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THE DEVELOPMENT OF AN EXPANDED READING CODE FOR THE BLIND. INTERIM TECHNICAL REPORT.

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DESCRIPTORS- *EXCEPTIONAL CHILD RESEARCH, *VISUALLY HANDICAPPED, *BRAILLE, TACTUAL PERCEPTION, SENSORY EXPERIENCE, SENSORY TRAINING, PERFORMANCE FACTORS, REDUNDANCY, BLIND, READING,

GROUPS OF 24 BLIND ADULTS (ALL SKILLED BRAILLE READERS) AND 24 SIGHTED COLLEGE STUDENTS WERE COMPARED ON A TACTUAL IDENTIFICATION OF FORM TASK IN WHICH RAISED DOTS WERE USED. THE TWO INFORMATION PARAMETERS, COMPLEXITY AND REDUNDANCY OF THE DOTS, WERE ASSESSED USING PUNCTIFORM METRIC FIGURES RESEMBLING HISTOGRAMS AND SIMILAR IN SIZE AND SPACING TO STANDARD BRAILLE DOTS. THE TASK WAS TO DECIDE WHICH, IF EITHER, OF THE TWO COMPARISON STIMULI WAS IDENTICAL TO THE STANDARD STIMULUS. A 4 X 2 X 2 FACTORIAL DESIGN WAS EMPLOYED. STATISTICALLY SIGNIFICANT RESULTS WERE FOUND BETWEEN THE VISUAL STATUS GROUPS, BETWEEN LEVELS OF COMPLEXITY, AND BETWEEN RANDOM AND REDUNDANT FIGURES (P IS LESS THAN .01 IN EACH CASE). ALSO, THE INTERACTIONS BETWEEN GROUPS AND COMPLEXITY, GROUPS AND TYPE OF FIGURES, AND COMPLEXITY AND TYPE OF FIGURES WERE FOUND TO BE STATISTICALLY RELIABLE (P IS LESS THAN .01 IN EACH CASE). FINDINGS INDICATED THAT EFFICIENCY OF PERFORMANCE TENDS TO DECLINE WITH INCREMENTS IN STIMULUS COMPLEXITY. THE OVERALL TREND TOWARD GREATER EFFICIENCY OF PERFORMANCE WITH RANDOM THAN WITH REDUNDANT FIGURES WAS FOUND TO ACCORD WITH PREVIOUS FINDINGS REGARDING THE VARIABLES OF THE INFORMATION PARAMETERS USING VISUAL STIMULI. THE CONCLUSION WAS THAT THE INFORMATION HANDLING APPROACH TAPS A SINGLE PROCESS OF FORM PERCEPTION IN MAN. THE STUDY ALSO SUGGESTS REVISION OF THE PRESENT BRAILLE CODE TO EXPAND ITS 2 X 3 BRAILLE MATRIX TO A 4 X 4 SIZE FOR INCREASED BRAILLE READING RATE AND ACCOMMODATION OF TECHNICAL SYMBOLS IN VARIOUS SCIENCES. DIAGRAMS SHOWING SAMPLES OF CELL MATRICES OF DIFFERENT COMPLEXITY AND METRIC FIGURES USING BRAILLE DOTS AND A GRAPH SHOWING PERFORMANCE DIFFERENCES ARE INCLUDED. A BIBLIOGRAPHY LISTS 18 ITEMS. (KH)

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Effects of Complexity and Redundancy on the Tactual Recognition of Metric Figures[1]

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Summary

An attempt was made to assess the influence of two information parameters, viz., complexity and redundancy on the tactual recognition of metric figures. Four levels of complexity were used with random and Redundancy-1 forms. The stimuli displayed consisted of raised dots; standard braille values were employed for dot height and spacing. Twenty-four sighted and twenty-four blind subjects served in the study. Efficiency of performance was measured in terms of both speed and accuracy of recognition.

Although the results were in part dependent upon response measures, the following overall trends were noted: (a) efficiency of performance was greater in the blind than in the sighted subjects and for random as compared to Redundancy-1 figures; (b) speed and accuracy of recognition tended to decrease with increments in stimulus complexity. The data were interpreted as supporting central factors in form perception and as illustrating the need for close attention to the nature of performance indicies employed in the study of the perception of form.

Introduction

In recent years, a number of investigators have been concerned with the appropriateness of information measures to the problem of form perception (Forgus, 1966; Michels & Zusne, 1965). One strategy under this approach, has been to specify exactly the statistical features of populations of forms in terms of information parameters and then to study man's ability to identify stimuli drawn from these populations (Alluisi, 1960; Fitts, Weinstein, Rappaport, Anderson, & Leonard, 1956).

Form complexity and redundancy are among the information parameters which have received considerable attention. As described by Fitts, et al., (1956), complexity is specified by the average uncertainty or the information content of a figure and is a function of the size of the population of possible figures from which a given figure is drawn. Constraints upon the way in which figures are sampled can produce numerous forms of redundancy. An extensive body of evidence is available indicating that

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both the speed and accuracy of identification of visually presented forms are related to the parameters of complexity and redundancy (Alluisi & Hall, 1965; Baker & Alluisi, 1962; Rappaport, 1957; Thurmond & Alluisi, 1967). These findings have been taken as support for an information model of form perception which suggests that in perceiving, man acts as an information handling channel and that consequently, the efficiency of performance in form perception tasks should be related inversely to the information or uncertainty in the stimulus (Alluisi, 1960).

It is important to note that such a model implies a unitary central mechanism of stimulus encoding in the perception of form. Since the appreciation of form is not limited to the visual channel, inter-modal studies of form perception in which information parameters are varied should provide evidence relative to the hypothesis of a central process. For instance, Baker & Alluisi (1962), using visual forms and their auditory analogs, reported that variations in stimulus complexity and redundancy yielded similar effects in both modalities. In the present investigation, Ss were required to identify tactual forms analogous to the visual forms used in the studies described above. This was done in the belief that a comparison of the results of the present investigation with a substantial body of research results obtained with visual and auditory forms would allow a further test of the hypothesis of a central information reduction mechanism in form perception.

Additional evidence regarding the generality of information processing in the perception of form might be obtained by examining the performance of blind Ss on tasks requiring the identification of tactual forms. If form perception is mediated by a process that is independent of modality, the performance of blind Ss on a task requiring figure identification should resemble the performance of a comparable group of sighted Ss. Ewart & Carp (1963) and Worchel (1951) have shown that blind Ss can identify geometric forms by touch as accurately as sighted Ss can by sight. However, the forms used in these studies were of the sort that cannot be described conveniently by information measures. Consequently, such results, though suggestive, do not lend themselves to a comparison of the performance of blind and sighted Ss on a task in which information parameters are varied directly. Accordingly, in the present study, blind and sighted Ss were compared on a task requiring tactual identification of form in which stimuli were varied with respect to complexity and redundancy.

Method

Subjects

Twenty-four students, drawn from psychology classes at the University of Louisville, and twenty-four legally blind individuals living in the Louisville metropolitan area, served as Ss in the experiment. Each group contained eleven males and thirteen females. The Ss in the sighted group ranged in age from seventeen to thirty-five years, with a mean age of twenty years. Blind Ss were older, ranging in age from seventeen to sixty-five years, with a mean age of forty-one years. All of the blind Ss had completed at least six school grades, and all of them made regular use of braille in recreational reading or as a job requirement. All Ss were paid volunteers.

Stimuli

The stimuli in the experiment were punctiform metric figures, to be identified by touch. Metric figures are relatively simple shapes resembling histograms, and are generated by sampling column heights, according to a predetermined sampling rule, in a symmetrical row-by-column matrix. Their complexity is defined by the maximum number of such figures that can be generated from the matrix on which they are based, and this number depends, in turn, upon the number of cells in the matrix. The logic upon which the use of metric figures is based and the methods employed in their quantification have been described in detail by Alluisi (1960), Baker & Alluisi (1962), and Fitts, et al., (1956).

Figures at four levels of complexity were generated by the use of 3 x 3, 4 x 4, 5 x 5, and 6 x 6 matrices. Random figures were obtained by random sampling of column heights. The average amounts of information needed to specify one out of all possible random figures at each of the four levels of complexity were: 4.8, 8.0, 11.6, and 15.5 bits, respectively.

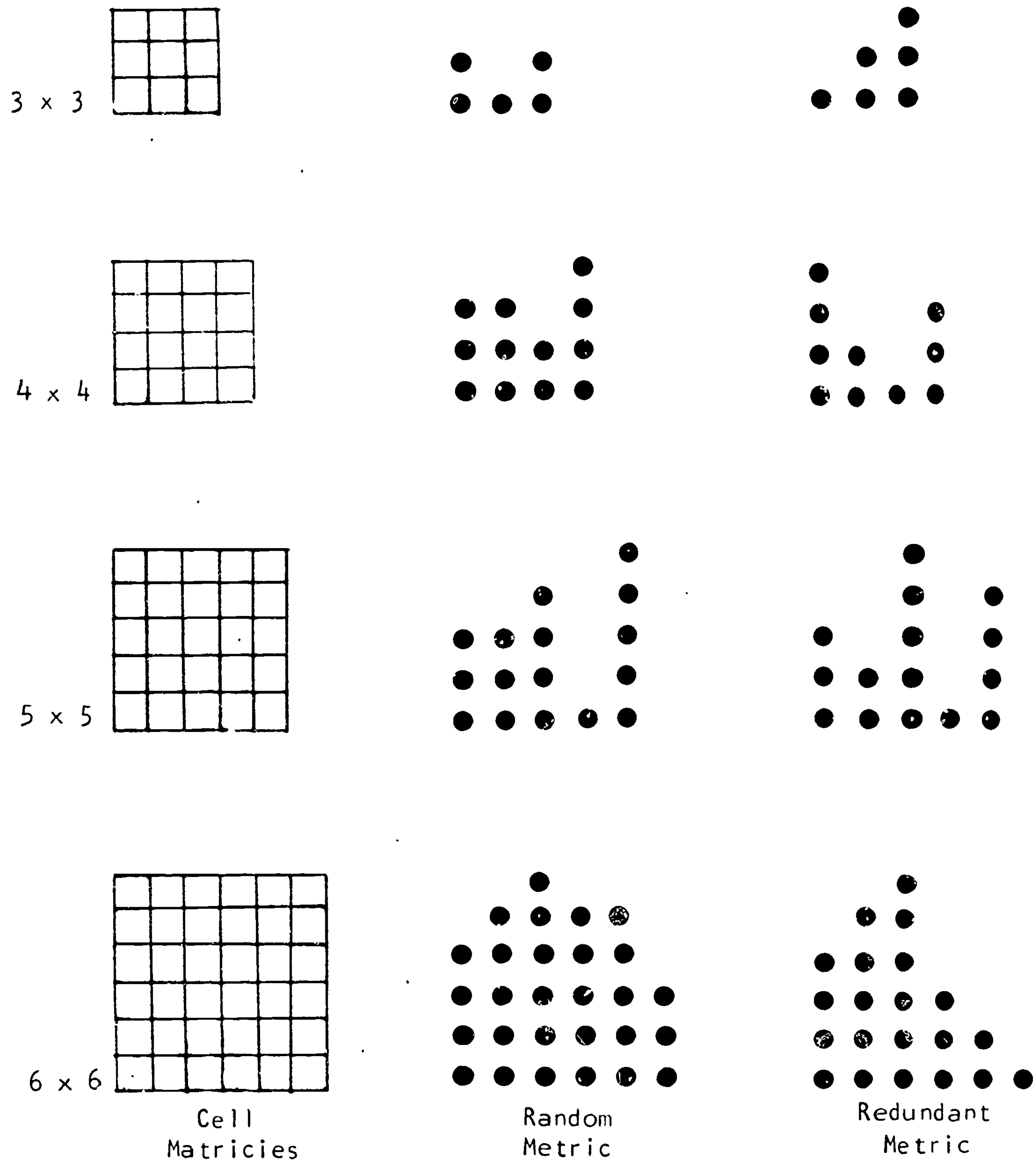
To produce redundant figures at each level of complexity, column heights were sampled at random for each figure, with the constraint that each of the possible column heights must appear once and only once in any given figure. The redundancy that results from the imposition of this constraint has been designated "Redundancy-1" (Alluisi, 1960). The average amounts of information needed to specify one out of all possible redundant figures at each level of complexity were: 2.6, 4.6, 6.9, and 9.5 bits, respectively. At each level of complexity, redundant figures constituted a subpopulation of the population of random figures at that level of complexity, and it is in this sense that they are said to be redundant relative to random figures (Baker & Alluisi, 1962). Illustrations of stimulus forms used in the present study are shown in Figure 1.

Apparatus

The forms presented for tactual inspection were embossed on aluminum, using a specially constructed braille slate. Vertical and horizontal spacing between adjacent dots, center to center, was .095 of an inch. This value is standard for the braille code. Forms were centered on aluminum sheets, approximately two inches on a side, and these were mounted on one quarter inch massonite blocks to promote ease of handling and durability.

Stimuli were presented for tactual inspection in a partially enclosed box, placed on a table between S and E. The three blocks

Figure 1. Cell Matrices of Different Complexity and Samples of Metric Figures Using Braille Dots.



containing the stimulus forms involved in any given comparison were fitted into appropriate jigs on the floor of this box. S gained access to the stimuli by putting his preferred hand through the curtained front of the box and he located a "standard stimulus" by following with his index finger, a raised runway near the left hand edge of the box. When his finger made contact with the standard stimulus, a time delay relay, controlled by photo cell circuitry, was energized. When this relay closed at the end of four seconds, a buzzer sounding for one half sec. informed S that the examination period was over. At this point, S removed his finger from the standard stimulus. Upon a signal from E, S then followed a raised runway near the right hand side of the box which led to a pair of "comparison stimuli." The positions of each of the comparison stimuli were termed answer position one and answer position two respectively. Contact with either of the comparison stimuli interrupted a beam of light, and this interruption started a Standard Timer Type S-1 controlled by photo cell circuitry. S's task was to decide which, if either, of the two comparison stimuli was identical to the standard stimulus. He indicated his choice by operating, with his other hand, a response keyboard consisting of three momentary switches labeled one, two and neither. S's response stopped the Standard Timer and turned on one of three lights. Thus E, by noting the light that was turned on and by reading the timer, could keep a record of response accuracy and time.

Experimental Design

A 4 x 2 x 2 factorial design was employed. Effects due to visual status (blind vs. sighted) constituted a between subjects variable while effects due to level of complexity and to degree of redundancy (random vs. redundant) constituted within subjects variables.

All Ss participated in four experimental sessions. Each session consisted of 36 trials, 18 consecutive trails with random figures and the remaining trials with redundant figures. Figures at one level of complexity were presented during each session and the order or presentation of random and redundant figures was balanced across Ss. In both the blind and the sighted groups, each S encountered a different one of the twenty-four possible orders of four levels of complexity, as he progressed through the four experimental sessions.

Six figures were constructed for each of the eight combinations that result from four levels of complexity and two levels of redundancy. The six figures representing a given combination were used to compose the 18 consecutive trails in which that combination was employed. Each figure served as the standard stimulus in three of the eighteen trials. On two of these occasions, it was also used as a comparison stimulus, once in answer position one, and once in answer position two. On the remaining occasion, it did not appear among the comparison stimuli. Choice figures for each of these three trials were drawn from among the remaining five figures in the sample. For each S, the three trials in which a given figure served as the standard stimulus were distributed randomly among the 18 trials of the combination under test, with the restriction that no figure could serve as the standard stimulus more than twice in succession. The

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figures that served as comparison stimuli, and their positions, were determined for each S on every trial by random selection, with the restriction that no figure could serve as a comparison stimulus more than twice in succession.

Procedure

At the beginning of the first experimental session, E read instructions acquainting S with the nature of the task. S was told that both speed and accuracy were important in making his judgments.

During the initial phase of each session, Ss were given practice trials with figures at the level of complexity specified for that session. Practice figures generated from the 3 x 3 and 5 x 5 matrices were random figures, while practice figures generated from the other two matrices were redundant figures. Practice figures were not used in the experiment proper. During practice, Ss were given immediate knowledge of results, and practice was continued until a criterion of four consecutive correct responses was met. Following this, the thirty-six experimental trials (eighteen with random figures and eighteen with redundant figures) that made up a session were administered without knowledge of results.

Results

Two measures of performance were computed from the data of each S: (a) the percentage of correct identifications and (b) median response latencies for correct identifications. Mean percentages of correct responses for blind and sighted Ss under all experimental treatments are plotted in Figure 2.

With the use of three response alternatives per trail, Ss in the present study had to obtain accuracy scores of 59 percent or more in order to demonstrate better than chance performance at the .01 level for any block of 18 trials. Examination of Figure 2 reveals that on the average, Ss in the present study were able to identify the stimulus forms with a degree of precision far exceeding chance expectations.

The percentages of correct responses for each S under all conditions of the experiment were transformed into arcsines (Winer, 1962) and the data were then treated by analysis of variance. Statistically significant effects were found between the visual status groups ($F = 8.02$, $df = 1/46$, $p < .01$), between levels of complexity ($F = 32.57$, $df = 3/138$, $p < .01$) and between random and redundant figures ($F = 10.70$, $df = 1/46$, $p < .01$). Further, the interactions between groups and complexity ($F = 9.03$, $df = 3/138$), groups and type of figures ($F = 7.74$, $df = 1/46$) and complexity and type of figures ($F = 6.49$, $df = 3/138$), were also found to be statistically reliable ($p < .01$ in each case).

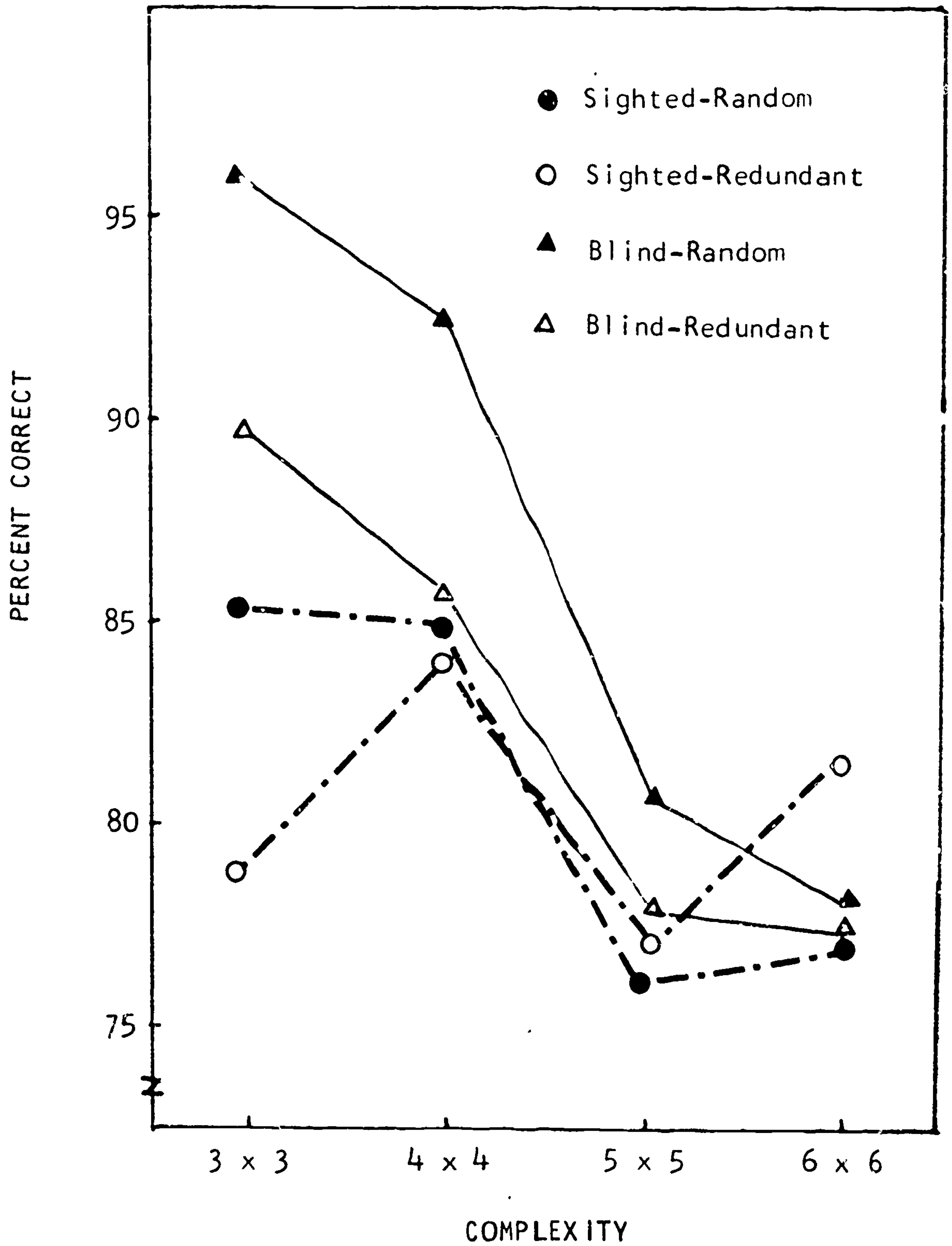

Figure 2. Mean Percentages of Correct Identifications.

In order to understand more clearly the implications of the various interactions, F-ratios were computed for differences between the blind and sighted groups at each level of complexity and with random and redundant figures (Winer, 1962). Additionally, separate analyses of variance and associated Duncan Multiple Range Tests (Edwards, 1960) were performed on the data of the sighted and blind Ss with respect to differences between complexities and type of figures. An alpha level of .05 was set for all comparisons. Results are summarized below for each major dimension of the study.

Blind vs. Sighted Ss.-Blind Ss were more accurate than sighted Ss in identifying forms generated from the two lower levels of complexity, but no differences between these groups were evident with the more complex forms. Further, the superiority of response accuracy in the blind Ss was more pronounced with random than redundant figures.

Random vs. Redundant Figures.-Differences between random and redundant figures were negligible among the sighted Ss. The blind Ss however, were able to identify random figures with a significantly higher degree of accuracy than redundant figures.

Complexity.-While overall accuracy of performance tended to decline as a function of increments in stimulus complexity, the nature of the differences between levels of complexity was closely tied to sampling rule in both blind and sighted Ss. Using random figures, sighted Ss were able to identify forms generated from the two lower levels of complexity with greater precision than figures generated from either of the two higher levels of complexity. Differences between the two lower levels of complexity and between the two higher levels of complexity were not statistically significant. Similar effects for complexity were noted for blind Ss with the use of random figures with one exception--in this group, forms generated from the 3 x 3 matrix were identified more accurately than forms generated from the 4 x 4 level of complexity. When redundant figures were employed, real differences in response accuracy as a function of stimulus complexity were not noted for the sighted Ss. Among the blind Ss, differences in the precision of identification between complexity levels paralleled those obtained with random figures among the sighted Ss.

Means of median response latencies for blind and sighted Ss under all conditions of the experiment are shown in Figure 3. Analysis of variance of these data indicated that response latencies to correct identifications were significantly shorter for the blind than for the sighted Ss ($F=30.22$, $df = 1/46$, $p<.01$) and that random figures were identified more rapidly than redundant forms ($F=48.85$, $df = 1/46$, $p<.01$). The analysis of variance also showed a significant main effect for complexity ($F=13.01$, $df = 3/138$, $p<.01$) and it indicated that none of the relevant interactions were statistically reliable ($F<1$). Results of a subsequent Duncan Multiple Range Test revealed that forms generated from the two lowest levels of complexity were identified more rapidly than figures from either of the two higher levels of complexity ($p<.05$ in each case). Differences in response latency between the two lower levels of complexity and between the two higher levels of complexity were negligible.

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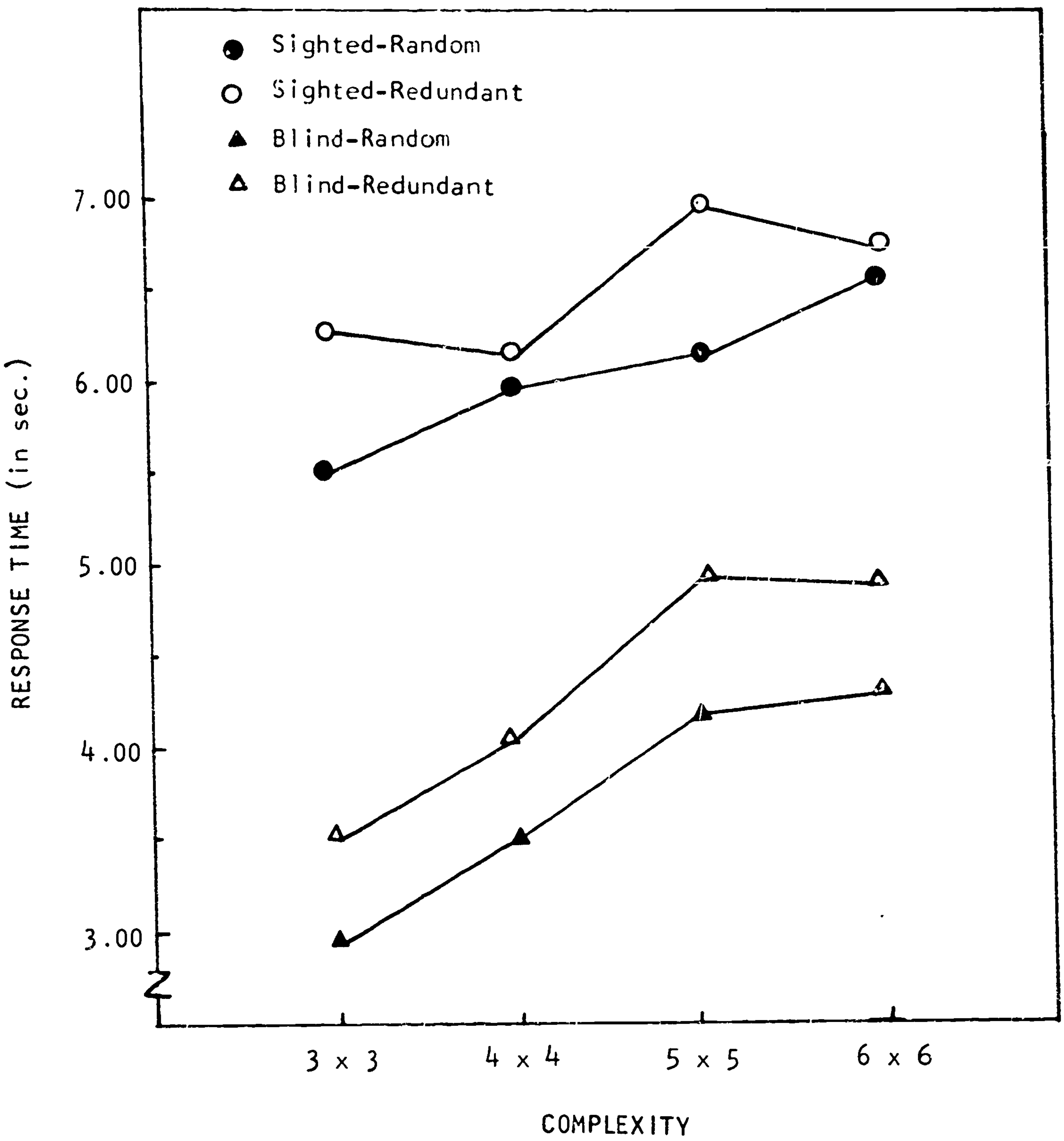

Figure 3. Means of Median Response Times (in sec.) for Correct Identifications.

Finally, in an effort to assess quantitatively the degree of similarity between the indices of performance used in the present study, a product moment correlation was computed between each S's mean of median response times to correct identifications over all experimental treatments and his mean percentage of correct response on all experimental conditions. The results indicated that 29 percent of the variance in response time was associated with differences in response accuracy ($r=-.54$, $df = 46$, $p<.01$).

Discussion

In the present investigation, an attempt was made to determine if two information parameters which had been shown to be critical variables in the perception of visual form were also applicable to the identification of tactual forms. The general tendency found here, for efficiency of performance to decline with increments in stimulus complexity and the overall trend toward greater efficiency of performance with random than with redundant figures accords with findings regarding these variables using visual stimuli. Consequently, the outcome of the present study supports a previous conclusion drawn by Baker and Alluisi (1962), namely, that the information handling approach taps a single process of form perception in man.

It should be noted that in terms of an information reduction model of form perception, superior performance with random as compared to redundant figures is, at first glance, paradoxical. The paradox arises from the fact that random figures are associated with a greater amount of uncertainty than are redundant figures. In an effort to solve this problem, Baker & Alluisi (1962) have suggested that man does not necessarily process all the information in a figure when perceiving form. Instead, discriminations tend to be made on the basis of the parts of a figure having the highest uncertainty for the observer--the distinctive details of the figure. These investigators also point out that in as much as redundant forms constitutes sub-populations of random figure populations at each level of complexity, redundant forms are less likely to demonstrate distinctive details than are random figures. Consequently, Redundancy-1 represents a type of redundancy that hinders the identification of form. Although Baker & Alluisi have developed this argument with respect to visual and auditory forms, extension of their account to the results of the present study in which tactual forms were used does not seem unreasonable.

Comparisons between blind and sighted Ss in the present study revealed two major differences: (a) overall efficiency of performance for the blind was superior to that of the sighted and (b) the effects of sampling rule on form identification appeared to differ in blind and sighted individuals when response accuracy was used as a dependent variable but not to differ when performance was indexed by response time to correct identifications. A plausible explanation for the overall difference in efficiency of performance between the blind and sighted groups can be based upon differences in prior experience in tasks requiring the recognition of tactual form. All of the blind Ss were skilled braille readers while this skill was absent among the sighted Ss. In as much as the stimulus forms used here were analogous to braille forms, it seems reasonable to expect a degree of positive transfer among the blind Ss with consequent superiority in performance for this group. It should be noted that such an explanation is consistent with an earlier attempt to account for the superior performance of blind, as compared to sighted Ss, in other tactual-perception tasks on the basis of disparities in initial practice levels (Hunter, 1954). The finding that blind Ss responded more accurately than sighted Ss at the two lower levels of complexity but not at the two higher levels, and the finding that this superiority was more pronounced with random than with redundant figures, have interesting implications. If the difference between the two groups with respect to prior experience on tasks resembling the experimental task is an important difference, the conclusion is suggested that when response accuracy is used as an index of performance, easy discriminations benefit more from the generalized effects of prior practice than difficult discriminations.

The question of the equivalence of different response measures has been an important issue in research on form perception (Adams, Fitts, Rappaport, and Weinstein, 1954; Hake & Rodwan, 1966, Michels & Zusne, 1965; Schiff & Isikow, 1966). While previous research has demonstrated a negative correlation between response latency and response accuracy (Austin & Slight, 1952), response latency has been found to be a more sensitive measure in reflecting the effects of various experimental treatments (Baker & Alluisi, 1962; Fitts, et al., 1956). These relations are illustrated again in the present data by the correlation of -.54 between the dependent measures used here and by the fact that the identification of characteristic differences due to redundancy in the recognition of metric figures by sighted Ss was dependent upon the use of a performance criterion based upon response time rather than response accuracy. These findings suggest again that consideration be given to disparities between response measures in attempts to generalize from the results of different investigations involving the perception of form.

The general tendency in the present study for efficiency of performance to decline with increments in stimulus complexity was not unexpected. However, the exact character of this relationship requires additional explanation. It should be recalled that figures from the two lower levels of complexity were roughly similar in difficulty, and that figures from the two higher levels of complexity were also roughly similar in difficulty, but that figures from the two higher levels of complexity were clearly more difficult than figures from the lower levels of complexity. This rather abrupt change in difficulty suggests a corresponding change in one or more of the determinants of performance, such as the nature of the task confronting the S. It may be that the figures generated from the two larger matrices were more difficult because their greater areal extents required S to alter his approach in examining them. The figures generated from the two smaller matrices were small enough in most cases so that the entire figure could be covered by a single fingertip. The remaining figures, on the other hand, were large enough so that only a part of the figure could be examined at a time, therefore requiring that form detail be perceived serially.

In addition to implications for basic research, the present data have bearing on applied problems involved in the use of tactual forms as cues in communication systems. Specifically, it has recently become clear that a need exists for revision of the braille code to allow for more rapid reading rates and to permit the inclusion of technical symbols used in the various sciences (Rodgers, 1964). One means of achieving such a revision is to expand the standard 2 x 3 braille matrix and thus provide for the generation of an increased number of different forms. Although the ability to identify tactual forms generally declined in the present investigation with increments in matrix size, the levels of performance obtained with forms generated from 3 x 3 and 4 x 4 matrices were more similar to each other than they were to the levels of performance obtained with forms based upon matrices having larger dimensions. Hence, the present data suggest that if symmetrical matrices having standard braille values for vertical and horizontal spacing between elements are used in a revision of the braille code, maximum efficiency with respect to the encoding and decoding of information can be achieved with a 4 x 4 matrix.

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