Visual selection: The effects of number of encodable elements and physical complexity

WILLIAM H. WILSON

Middle Tennessee State University, Murfreesboro, Tennessee 37132

Research in the area of visual selection has consistently demonstrated that viewing time increases with the complexity of the stimuli. A theoretical position has been proposed to account for these findings in terms of stimulus encoding. This position by Nunnally and his associates (e.g., Nunnally & Lemond, 1973) places primary emphasis on the number of meaningful encodable elements as the stimulus variables to account for the effects attributed to complexity. Two experiments were performed to examine these two stimulus variables. Both experiments employed college students in a free-viewing time procedure. The dependent variable was length of viewing time for each of a series of slides. Experiment I manipulated the number of encodable elements in each slide and the homogeneity or heterogeneity of the stimulus elements. Experiment II compared physical complexity with the number of encodable elements in a factorial design. Both experiments found significant support for the number of meaningful encodable elements as an important determiner of visual selection.

Visual selection has been labeled "selective visual attention", "looking behavior," and "visual exploration." All these terms are intended to imply the same set of response systems, namely, those activities of the subject that bring a stimulus into view and maintain a stimulus in view. The principal dependent variable in most of this research is length of viewing time. Much of the research on visual selection concerns those characteristics of the stimulus that influence viewing time. This paper concerns two experiments that dealt with the role of stimulus complexity.

Complexity has typically been defined in terms of some physical attribute of the stimulus that permits quantification without resorting to subjects' ratings. The materials most frequently employed in research on visual selection are random geometric forms, i.e., polygons (e.g., Wilson & Nunnally, 1973). The measure of complexity is typically the number of sides of the polygon.

Nunnally and Lemond (1973) have provided an extensive review of research conducted to examine the influence of stimulus complexity on visual

selection. The overwhelming majority of the studies demonstrates that more complex stimuli tend to dominate less complex stimuli in terms of length of viewing time. Of 42 studies reviewed, 39 reported that viewing time increased with complexity. All the remaining studies report no consistent findings as a function of complexity. Twenty-one of these experiments employed polygons. Other materials employed include dot patterns, flashing lights, and stimuli developed by Berlyne (e.g., Berlyne, 1958).

Although the aforementioned research tends to suggest a clear relationship between physical parameters of complexity and visual selection, another, potentially more important, variable may be involved. Most types of stimuli that were developed for studies concerning complexity (e.g., random polygons) were not intended to contain meaningful or representational elements. However, Nunnally and Lemond (1973) have proposed that the principal psychological process involved in looking at such stimuli is "the identification of all or part of the stimulus as depicting objects in daily life" (p. 96). They further hypothesized that "the more complex the design, the greater the number of possible 'objects' which can be 'seen' in the stimulus" (p. 96). This proposal by Nunnally and his associates is based upon the assumption that a major aspect of visual selection is a meaningful encoding of the stimulus. The term "encoding" is used to imply a process of attributing meaning in the sense of labeling, identifying, or categorizing the stimulus.

That the number of meaningful representational elements may be an important variable is suggested by several investigations that have found a positive

This article is based on the author's doctoral dissertation conducted while at Vanderbilt University. I wish to express my thanks to Dr. Jum Nunnally for his scholarly review of the manuscript. This investigation was supported, in part, by research grants from the National Science Foundation (No. GB29416) and from the National Institute of Education (No. OEG-4-71-0051) to J. C. Nunnally. The opinions expressed herein, however, do not necessarily reflect the position or policy of the National Institute of Education, and no official endorsement should be inferred. Address reprint requests to: Department of Psychology, Middle Tennessee State University, Murfreesboro, Tennessee 37132.

relationship between complexity of random polygons and ratings of number of things seen (e.g., Munsinger & Kessen, 1964). In a more recent study, Nunnally and his associates found a correlation of $r = .91$ between number of sides of random polygons (3 to 200) and ratings of numbers of things seen (presently unpublished). In a somewhat different vein, McCall and Kagan (1967) found that an infant's viewing time is influenced much more by meaningful stimuli. They concluded that "meaning begins to compete with purely physical parameters for the attention of the child relatively early in the first year" (p. 952).

The primary objective of the present research was to examine the relative influence on visual selection of physical complexity and number of meaningfully encodable representational elements. The latter is defined in terms of stimulus configurations that contain many separable parts (e.g., picture containing many faces). The terms "encoding" is used in the sense of labeling, identifying, or categorizing the stimulus, as discussed above.

Experiment I contrasted subjects' viewing time of stimulus materials in which all the elements were the same with viewing time of materials in which all the elements were different. Comparisons were made across three levels of the number of elements in each stimulus display. In Experiment II, stimulus materials were specifically constructed in such a fashion as to compare physical complexity with number of meaningfully encodable elements.

EXPERIMENT I

Research by Brown and O'Donnell (1966) examined the effects of sheer number of objects; however, in that research an effort was made to eliminate all meaningful or representational stimuli. In the present study, a wide variety of stimulus materials was employed specifically to examine number of representational elements. These materials varied on two major factors. The first factor was the number of discrete objects in the pictures (e.g., 2, 6, or 10 faces). The second factor was whether each total picture was composed of a homogeneous or a heterogeneous collection of objects (e.g., 10 copies of one face or 10 different faces).

Subjects should look longer at a stimulus that contains a number of different things rather than at one containing many copies of the same thing. Also, one would predict that subjects will look longer at a picture containing 10 elements than at one containing 2.

Method

Subjects. The subjects were 24 male college students enrolled in the introductory psychology course at Vanderbilt University.

Their participation was in partial fulfillment of a course requirement.

Stimuli. The stimuli consisted of six sets of black and white slides with six slides in each set. The slides in each set comprised a 3 by 2 matrix for the factors of number of elements and homogeneous-heterogeneous elements. Each set had slides with 2, 6, or 10 elements (number of things in the picture); for example, a set contained pictures of 2, 6, or 10 faces. Also within each set there were slides that had 2, 6, or 10 different elements (heterogeneous items) or 2, 6, or 10 copies of the same element (homogeneous items). To increase the generality of the findings, two sets of materials were composed from each of three general classes of materials: (1) faces of human males, (2) inanimate objects (i.e., tools and electrical parts), and (3) random polygons (10 or 20 sides only). There was no overlap in the elements either between sets or within slides in sets. (see Wilson, 1973, for these materials.)

Apparatus. Both experiments were conducted in a room that contained a soundproof acoustical chamber measuring $2.75 \times 2.13 \times 1.98$ m. A chair, a table, a television monitor, an intercom, and a loudspeaker connected to an audio oscillator (outside) were in the acoustical chamber. The chamber was so arranged that the student sat in a chair at one end of the table. At the other end of the table was the 23-in. television monitor.

Outside the chamber, the slide projector focused stimulus slides on a viewing screen. These slides were then transferred to the TV monitor via closed circuit TV. When not in use, the TV screen was blank but not off.

Each student sat in the chamber and viewed the stimulus slides displayed on the TV screen. A stimulus remained on the TV screen until the student pushed the control switch on the table. This action caused the next stimulus in the series to appear. Unknown to the student, this action also caused the amount of time spent viewing each stimulus to be recorded by a paper-tape event recorder located outside the chamber.

Procedure. The students were tested individually in sessions that lasted between 35 and 50 min. After being familiarized with the chamber, the student was given instructions that were intended to disguise the true purpose of the experiment. In experiments where the student controls length of stimulus presentation, this disguise set has been demonstrated to be important to permit a more natural behavior on the part of the subject by reducing demand characteristics (Faw, Nunnally, & Ator, 1969). With minor changes for the total number of slides the student expected to see, these instructions were the same in both studies.

It was explained to the student that the experiment involved the effect of auditory isolation on auditory threshold levels. The experimenter indicated that previous investigations had employed both visual and auditory isolation and that the objective in the present study was to examine only auditory isolation. This disguise provided a plausible excuse for permitting the student to view stimuli while in auditory isolation. It was further explained that auditory thresholds would be measured before and after the treatment condition (auditory isolation). The student was instructed on the use of the remote control button that allowed him to control the presentation of the experimental materials.

After giving the instructions, the experimenter closed the door to the chamber and proceeded with the disguised portion of the study. At the end of the disguised portion, the event recorder, TV camera, and slide projector were activated, thus allowing the student to view the stimulus slides. An asterisk appeared on the TV screen, indicating to the student that it was time to view the slides. The student then pushed the button, and the first slide appeared. The first two slides were practice slides which gave the student experience with operating the slide projector. In all cases, these practice slides were simple dot patterns containing five dots. Each student received a different random order of the 36 stimulus slides. After the student finished viewing the slides, the simulated measurements of auditory thresholds were repeated, and then the student was dismissed from the experiment (see Wilson, 1973, for the complete procedures and instructions).

Results

In both experiments, viewing time was measured in millimeters and converted to seconds (1 sec = 5 mm). Because scores in seconds tend to be skewed, the data were normalized by transforming each subject's scores into $\log_{10}$ seconds of viewing time. All analyses were conducted on this latter form of the data.

In this first experiment, the $\log_{10}$ seconds of viewing time scores were averaged across the two sets of material within each of the three classes of materials. An A(3) by B(2) by C(3) within-subjects analysis of variance was performed on these average $\log_{10}$ seconds of viewing time scores. Factor A was the three classes of materials (i.e., faces, polygons, and inanimate objects). Factor B was the comparison between homogeneous and heterogeneous elements. Factor C was the number of elements in a slide (i.e., 2, 6, or 10).

The results of the analysis indicated significant main effects for Factor A [$F(2,46) = 3.643$, $p = .003$], Factor B [$F(1,23) = 18.023$, $p < .001$], and Factor C [$F(2,46) = 52.548$, $p < .001$]. There were also significant interactions of Factors A and C [$F(2,92) = 2.470$, $p = .049$] and Factors B and C [$F(2,46) = 14.965$, $p < .001$].

Subsequent Newman-Keuls tests of multiple comparisons on Factor A indicated that faces were viewed longer than polygons, $p < .05$. No other differences were significant. The mean viewing times in $\log_{10}$ seconds were: faces = 0.89, objects = 0.86, and polygons = 0.81.

Of primary interest here were the significant effects found for Factors B and C. The analysis on Factor B indicated that heterogeneous materials were viewed longer than homogeneous materials. The means of viewing time in $\log_{10}$ seconds were: homogeneous = 0.81 and heterogeneous = 0.89. Newman-Keuls tests of multiple comparison on Factor C indicated that all possible comparisons were significant beyond the $p = .01$ level. The means in $\log_{10}$ seconds for the three levels of this factor were: 2 elements = 0.76, 4 elements = 0.87, and 10 elements = 0.92.

These results, however, must be viewed in light of the two significant interactions. Newman-Keuls tests of multiple comparisons were employed to examine the AC interaction. Comparisons were made among the three classes of materials at each level of number of elements. At the first level (2 elements), there were no significant differences. At Level 2 (6 elements), faces were viewed longer than polygons or objects ($p = .05$). At Level 3 (10 elements), all differences were significant at the $p < .05$ level.

Presented in Tables 1 and 2 are the means of viewing time for the interactions of Class by Level and Homogeneous-Heterogeneous by Level, respectively. Inspection of these means indicates

Table 1
Means of Viewing Time in $\log_{10}$ Seconds for the Class of Material by Number of Elements Interaction

	Number of Elements		
	2	6	10
Faces	.770	.912	.976
Objects	.781	.862	.933
Polygons	.739	.824	.865

Table 2
Means of Viewing Time in $\log_{10}$ Seconds for the Homogeneous/Heterogeneous Materials by Number of Elements Interaction

	Number of Elements		
	2	6	10
Homogeneous	.742	.841	.849
Heterogeneous	.785	.891	1.000

that, in all cases, viewing time increases with the number of elements. Thus, the interactions do not seriously bring into question the major results of the study.

Discussion

The results of this study clearly support the hypothesis that subjects look longer at heterogeneous than at homogeneous materials. They also demonstrate that the total number of elements is important, although the effect appears to level off in homogeneous materials (see Table 2). Also of interest is the finding that faces, which may be more meaningful stimuli for the subjects, elicit longer viewing time than polygons. Although the inanimate objects were not viewed significantly longer than the polygons in the main effect of this factor, the direction of difference was in line with a meaningfulness interpretation. This is supported by the Newman-Keuls analysis at Level 3 (10 elements) on the AC interaction.

The major findings of this study are not surprising; however, they represent a necessary demonstration. If this demonstration had not produced clear results, the number of representational elements would not have been suspect as a variable influencing visual selection.

EXPERIMENT II

Physical complexity, in terms of the number of random sides of polygons and number of things people see in these stimuli, appears almost perfectly confounded in much of the research on visual selection. If these variables were confounded in previous research, it is important that stimulus materials be structured in such fashion as to determine the relative influence of the two variables. The objective of this second study was to make such a

comparison. The stimuli employed were polygons produced specifically to fit a 2 by 2 factorial design. The comparison made was a high-low complexity vs. one-four representational figures (e.g., birds, dragons, etc.).

Ideally, it would have been best to select randomly constructed materials that fit the four cells of the design. Selection would have been on the basis of subjects' ratings. However, previous research suggests that obtaining such materials is nearly impossible in practice. This is because of the very high correlation ($r = .91$) between number of sides and number of things seen. One reasonable recourse, therefore, was to purposely construct figures that fit the design.

Method

Subjects. The subjects were 12 male and 12 female undergraduate students enrolled in various classes at Vanderbilt. In contrast to Experiment I, it was necessary to recruit subjects by offering to pay them \$2 for participation. The students were told only that the study concerned the influence of auditory isolation on auditory threshold levels.

Stimuli. The stimuli consisted of 16 black and white slides. Four stimuli were composed for each of the four cells of the design. There were eight figures clustered around each of the two levels of complexity, i.e., 30 and 90 sides. The 30-sided figures ranged from 28 to 32 sides. The 90-sided figures ranged from 89 to 95 sides. The two levels, in terms of number of things seen, were one and four objects. To facilitate preparation of these materials, the author's research associates rated these stimuli for number of things seen. The materials were redrawn until agreement was reached on the number of things seen (see Wilson, 1973, for the materials). Subsequently, a group of students, 10 males and 6 females, rated the stimuli in terms of complexity. Each rating scale was divided into 11 segments, with each scale having the words "simple" and "complex" as anchor terms.

Procedure. The procedure described for Experiment I was followed for the viewing time portion of this study. Each student was assigned a different random order of stimulus presentation.

Results

The $\log_{10}$ seconds of viewing time scores of each student were averaged across the four stimuli in each cell of the design. These scores were then employed in an A(2) by B(2) by C(2) analysis of variance. Factor A was sex. Factors B and C, respectively, were within-subjects factors of number of objects (one or four) and complexity (30 or 90 sides).

All three main effects were significant. Males viewed the stimuli longer than females [$F(1,22) = 9.336$, $p = .006$]. The means in $\log_{10}$ seconds of viewing time were: females = 0.64 and males = 1.05. Four-element figures were viewed longer than 1-element figures [$F(1,22) = 38.280$, $p < .001$]. The means in $\log_{10}$ seconds of viewing time were: 1 element = 0.80 and 4 elements = 0.89. Ninety-sided figures were viewed longer than 30-sided figures [$F(1,22) = 10.916$, $p = .003$]. The means in $\log_{10}$ seconds of viewing time were: 30-sided = 0.83 and 90-sided = 0.86. There were no significant interactions.

To test the hypothesis that the four element/30-sided figures would be viewed longer than the 1-element/90-sided figures, a one-tailed direct difference t test for correlated data was calculated on the average $\log_{10}$ viewing time scores between the two sets of materials. The results of the t test confirmed this hypothesis [$t(23) = 4.02$, $p < .001$]. A second one-tailed t test was calculated on the mean ratings of complexity, with the same comparison and the same direction of testing as above. This t test revealed that the 4-element/30-sided figures were not rated as significantly more complex than the 1-element/90-sided figures ($t < 1.0$). The mean rated complexity averaged across the four stimuli in each group was: $1/30 = 3.82$, $1/90 = 5.04$, $4/30 = 5.92$, and $4/90 = 8.34$.

Discussion

The results of the major analysis support the prediction that the number of encodable elements is an important variable in determining length of viewing time. This conclusion is supported by the comparison between complexity ratings and viewing times, demonstrating that, even though the 4-element/30-sided figures were not rated as significantly more complex than the 1-element/90-sided figures, they are still viewed significantly longer. These results clearly mitigate against the importance of sheer physical complexity as the principal determinant of viewing time in this experiment.

The results of the major analysis also demonstrated an effect attributable to complexity. This result demonstrated that physical complexity is a variable that must be considered.

Although not a major point for this paper, one interesting finding was that males' viewing time was more than twice as long as females' viewing time. Such findings may point to basic differences in the visual selection behavior of males and females. Thus, one must exercise caution in making general statements concerning visual selection when referring to both males and females.

Because it was necessary to construct the stimulus materials on an intuitive basis rather than by strictly random procedures generally employed for such materials, one can rightly wonder what the limitations are in generalizing these results to other types of visual stimuli. Nevertheless, the results of both experiments do provide considerable circumstantial evidence for the importance of the number of meaningfully encodable elements in explaining visual selection.

REFERENCES

- BERLYNE, D. E. The influence of complexity and novelty in visual figures on orienting responses. *Journal of Experimental Psychology*, 1958, 55, 289-296.

- BROWN, L. T., & O'DONNELL, C. R. The attention responses of humans and squirrel monkeys to visual patterns varying in three physical dimensions. *Perceptual and Motor Skills*, 1966, 22, 707-717.
- FAW, T. T., NUNNALLY, J. S., & ATOR, N. A. The influence of stimulus uncertainty and experimental instructions on visual selection. *Perception & Psychophysics*, 1969, 5, 137-140.
- MCCALL, R. B., & KAGAN, J. Attention in the infant: Effects of complexity, contour, perimeter and familiarity. *Child Development*, 1967, 38, 939-952.
- MUNSINGER, H., & KESSEN, W. Uncertainty, structure, and preference. *Psychological Monographs*, 1964, 78(Whole No. 596).
- NUNNALLY, J. C., & LEMOND, L. C. Exploratory behavior and human development. In H. W. Reese (Ed.), *Advances in child development and behavior* (Vol. 8). New York: Academic Press, 1973.
- WILSON, W. H. *The influence of complexity on visual selection: Implications for a meaning-processing model*. Unpublished doctoral dissertation, Vanderbilt University, 1973.
- WILSON, W. H., & NUNNALLY, J. C. A technique for producing highly complex visual stimuli. *Behavior Research Methods & Instrumentation*, 1973, 5, 266-268.

(Received for publication August 4, 1975;
revision received May 25, 1976.)