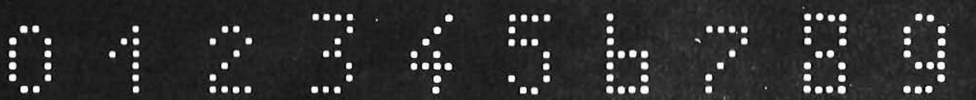
Series 0. Seven-segment numerals.



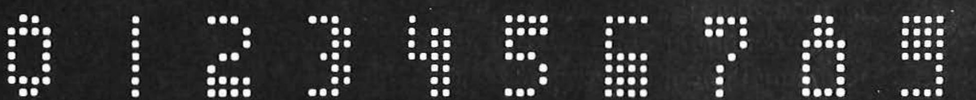
Series 1.

Series 2.

Series 3.



Series 4.



Series 5.

Series 6.

105 to 120 minutes; i.e., about 7 or 8 minutes per series of 100 stimuli, plus instructions, plus inspection of the individual characters prior to each series, plus break. Subjects were 49 volunteering graphic design and psychology students in Hamburg, West Germany.

The dependent variable—the measure of legibility—was the proportion of correct identifications, or rather some logarithmic transformation of it: the amount of information transmitted. Also analyzed was the structure of errors made in this task; i.e., the confusion between characters.

The total number of data collected was: 3 (digit positions) x 100 (trials) x 49 (subjects) x 7 (series of stimuli) = 102,900 at short distance and short exposure time; plus 3 (digit positions) x 100 (trials) x 41 (subjects) x 2 (Series 0 and 2) = 24,600 at longer distance and longer exposure time.

Data were collected for each subject and each series individually in a stimulus-response list. Each of these protocols was then transformed into a 10 x 11 confusion matrix, with the stimuli displayed represented in rows, and subjects' reactions (numerals named by them) in columns. There was one more column than rows, to count stimuli not identified by the subject. With ideal and completely correct identification, all entries should be in the main diagonal of this matrix. A tally occurring in cell $(i, j)$ (row $i$, column $j$) indicates that the numeral $i$ was shown whereas the subject reported a $j$.

These matrices, summed up over all subjects and transformed into relative frequencies, are shown in Tables I-IX, with the data from the respective stimulus sets 0 through 6 in Tables I through VII, and for the second presentation of sets 0 and 2 at a longer distance and with a longer exposure time in Tables VIII and IX, respectively. Original tables for each subject were recorded separately for the first and second half of each series (to control learning effects), and for each digit position (i.e., first, second, or third digit in the number displayed). Thus, the procedure of summing up individual matrices resulted in 6 matrices for each of the 9 series of stimuli:

a. all data (the matrices shown in Tables I-IX
b. first digit only, summed over all subjects and trials

Table I. Series 0.

| *Stimuli* | *Reaction of Subjects* | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *0* | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* | |
| **0** | .74 | – | .01 | – | .01 | .01 | .02 | .02 | .06 | .03 | .09 |
| **1** | .02 | .66 | .01 | .01 | .02 | – | .01 | .07 | – | .01 | .18 |
| **2** | .03 | .03 | .62 | .02 | .01 | .01 | .02 | .03 | .04 | .02 | .17 |
| **3** | .04 | .05 | .02 | .53 | .01 | .01 | .01 | .05 | .03 | .12 | .13 |
| **4** | .04 | .03 | .01 | – | .67 | .01 | – | .02 | .01 | .10 | .12 |
| **5** | .02 | .01 | .01 | .02 | .02 | .63 | .05 | .01 | .02 | .07 | .15 |
| **6** | .03 | .02 | .01 | – | .03 | .03 | .69 | .01 | .03 | .01 | .15 |
| **7** | .02 | .15 | .01 | .03 | .01 | .01 | .01 | .61 | – | .03 | .13 |
| **8** | .15 | .01 | .02 | .02 | .02 | .01 | .09 | .02 | .46 | .07 | .14 |
| **9** | .06 | .03 | .02 | .01 | .05 | .02 | .01 | .05 | .03 | .55 | .16 |

Table II. Series 1.

| *Stimuli* | *Reaction of Subjects* | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *0* | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* | – |
| **0** | .79 | .01 | – | – | .01 | – | .03 | – | .09 | .02 | .05 |
| **1** | .01 | .90 | – | – | .01 | – | – | .02 | – | – | .05 |
| **2** | .01 | – | .86 | .02 | .01 | – | .01 | .01 | .02 | – | .05 |
| **3** | .01 | .02 | .02 | .67 | .01 | .02 | .01 | .02 | .03 | .11 | .06 |
| **4** | .01 | .03 | – | – | .79 | .02 | – | .02 | .01 | .06 | .06 |
| **5** | .01 | .01 | – | .01 | .01 | .80 | .05 | – | .01 | .04 | .05 |
| **6** | .02 | – | .01 | .01 | – | .10 | .72 | – | .07 | .01 | .06 |
| **7** | .02 | .27 | – | .02 | .01 | – | – | .64 | – | – | .03 |
| **8** | .12 | .01 | .02 | .01 | .01 | .01 | .08 | – | .63 | .04 | .07 |
| **9** | .03 | .01 | .01 | .06 | .02 | .08 | .01 | – | .05 | .66 | .06 |

Table III. Series 2.

| *Stimuli* | *Reaction of Subjects* | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *0* | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* | – |
| **0** | .79 | .01 | – | – | .01 | – | .04 | – | .07 | .03 | .04 |
| **1** | .02 | .86 | – | .01 | .02 | – | .01 | .03 | .01 | .01 | .04 |
| **2** | – | .01 | .89 | .01 | – | .01 | .01 | .01 | .02 | .01 | .03 |
| **3** | .02 | .01 | .02 | .78 | .01 | .02 | .01 | .02 | .03 | .03 | .06 |
| **4** | – | .02 | – | .01 | .84 | .02 | .01 | .01 | .01 | .03 | .05 |
| **5** | .01 | – | – | .01 | .01 | .87 | .04 | – | .01 | .01 | .03 |
| **6** | .01 | .02 | .01 | .01 | .03 | .04 | .77 | .01 | .05 | – | .06 |
| **7** | .01 | .22 | .01 | .02 | – | – | – | .69 | – | .01 | .03 |
| **8** | .07 | .01 | .02 | .03 | .03 | .02 | .07 | – | .65 | .03 | .07 |
| **9** | .03 | .02 | .01 | .12 | .07 | .04 | .01 | .01 | .04 | .58 | .06 |

Table IV. Series 3.

| *Stimuli* | *Reaction of Subjects* | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *0* | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* | *–* |
| **0** | .47 | .04 | .01 | .01 | .09 | .01 | .15 | .01 | .09 | .02 | .10 |
| **1** | – | .91 | .01 | .01 | .01 | .01 | .01 | .01 | .01 | – | .03 |
| **2** | – | .01 | .87 | .01 | – | .01 | – | .03 | – | – | .04 |
| **3** | .01 | .01 | .02 | .74 | .01 | .09 | .01 | .03 | .01 | .03 | .06 |
| **4** | .01 | .06 | – | .01 | .81 | .02 | .01 | .01 | – | .03 | .05 |
| **5** | – | .01 | .01 | .06 | .01 | .82 | .02 | .01 | .01 | .01 | .04 |
| **6** | .02 | .01 | .01 | .01 | .02 | .02 | .85 | .01 | .02 | – | .04 |
| **7** | – | .01 | .06 | .01 | – | .01 | – | .85 | – | – | .05 |
| **8** | .08 | .02 | .01 | .02 | .02 | .02 | .27 | – | .46 | .01 | .07 |
| **9** | .03 | .01 | .01 | .08 | .02 | .06 | .01 | .02 | .02 | .66 | .08 |

Table V. Series 4.

| *Stimuli* | *Reaction of Subjects* | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *0* | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* | *–* |
| **0** | .74 | .01 | – | – | .02 | – | .11 | – | .04 | .02 | .05 |
| **1** | .01 | .86 | – | – | .07 | – | .01 | .01 | – | – | .04 |
| **2** | .01 | .01 | .76 | .02 | .03 | .01 | .02 | .03 | .04 | – | .08 |
| **3** | .01 | .01 | .02 | .82 | .01 | .03 | – | .04 | .01 | .01 | .05 |
| **4** | – | .02 | .01 | .01 | .86 | .02 | .03 | – | – | – | .06 |
| **5** | – | – | – | .05 | .01 | .81 | .03 | .01 | .02 | .02 | .05 |
| **6** | .01 | .01 | – | – | .06 | .02 | .80 | – | .03 | – | .06 |
| **7** | – | .01 | .06 | .01 | – | .01 | – | .86 | – | – | .04 |
| **8** | .04 | .01 | .05 | .03 | .01 | .03 | .06 | .01 | .66 | .03 | .08 |
| **9** | .04 | – | .02 | .02 | .01 | .03 | .01 | .01 | .04 | .79 | .04 |

Table VI. Series 5.

| *Stimuli* | *Reaction of Subjects* | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *0* | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* | *–* |
| **0** | .63 | – | .01 | .01 | .02 | .02 | .14 | – | .09 | .03 | .06 |
| **1** | – | .93 | – | .01 | .01 | – | – | .01 | – | – | .04 |
| **2** | .01 | .01 | .85 | .04 | .02 | .01 | .02 | .01 | .01 | – | .04 |
| **3** | .01 | .07 | .04 | .75 | .01 | .02 | – | .04 | .01 | – | .06 |
| **4** | .01 | .09 | .01 | .02 | .71 | .01 | .01 | .05 | – | .03 | .06 |
| **5** | .01 | .01 | .01 | .04 | .01 | .79 | .04 | .01 | .01 | .01 | .05 |
| **6** | .01 | – | .02 | – | .03 | .31 | .52 | .01 | .03 | .01 | .07 |
| **7** | – | .02 | .04 | .01 | .01 | .01 | – | .85 | .01 | – | .05 |
| **8** | .16 | .01 | .01 | .01 | .04 | .02 | .38 | .01 | .28 | .01 | .08 |
| **9** | .01 | .01 | – | .12 | .02 | .58 | .01 | .01 | .02 | .16 | .06 |

Table VII. Series 6.

| *Stimuli* | *Reaction of Subjects* | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *0* | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* | – |
| **0** | .75 | .01 | – | .01 | .02 | .01 | .10 | – | .04 | .01 | .05 |
| **1** | – | .93 | – | .01 | .01 | – | – | .01 | – | – | .02 |
| **2** | – | – | .83 | .04 | .02 | .01 | .01 | .01 | .01 | – | .05 |
| **3** | .01 | .01 | .02 | .75 | – | .07 | – | .03 | – | .02 | .07 |
| **4** | .01 | .01 | .01 | .01 | .87 | .01 | .03 | .01 | – | – | .05 |
| **5** | – | – | .01 | .04 | .01 | .80 | .02 | .01 | .02 | .03 | .06 |
| **6** | – | – | .01 | .01 | .02 | .24 | .62 | – | .02 | .01 | .06 |
| **7** | – | – | .04 | .01 | – | – | – | .90 | – | – | .03 |
| **8** | .05 | .01 | .03 | .02 | .02 | .02 | .10 | .01 | .57 | .08 | .09 |
| **9** | .01 | .01 | .01 | .11 | .02 | .43 | .01 | .01 | .03 | .29 | .07 |

Table VIII. Series 0-long.

| *Stimuli* | *Reaction of Subjects* | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *0* | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* | – |
| **0** | .60 | .01 | .04 | .01 | .02 | .01 | .04 | .01 | .15 | .05 | .07 |
| **1** | .01 | .78 | .01 | .01 | .04 | – | .01 | .05 | .01 | .01 | .09 |
| **2** | .02 | .01 | .76 | .02 | .02 | .01 | .02 | .03 | .04 | .02 | .07 |
| **3** | .01 | .05 | .08 | .54 | .01 | .03 | .01 | .05 | .04 | .08 | .10 |
| **4** | .01 | .02 | .01 | .01 | .80 | .01 | – | .02 | .01 | .05 | .06 |
| **5** | .01 | .01 | .01 | .03 | .03 | .65 | .07 | .01 | .03 | .06 | .09 |
| **6** | .01 | .01 | .02 | .01 | .09 | .03 | .71 | .01 | .03 | .02 | .07 |
| **7** | .01 | .33 | .02 | .04 | .02 | .01 | – | .48 | .01 | .02 | .07 |
| **8** | .10 | .01 | .06 | .01 | .03 | .01 | .06 | .01 | .53 | .09 | .09 |
| **9** | .02 | .02 | .01 | .02 | .24 | .04 | .01 | .05 | .04 | .46 | .09 |

Table IX. Series 2-long.

| *Stimuli* | *Reaction of Subjects* | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *0* | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* | – |
| **0** | .71 | – | .01 | .01 | .01 | .01 | .06 | – | .10 | .03 | .06 |
| **1** | – | .88 | – | – | .01 | – | .01 | .01 | .02 | .01 | .04 |
| **2** | – | – | .92 | .01 | – | .01 | .01 | – | .01 | – | .03 |
| **3** | .01 | – | .08 | .76 | .01 | .03 | .01 | .02 | .03 | .03 | .03 |
| **4** | .01 | .01 | – | – | .90 | .02 | – | .01 | – | .01 | .03 |
| **5** | – | – | .01 | .01 | .01 | .85 | .05 | .01 | .01 | .02 | .03 |
| **6** | .01 | – | .01 | – | .05 | .05 | .81 | – | .02 | .01 | .04 |
| **7** | .01 | .26 | .01 | .02 | .01 | – | – | .67 | – | .01 | .03 |
| **8** | .09 | – | .04 | .01 | .02 | .02 | .10 | – | .57 | .05 | .09 |
| **9** | .03 | .02 | .02 | .06 | .05 | .07 | .02 | .01 | .03 | .65 | .05 |

c. second digit only, summed over all subjects and trials
d. third digit only, summed over all subjects and trials
e. first half of series only (trials 1-50) summed over all digit positions and all subjects
f. second half of series only (trials 51-100) summed over all digit positions and all subjects

As a criterion of evaluation, the amount of transmitted information was calculated for each of these 54 matrices. The information transmitted (from the stimuli to the subjects) may be regarded as a measure of discrimination ability of the subject (see Garner, 1962, ch. 3). This statistic takes into account the relative distribution of errors made by subjects, and thus is more adequate than the average error probability (since not all errors are equally wrong). The amount of transmitted information is defined as

$$T(S:R) = H(S) + H(R) - H(S, R)$$

where

$$H(S) = -\Sigma_i p(S_i) \log_2 p(S_i)$$

$$H(R) = -\Sigma_j p(R_j) \log_2 p(R_j) \text{ ad}$$

$$H(S, R) = -\Sigma_j \Sigma_i p(S_i, R_j) \log_2 p(S_i, R_j)$$

are the average amounts of information provided by a stimulus $S_i$, a response $R_j$, or a combination $(S_i, R_j)$, respectively.

Differences between the amounts of information transmitted by the different series of digits were tested for significance by means of

$$x^2 = 1.3863 \left\{ T(S:R)_{S-\text{set A}} - T(S:R)_{S-\text{set B}} \right\}$$

As a perhaps more convenient statistic, we also calculated coefficients of constraint, defined as

$$\eta = \frac{T(S:R)}{H(S)}$$

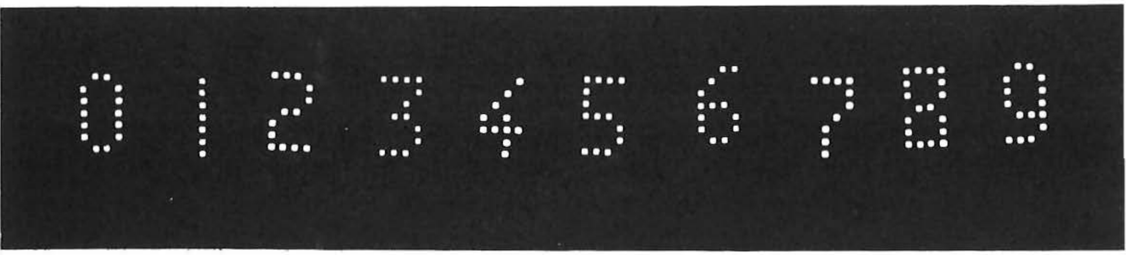
which vary between 0 (no information transmitted) and 1 (the transmitted information is equal to its maximum, H(S) ). For a more detailed discussion of an analysis of confusion matrices in terms of information theory, see Quastler 1955, Attneave 1959,

Table X.

| *Series* | *H(S)* | *H(R)* | *H(S, R)* | *T(S:R)* | *H(R/S)* | *H(S/R)* | η | *rank* | *p(error)* | *rank* |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 3.3039 | 3.4266 | 5.2854 | 1.4452 | 1.9815 | 1.8587 | .4347 | – | .392 | – |
| 1 | 3.3166 | 3.4233 | 4.7256 | 2.0144 | 1.4089 | 1.3023 | .6074 | 4 | .252 | 4 |
| 2 | 3.3163 | 3.4279 | 4.6847 | 2.0595 | 1.3684 | 1.2567 | .6210 | 2 | .231 | 2 |
| 3 | 3.3023 | 3.3872 | 4.6918 | 1.9977 | 1.3895 | 1.3046 | .6049 | 5 | .248 | 3 |
| 4 | 3.3126 | 3.4411 | 4.6022 | 2.1515 | 1.2896 | 1.1611 | .6495 | 1 | .210 | 1 |
| 5 | 3.3173 | 3.3273 | 4.8616 | 1.7831 | 1.5442 | 1.5343 | .5375 | 6 | .359 | 6 |
| 6 | 3.3114 | 3.3746 | 4.6719 | 2.0141 | 1.3605 | 1.2973 | .6082 | 3 | .267 | 5 |
| $0_1$ | 3.3039 | 3.4398 | 5.2393 | 1.5045 | 1.9354 | 1.7994 | .4554 | – | .381 | – |
| $2_1$ | 3.3163 | 3.4231 | 4.6428 | 2.0965 | 1.3266 | 1.2198 | .6322 | – | .232 | – |

Garner 1962, Meyer-Eppler 1959, or Coombs, Dawes and Tversky 1970. Both the results of this analysis and, for comparative reasons, the average error probabilities, p (error), for each series of numerals are displayed in Table X. It shows that the newly designed Series 4 is considerably superior to the 7-segment Series 0, both in terms of information transmitted and in error probability: .392 for the 7-segment numerals and only .210 for the best dot-matrix, Series 4. The more fancy Series 5 and 6 did not prove superior to the more conventional Series 2 and 3, and Series 1 which is a 4 x 7 dot matrix representation of Series 0 (7-segment numerals) does not look very favorable, either. The bad result with Series 5 was mainly due to confusion of 9 with 5. The same confusion prevents Series 6 from proving superior to Series 2. Comparison of Series 0 (7-segment) and 2 at a longer exposure time and longer distance ($0_1$ and $2_1$) confirmed the inferiority of 7-segment digit displays to 4 x 7 dot matrices.

Analyses of confusion probabilities for individual numerals within the series (not reproduced here) showed that, in general, numerals 6, 8, and 9 are hard to discriminate. An optimal selection of 4 x 7 dot numerals would consist of:



| *Numeral* | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| *From Series* | 1 or 2 | 6 | 2 | 4 | 6 | 2 | 3 | 6 | 4 | 4 |

However, this new series would have to be tested again because we cannot infer what new confusions might occur. All pairwise differences between series are statistically significant at the 0.01 level; except between Series 1 and 6.

The third digit (last position) was less likely to be identified correctly than the first two digits, with no noteworthy difference between the first and second digit. There was no notable systematic difference between first and second half of trials; thus we can rule out learning effects during the experiment.

In a separate paper, Orth (1974) reanalyzed the data from this experiment under a measurement-theoretical point of view. He transformed the confusion probabilities into measures of dissimilarities—or cognitive (perceptual) distances between stimuli (numerals)—and found that Series 5 and 6 actually do need more dimensions for representation of pairwise distances in a geometric space, where differentiation between numerals is chiefly based on the most obvious dimension (attribute). However, the influence of cognitive factors determining the discrimination between nominally different numerals was larger than the influence of graphic design factors on the perception of the stimuli.

Although the subjects' habituation to the traditional digit displays may have worked against the success of those newly designed in this experiment, it has still been possible to show that the legibility of traditional designs can be improved.

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## HOW TO FIND CHARACTERS PER PICA FOR CAPS

The method of finding characters per pica (c.p.p.) for lines of all capitals is long and laborious if calculations are done by pencil. I am referring to finding the c.p.p. for type sizes from 6-point to 36-point, for instance. The use of the slide rule shortens the work involved, but some individuals have trouble learning how to use the slide rule. The electronic or mini calculators are easy to use and extremely accurate.

We will use 10-point Futura Demi Bold for this demonstration. Measure lower-case alphabet from a to t. This figure is 8 picas and 1 point. Divide 8.1 into 21 (21 is more accurate than 20, the actual number of characters from a to t). 2.59 is the answer on the computer. This is the figure listed in a type specimen book. This is the c.p.p. for 10-point FDB lower-case.

The next step is to do the same with a line of caps from A to T. This will measure 10 picas. Divided into 21 equals 2.1—c.p.p. for 10-point FDB caps.

The c.p.p. 2.1 for 10-point FDB caps arrived at in the preceding paragraph is correct and can be used, but the following development to be used for obtaining the c.p.p. for all size caps will give a figure of 2.09.

This is the formula for getting the c.p.p. for 10-point caps of FDB:

$$2.59 \times 8.1 = 20.97 \div 10 = 2.09$$

2.09 is the c.p.p. for 10-point FDB caps. We have multiplied the lower-case c.p.p. by the width of the lower-case a to t, and divided it by 10 which is the width of 10-point caps in picas.

The following formula will give the c.p.p. for any size caps once the c.p.p. for 10-point caps is found:

| | | | |
|---|---|---|---|
| *c.p.p. size* | *new size* *cap c.p.p.* | | |
| 2.09 x 10=20.9÷ | 6=3.48 | 12=1.74 | 24=0.87 |
| | 8=2.61 | 14=1.49 | 30=0.69 |
| | 10=2.09 | 18=1.16 | 36=0.58 |

When c.p.p. is found, multiply that by the measure to give the number of characters that will fit in a measure.

When this exercise is done a few times, and learned, the c.p.p. for any size caps in any typeface can be readily found. I have used 10-point type as the base size because this size is found on the bottom of most pages of the type catalog.

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