1967

The determination of a set of alphanumeric characters of equal recognizability

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Recommended Citation
The Determination of A set
of Alphanumeric Characters
of Equal Recognizability

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A thesis presented in part
requirements of the Bachelor
Rochester Institute of Tech,
Rochester, N.Y.
ABSTRACT

An experiment is described whose objective was to determine a set of alphanumeric characters of equal recognizability. Constraints were that the characters be similar in aspect ratio to the conventional tri-bar target, i.e., 5:1, and that they and the surround have a low density difference. Such a set is described, together with the experimental technique and data analysis used by the present authors to evaluate the set. At an alpha risk of 0.10 the set of characters E S 2 3 8 9 was found to have equal recognizability under two varied viewing conditions.
INTRODUCTION

for evaluating optical and photo-optical instruments
one method in wide use is that employing the familiar tri-bar target of 5:1 aspect ratio.

![Tri-Bar Target](image)

Figure 1. Tri-Bar Target (A/R 5:1)

The test target consists of an array of tri-bars, grouped in threes, decreasing in size in a systematic pattern. The figure of merit using this method depends on the smallest tri-bar pattern imaged by the instrument and recognizable by an observer. There is sometimes disagreement among observers about whether or not a given set of bars is recognized, and no solution to this argument is readily available.

It has been suggested by McCamy\(^1\), and others, that alphanumeric characters be substituted for the tri-bar target. If this could be done, much of the difficulty associated with the definition of recognizability would disappear, since the observer could be asked to identify
a character rather than make a judgement whether three bars are distinguishable as such. This is a genuine problem in recognition, and the observer can be scored as right or wrong, a procedure not possible with the present target.

A primary consideration in the construction of such a character target is that all characters employed be of inherently equal recognizability. Considerable work has been done in the past with this aim in view in the field of ophthalmology, where visual acuity is most often tested using the familiar letter chart. The usefulness of the previous work to the present research is doubtful; they invariably employed high contrast characters, i.e., black letters on a white surround; character geometry frequently varied from worker to worker; curved and oblique contours were included, for the purpose of detecting errors in visual refraction. Additionally, there are serious differences of opinion about what constitutes a set of "equally legible" or "equally difficult" characters. For example, Hartridge and Owen claim the set: C F H N P T U X Z to be of the "same difficulty"; Sloan says the set: C J H K N O R S V Z is "nearly equal in legibility".

A second consideration is that the characters selected bear, to some degree, a resemblance to the three-bar array, since there is some desirability in relating information from the character target to data based on the tri-bar target. Figure 2 shows such a set of characters.
Since most interest in optical system evaluation is in the area of low subject-contrast imaging performance, the characters should be of low contrast, e.g., 0.15 - 0.20 density difference between character and surround.

OBJECTIVES

The objective of the present research was to test the hypothesis that the characters E 3 S 2 3 6 8 9, in block form with aspect ratio 5:1, are equally recognizable. A chi-square test was to be applied to the data to determine equality; the alpha risk selected was 0.10.

EXPERIMENTAL PROCEDURE

A. Apparatus: Characters were cut from Color-Aid paper, No. 3 Gray, reflection density = .56; the same paper, No. 5A Gray, reflection density = .72, was used for the surround. These papers were selected as having a density difference within the range originally selected; No. 5A has a density close to that of an 18% Gray Card. Characters measured 25mm on a side; they were affixed to 6-inch squares of No. 5A paper which were located about the circumference of a disc. Figure 3 shows a drawing of the presentation device; the disc is rotated to bring individual characters to the 5½" square aperture in the plate behind which the disc is placed. The front plate was covered with No. 5A paper.

B. Viewing Conditions: The target was hit by two flood lamps in reflectors; illumination was held constant at 125 ft-c. Data are available 7,8 which indicate that
at the observer). This relationship is shown in Figure 4. With the large-group viewing the intention was: to position the observer approximately by use of the Snellen Chart, present a short series of characters, calculate the percent correct response, and relocate the observer at the distance which would result in 50% correct response. This prediction technique was unsatisfactory, probably because the observers from whose data it was derived were experienced in the viewing operation and groups of observers were not. On this basis, the second of two sets of observations was used in the analysis.

Each observer was given a report form for each series of characters presented. As each member of the randomly-ordered series was shown the experimenter called out the presentation order number (this had been found necessary to avoid confusion in recording), and the observer recorded his response in the corresponding space on his form. For the data analyzed in this paper, the presentation series to the first group, 11 men, was each character six times, 48 total; the second group, 10 men, saw each character twelve times, 96 total. A response was forced in all cases.
DATA ANALYSIS

Data from observers were tabulated individually showing, for each character, (a) number of times presented, (b) number of times reported, and (c) number of times reported correctly. A typical individual tabulation is shown in Figure 5.

<table>
<thead>
<tr>
<th>Character</th>
<th>E</th>
<th>G</th>
<th>S</th>
<th>2</th>
<th>3</th>
<th>6</th>
<th>8</th>
<th>9</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Presented</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>96</td>
</tr>
<tr>
<td>(b) Reported</td>
<td>10</td>
<td>10</td>
<td>16</td>
<td>11</td>
<td>12</td>
<td>6</td>
<td>15</td>
<td>15</td>
<td>56</td>
</tr>
<tr>
<td>(c) Correct</td>
<td>10</td>
<td>5</td>
<td>11</td>
<td>11</td>
<td>11</td>
<td>3</td>
<td>10</td>
<td>9</td>
<td>70</td>
</tr>
</tbody>
</table>

Per cent. correct: 72.9%

Figure 5. Tabulation of Data of Typical Observer

In the data analysis an experimental chi-square value was calculated from the test statistic,

\[ \chi^2 = \sum \frac{(O-E)^2}{E} \]  \hspace{1cm} (1)

where \( O \) is the number of times the event happened - in this case, the number of times a character was reported - and \( E \) is the number of times the event would be expected if the characters were equal, \textit{inter se}. The arithmetic is quite straightforward; using the above data to calculate response chi-square:

\[ \chi^2 = \left[ \frac{(10-12)^2}{12} + \frac{(10-12)^2}{12} + \ldots + \frac{(15-12)^2}{12} \right] / 12 = 7.1665 \]  \hspace{1cm} (2)

Similarly, correct response chi square:

\[ \chi^2 = \left[ \frac{(10-E)^2}{E} + \frac{(5-E)^2}{E} + \ldots + \frac{(9-E)^2}{E} \right] / E = 7.4861 \]  \hspace{1cm} (3)

where the expected value, \( E \), is the product of the (total) per cent. correct and the number of presentations of a
character, i.e., $E = (12)(.729)$. In these examples the experimental values of chi-square are less than the critical value of chi-square for a sample of eight and an alpha risk of 0.10, i.e., 12.0170. Thus the data indicate that there is no difference within the set of the responses or the correct responses.

Two criteria were used to reject data from individuals. Those from observers showing unequal response were rejected; the reasoning was that any bias in response - whatever the reason - would surely contaminate the data for correct response. Data were also discarded from observers scoring 100% correct responses for more than one character.

A tabulation was made of the summed responses of observers meeting the above criteria and chi-square calculated for response and correct response. Response chi-square was less than the critical value, indicating that responses were equal; correct-response chi-square was greater than the critical value, which indicated that the responses - and therefore the set of characters - were not equal.

It was noticed that the summed correct responses for the characters G and 6 were lower than similar values for the other characters. Individual tabulations were reconsidered, eliminating from the calculations all responses for the suspected characters. Four observers previously rejected for unequal responses became acceptable; three were not helped by this operation, since the inequality of their responses was due to apparent biases for other characters in which no pattern was noticeable. Also, with the
elimination of G and 6 responses, the correct-response chi-square based on the ten acceptable observers, taken individually and collectively, was less than the critical value, 9.23635 for the same 0.10 alpha risk and sample size of 6. The tabulation of the summed responses for these data is shown in Figure 6.

<table>
<thead>
<tr>
<th>Character</th>
<th>E</th>
<th>S</th>
<th>2</th>
<th>3</th>
<th>8</th>
<th>9</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Presented</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>540</td>
</tr>
<tr>
<td>(b) Reported</td>
<td>87</td>
<td>102</td>
<td>89</td>
<td>85</td>
<td>87</td>
<td>84</td>
<td>534</td>
</tr>
<tr>
<td>(c) Correct</td>
<td>70</td>
<td>65</td>
<td>74</td>
<td>68</td>
<td>51</td>
<td>53</td>
<td>381</td>
</tr>
<tr>
<td>Per cent. correct</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>70.2</td>
</tr>
</tbody>
</table>

Chi-square: Response:  2.4888
Correct: 6.9531

Figure 6. Tabulation of Summed Data of TenObservers Having Equal Response

A check of internal consistency was made by considering the individual observers' data by halves. In all cases the experimental chi-square was less than the critical value. Of the ten observers five improved in performance between the first and second halves of the presentation series; two scored the same on both halves, and three scored worse on the second half.

**MODIFIED VIEWING CONDITIONS**

It was decided to confirm the conclusions drawn from the preceding analysis, that the six-member set of characters was equally recognizable. It was thought that this should be done so that the character viewed would be degraded
image-wise, in a manner similar to that which might be found in a practical situation. Several schemes were considered; the one finally adopted was that of defocusing the projected image of the character. Accordingly, each character was photographed and the resulting negatives were slide-mounted. Density difference between character and background was 0.15 - 0.16; screen illumination was 210 ft-C, with no slide in the light path; and 5.3 ft-C with a slide in place (projected background).

Twelve slides of each character, 72 total, were randomly presented to six observers, four of whom were replicated. Tabulation and sorting were accomplished according to the previously mentioned criteria.

DATA ANALYSIS

The data from three observers were acceptable; two of these were replicated. Only one of the rejected observers was rejected by reason of unequal response; the others were rejected for 100% correct responses for more than one character.

Correct-response chi-squares were calculated from the individual data and the summed responses; all were less than the critical value. Of the two observers who were replicated one scored better in the second series, the other worse.

Figure 7. Tabulation of Summed Data of Three Observers

<table>
<thead>
<tr>
<th></th>
<th>2</th>
<th>3</th>
<th>8</th>
<th>9</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presented</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Reported</td>
<td>56</td>
<td>62</td>
<td>72</td>
<td>47</td>
<td>70</td>
</tr>
<tr>
<td>Correct</td>
<td>40</td>
<td>40</td>
<td>51</td>
<td>33</td>
<td>46</td>
</tr>
</tbody>
</table>

Per cent. correct: 67.2%

Chi-square: Response: 8.0330
Correct: 6.6779
CONCLUSIONS

The data indicate that, under two widely varied viewing conditions, there is no difference in the correct responses to members of the six-character set when they are presented each an equal number of times.

We therefore conclude that the original objective of the experiment has been satisfied; this is a set of characters of the required geometry which are, inter se, equally recognizable.
ACKNOWLEDGEMENTS

The authors express their thanks to the Photographic Science Faculty for much helpful consultation and advice; in particular to Professors Hollis Todd and Albert Rickmers, whose counsel was invaluable.

To the students who served as observers goes our undying gratitude, especially those who served during the early part of the project. Without their patient cooperation the research would have been literally impossible.
FIGURE-3
FOOTNOTES


   cited in: Hartridge and Owen, op cit.

   cited in: Banister, op cit.


BIBLIOGRAPHY


