THE EFFECT OF SET SIZE, AGE, AND MODE OF STIMULUS PRESENTATION ON INFORMATION PROCESSING SPEED

71-6809

NORTON, James Carling, 1944-
THE EFFECT OF SET SIZE, AGE, AND MODE OF STIMULUS PRESENTATION ON INFORMATION PROCESSING SPEED.

University of Arizona, Ph.D., 1970
Psychology, experimental

University Microfilms, Inc., Ann Arbor, Michigan

THE EFFECT OF SET SIZE, AGE, AND MODE OF STIMULUS PRESENTATION ON INFORMATION PROCESSING SPEED

by

James Carling Norton

A Dissertation Submitted to the Faculty of the

DEPARTMENT OF PSYCHOLOGY

In Partial Fulfillment of the Requirements
For the Degree of

DOCTOR OF PHILOSOPHY

In the Graduate College

THE UNIVERSITY OF ARIZONA

1 9 7 0

THE UNIVERSITY OF ARIZONA

GRADUATE COLLEGE

I hereby recommend that this dissertation prepared under my direction by James Carling Norton

entitled THE EFFECT OF SET SIZE, AGE, AND MODE OF STIMULUS PRESENTATION ON INFORMATION PROCESSING SPEED

be accepted as fulfilling the dissertation requirement of the degree of Doctor of Philosophy

Dissertation Director — Date Aug 18, 1970

After inspection of the final copy of the dissertation, the following members of the Final Examination Committee concur in its approval and recommend its acceptance:*

	August 18, 1970
	August 18, 1970
	August 18, 1970
	August 18, 1970
	August 18, 1970

*This approval and acceptance is contingent on the candidate's adequate performance and defense of this dissertation at the final oral examination. The inclusion of this sheet bound into the library copy of the dissertation is evidence of satisfactory performance at the final examination.

STATEMENT BY AUTHOR

This dissertation has been submitted in partial fulfillment of requirements for an advanced degree at The University of Arizona and is deposited in the University Library to be made available to borrowers under rules of the Library.

Brief quotations from this dissertation are allowable without special permission, provided that accurate acknowledgment of source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the head of the major department or the Dean of the Graduate College when in his judgment the proposed use of the material is in the interests of scholarship. In all other instances, however, permission must be obtained from the author.

SIGNED: [signature]

ACKNOWLEDGMENTS

The author would like to extend his thanks to the principal and staff of University Heights School, without whose cooperation this study would not have been possible. He would also like to extend sincerest gratitude to Dr. Neil R. Bartlett who was an understanding and helpful chairman, and to Dr. Dennis Clark, Dr. Terry Daniel, and Dr. Cecil Rogers for their concern and guidance.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

Figure | Page

ABSTRACT

First, second, and third grade pupils served as Ss in an experiment designed to reveal the effect of age, mode of stimulus presentation, and information value on recognition time. Stimuli were presented in picture and printed word form and in groups of 2, 4, and 8. The results of the study indicate that first graders are slower than second and third graders who are nearly equal. There is a gross shift in reaction time as a function of mode of stimulus presentation with advancing age. The first graders took much longer identifying words than pictures, while the reverse is true of the older groups. The effect of set size is also age related, there being smaller increases in recognition time with increasing information in the older relative to the younger Ss. Furthermore, a slope appears in the pictures condition in the older groups, while for first graders, a large slope occurs in the words condition and only a much smaller one for pictures. For the older groups, there is no increase in reaction time with larger set sizes in the words condition, and, in fact, the values tend to decrease.

INTRODUCTION

The problem of pattern recognition is an old one in psychology. In general, one may say that a stimulus is recognized when it is responded to differentially. Specifically, S is usually asked to supply a verbal label for the stimulus, but alternative modes of response have been employed. The fundamental theoretical and experimental problem, then, is to elaborate and investigate the mechanisms intervening between the external, usually visual stimulus array, and S's emission of a discriminative response.

This question has been approached from a number of vantage points. There is, first, the neurophysiological question of how the stimulus energies of the external environment are transduced into nervous energy and a phenomenal percept. The first answers to be offered for this question employed the model of a mosaic-like retina transmitting, point for point, to a sensorium whereat the retinal image was perceived and its nature inferred (Gibson, 1966, pp. 38-39). Helmholtz' theory of depth perception is paradigmatic for this type of perceptual thinking. He said that, through an unconscious inference, the depth characteristics of an image were perceived (Gibson, 1969, pp. 21-22). The image was seen as a one to one transduction of the stimulus energies arriving at the retina.

The Gestaltists laced their phenomenologically oriented perceptual writings with physiological notions. Central was the concept of isomorphism which held again that there existed a basically one to one correspondence between external and internal sensory processes. They added, however, that the dynamic organization of the central nervous system led to some alteration of these processes at the level of the cortex. Gestaltists argued that their laws of perceptual organization had a physiological basis. Closure, good continuation, etc. were seen as reflecting aspects of physiological organization and process.

For the sake of simplicity, one may lump these older physiological approaches together as template or sensation oriented. That is, there is said to be a relatively simple one to one transmission of sensation elements from the retina to the brain. Perception consists of the brain's inferring the meaning of these images, usually through some sort of matching of existing stimulations with past ones. Luria (1966) has argued that this approach to the problems of perception, based on Meuller's doctrine of specific nerve energies, has had a retarding effect. He offers an alternative reflexology approach based, predictably enough, on the work of Sechenov and Pavlov. This view stresses the active nature of perception, rather than the passive, receptor oriented approach.

In recent years, a number of physiological findings have called into serious question the tenability of any template theory of perception (Kolers, 1968). First, there is the discovery of centripetal fibers in the visual system, independent of the visuo-motor system, (e.g., Polyak, 1957). The presence of such fibers is hard to account for in a template theory. What purpose could they serve? Secondly, there are reports of work at the retinal and optic nerve levels which reveal high selectivity of response early in the system, with fibers and retinal fields reacting to complex and specific stimulus parameters. Lettvin, Maturana, McCulloch, and Pitts (1959), for example, found four distinct fiber types in the optic nerve of the frog. The fibers were differentially sensitive to such things as edges, convexity, on-off, and off phenomena. Hartline (1940a, 1940b) had earlier shown that each fiber of the optic nerve of the frog reflects stimulation of a specific retinal field and that these fields are organized having on, on-off, or off, sensitivities sometimes organized in concentric rings. Later, Hartline and Ratliff (1957) examined the compound eye of _Limulus_ and demonstrated complex interacting inhibitory and faciliatory effects even in this relatively simple visual system.

Recently, a number of papers have appeared which show that the visual cortex of various species is organized in a way reflecting complex feature analysis rather than simple point for point projecting of relative stimulus intensities. The work of Hubel and Wiesel (1962) might be considered exemplary. To summarize the significance of these physiological findings, they render any sort of template model of pattern recognition highly improbable. If structure in any way reflects function, the system clearly seems more like a feature analyzer than a template matcher.

A second line of development in addition to the physiological has been in the area of reaction time (RT) or, more specifically recognition time. Psychological events take time and the differing amounts of time some events take is revealing of different mechanisms entailed in their execution. Donders' early work on choice RT is an early example of the use of time as a dependent variable to reveal different processing mechanisms. He, along with Wundt, developed what was termed "mental chronometry" which investigated the time characteristics of different mental events. Basic to their work was the "subtraction hypothesis" which asserted simply that mental events occurred in tandem and that, by subtracting the known time required for one process, E could calculate the time for other processes (Sternberg, 1969).

While the subtraction hypothesis fell into disfavor, the use of time measures has seen a vigorous development.

The basic paradigm for perceptual research has been to see how long it takes S to recognize a stimulus while varying stimulus characteristics and/or setting events. The measure of recognition can be either a threshold or a reaction time. In the classic study of Bruner, Postman and Rodrigues (1951), for example, the effect of expectancy was revealed in the extremely high thresholds found for veridical recognition of a playing card with, e.g., a red club. Ss often misperceived the cards at durations far above that required to correctly identify a normal card. Ryan and Schwartz (1956) found that a line drawing caricature is more easily recognized, i.e., has a lower recognition threshold, than an accurate photograph, presumably because the key identifying features are accentuated in the former.

Recently, Posner (1969) has been studying the time characteristics of same-different judgments when stimuli share physical (a,a), name (A,a), or category (vowel) identity. Neisser (1967) has employed a somewhat different time measure to reveal some things about letter identification processes in adult human Ss. He has his S scan lists of letters searching for certain targets. By calculating the total time to scan to the target, he is able to calculate time spent per item. These times are extremely brief. Neisser reports that Ss can scan for several letters as easily as for one and this suggests that the processing is done in a parallel manner. Also, Ss report that they do not actually "see" the letters but, rather, that the sought after one just "pops out." Neisser has elaborated a model to account for his data which entails a hierarchy of perceptual processing steps. His work offers an elegant example of the way in which hypothetical constructs may be inferred from time measure data.

Thus, perceptual processes have been studied with physiological and RT methods. Evidence from the former has precluded a template theory and has thus exerted some influence on theorizing of a nonphysiological nature.

One of the variables that has repeatedly been shown to affect RT is the number of alternatives or the information value of the stimulus. Merkel's classic finding in 1885 (1965) that RT increases with the number of alternatives was given added significance in the light of information theory. As Hyman states,

> . . . the choice reaction-time experiment can be looked upon as a model of a communication system. The display represents a transmitter of information. Each alternative stimulus or _signal_ represents a _message_; more information can be transmitted the greater the number of messages from which one can be chosen. The _channel_ over which the signal is transmitted can be considered as the air space between the light and _S_, and might also include parts of _S_'s visual afferent system. The _S_ also acts as a _receiver_ or decoder in that at some point he decodes the signal into its message and reacts with the appropriate response (the _destination_ of the information) (1953, p. 188).

This information theory approach to perception was given support by repeated findings by a number of investigators of a linear relationship between RT and log n or "information" in the technical sense of binary digits. This finding has been reported in a variety of tasks over the years. Hyman (1953) used a panel of lights which could come on in various combinations. The combinations were given nonsense names and the conditions varied in the number of possible alternatives which might appear on a trial.

Suci, Davidoff, and Surwillo (1960) found linearity with 4, 3, 2, and 1 light conditions where each light had a nonsense name. Davis, Moray, and Treisman (1961) found linearity to hold in a consonant-vowel-consonant nonsense syllable naming task on early trials, though, with practice, there was no set size effect. The authors conclude that the linearity finding is likely only in tasks where S-R compatibility is relatively low. The information concept applies only where the response requires S truly to make decisions. Reading responses, the authors feel, are of an automatic, imitative type and hence are not responsive to set size variations. Brainard, Irby, Fitts, and Alluisi (1962) also found the linear relationship to break down with highly compatible responses (reading numbers). With less compatible responses, e.g., pressing keys in response to numbers, RT was found to be a linear function of information.

Other investigators have failed to find a linear relationship. In 1959, Mowbray and Rhoades practiced one heroic S 45,000 times on an RT task entailing discriminative finger responses to two or four lights, finding that, after 39,000 trials, there was no difference between the two and four choice conditions. Leonard (1959) also using tactual choice RT, found no differences between two, four, or eight choices, though one was faster. The response was depression of the finger while stimuli were applied directly to the finger--a highly compatible response. Seibel (1959) also failed to find the linear relationship with finger key responses to compatible, i.e., similarly arranged, lights. His Ss were, however, highly practiced with only the last 2,000 of 22,000 trials being analyzed.

Mowbray (1960) reports a study in which S had to name arabic numerals in 2, 4, 6, 8, and 10 sub set size conditions. All the means were equal. In a second study, S had only to name one numeral, not responding to the others. Here, the linear relationship did appear, but it is attributed by the author to the effect of differing intertrial intervals and their effect on S's expectancies. In the larger sub sets, the appearance of the stimulus creates a negative expectancy, i.e., S does not expect to see it again. If it appears, his RT is thus lengthened. This effect decreases in smaller sub set conditions.

It should be clear from the above review of some of the information processing literature, even though it is not exhaustive, that the relationship between RT and information or set size differs as a function of S-R compatibility and practice effects. With highly overlearned or compatible S-R units, RT is independent of set size.

The concept of information used in the studies above is highly situation bound. The sub set is E defined and sub set effects are dependent on S employing some sort of internal representation of the sub set in order to make the appropriate responses prepotent. Presumably, then, S makes a binary search of the sub set in finding the label for the stimulus when it is presented.

Approaching the identification from another angle, Oldfield (1966) has examined naturally occurring prepotencies in the form of Lorge-Thorndike frequencies. His interest is in the structure of the word store and in how it is searched in generating words. When an object is presented to S, he first has to identify it, then to find the correct name. Oldfield found that when words of differing Lorge-Thorndike frequency are presented, naming time is a linear function of log frequency. The presence of this effect demonstrates that the word store is organized in a systematic way relative to word frequency of use. Other studies have shown similar effects on visual duration threshold--Howes and Solomon (1951) showing it with printed words and Wingfield (1966) showing it with pictures. Oldfield concludes his paper with some comments apropos of the relations between his work and work with brain damaged aphasics, demonstrating again the concatenating nature of physiological and recognition time types of research in perception.

Reading printed words may be regarded as a special case of pattern recognition and a number of investigators have studied word naming latency as compared with object naming latency.

Stemming from Stroop's early work with colors and their names, a variety of interference effects have been found. Klein (1964), for example, measured what he called the semantic power of a word in a Stroop-type, color interference task. Words were printed in colors and varied in color relevance in six steps from nonsense syllables to the colors themselves in conflicting hue-word combinations. S named the ink color, and RT increased with each increase in color relevance of the word. In a second study, Klein found that, if S could read the word first, then name the color of the ink, his performance was better than in the standard situation. Klein argues that the word arouses a motor antagonism which is resolved by S restimulating himself with the appropriate dimension, i.e., hue. The increases in RT are due to the differences in amount of arousal of the competing reading responses with increasing relevance of the words to colors. The preliminary reading of the word resolves the antagonism, releasing the correct color response.

With regard to the naming of objects and the reading of the words which name those objects, in 1886, Cattell

(1966) showed that it takes adults longer to name an object than to read its label, and Brown (1915) showed the same effect for colors and their names. Brown further demonstrated that practice does not eliminate the word reading-color naming difference, though it reduces recognition time for both. Using children, Lund (1927) showed a reversal of the relationship to occur at about age seven. Before that time, children name the colors faster than they read the names of the colors. He also employed one five-year old in a study to reveal the effect of practice, finding practice to reduce but not to eliminate the greater speed of color naming relative to word reading for five-year olds. His conclusion is worth quoting,

> The association between the printed stimuli and the verbal responses has occurred with such frequency as to render the process more or less automatic. The associative connections, having been exercised much less frequently in the case of colors, function with less ease and require more effort. The type of association process represented in the two tests is the same, however, since it is formed on equally arbitrary grounds, there being no more necessary relation between the printed stimulus and the verbal response than between the color stimulus and the same response (p. 430).

The color naming and word reading experiment was studied developmentally by Ligon (1932). He found that word reading is faster than color naming in all grade levels from one through nine and that mean RT in both tasks falls over the years at an approximately equal rate. His finding with the youngest _S_s contradicts that of Lund since the latter found an RT difference favoring color naming before age seven. This is not too surprising since children's skill in reading at a given chronological age may vary considerably between school systems.

In a more recent series of studies, Fraisse (1960) found object naming of geometric figures to be slower than reading of the words naming them. In another study Fraisse (1967) found the thresholds to be lower for objects than for words. This he explained as being due to the greater complexity of the words as stimulus configurations.

In a variation on the reading-naming study Morin and Forrin (1965) found numeral naming to be faster than the naming of geometric figures. This was true for both first and third grade samples. With adults, Morin, Konick, Troxell and McPherson (1965) found there to be essentially no difference between recognition times for letters, hues, pictures of animals, friends' faces, or geometric symbols at low information levels, i.e., sub set sizes of only two. As sub set size increased, however, the expected difference favoring letters did appear, the RT to letters being nearly constant overall information levels while the others increased.

Fraisse (1968) attempted to isolate the factors causing the generally longer verbal RT to pictures than to words by having <u>S</u> perform a motor RT when he had identified the stimulus, knowing that he would later have to state what it was. In this situation, a slight reversal occurs, with the words taking slightly longer to identify than pictures. In a second study, the same stimuli generated the usual difference using verbal RT. Fraisse concludes that the difference must be due to the greater difficulty in finding the adequate response to a drawing since he has shown drawings and words to be equally discriminable or identifiable,

> Thery (sic) is no significant difference in the duration of the detection process (receipt, discrimination and identification) of a concrete or verbal material, but the coding of the verbal response to a concrete stimulus is more difficult than the coding of a verbal response to a verbal stimulus (p. 236).

It is as if the response is "in" the verbal stimulus while it must be sought for with the concrete.

The verbal versus concrete material recognition problem has been wedded, in a large number of studies, with the information value variable discussed earlier. That is, investigators have compared the effect of increasing sub set size on RT and threshold measures with verbal and concrete materials. Some of the studies discussed above employed this variable.

Fraisse and Bancheteau (1962) used nonsense syllable lists of lengths varying from 2 to 15 and found increases in recognition threshold with increasing list length. Morin and Forrin (1963) found, with adults, that numeral naming was independent of set size, though there was an interaction with some context variables indicating that even this highly overlearned response is not wholly isolated. Fraisse (1967) reports finding the recognition threshold for common French words to increase almost linearly with log n or information. It is to be noted here that the range of words was confined to frequently occurring ones as contrasted with the study of Oldfield (1966) in which frequency of occurrence in natural language was the variable leading to increases in recognition time. Fraisse also reports a nonsignificant trend in the expected direction for threshold recognition of geometric figures. Finally, he reports that with highly discriminable stimuli, the effect of uncertainty on recognition threshold is lost. He used geometric figures and words of differing inter item difference, e.g., circle and square as opposed to eight and nine sided figures, or <u>mais</u> and <u>rail</u> as opposed to <u>PaPa</u> and <u>LuLu</u>.

In the study by Morin and Forrin (1965) cited above, increasing information value was shown to elevate the recognition time for geometric symbols, but not for numerals. <u>S</u>s were first and third grade pupils and the effect was the same for both groups, though the third graders were faster on all measures. One interesting finding was a general <u>decrease</u> in RT with increasing information or set size in the first grade sample.

Morin, Konick, Troxell, and McPherson (1965) report increases in RT with increasing information value for familiar faces, animal pictures, colors and geometric symbols, but not for letters. For the last, a significant linear slope appeared but was quite small. The relationships in the first four cases were not perfectly linear as would be predicted from information theory, since both the linear and quadratic components were significant in each case.

In the present study, the variable of information value or set size was examined developmentally using first, second, and third grade pupils from the University Heights School in Tucson, Arizona. Stimuli consisted of words and line drawings of the common objects named by those words. The study is thus similar to that of Morin and Forrin (1965) in comparing Ss of different ages. It is also like that of Morin, Konick, Troxell, and McPherson (1965) in employing pictorial symbols. The set size variable was presented at three levels, 2, 4, and 8 stimuli, or 1, 2, and 3 bits of information. A linear relationship between set size and recognition time would be predicted from information theory. Decreases in RT as a function of age is a second prediction based on the general finding of increasing proficiency in sensory-motor and other skills during the elementary school years. Finally, for proficient readers (second and third graders), one would expect word reading to be faster than picture naming, the situation being analogous to the classic color naming and word reading situation. With less skilled readers (first graders), the reverse might be expected, as found by Lund (1927) for children below seven years. For them, the S-R association between a common word like "dog," for example, and the appropriate utterance is not yet of the highly overlearned and automatic type. The response must be searched out and this search takes time. To the degree that S is employing an E defined sub set of possible alternative responses, increasing or decreasing that set size will alter the search time and hence the recognition time.

METHOD

Subjects

The Ss were 60 grammar school children from University Heights School of Tucson District 1. There were 20 from each of the first three grades. The children were selected by their teachers as being "superior performers in reading." This was done to achieve approximate equality of academic achievement across grades since, for the first graders, only relatively advanced students would be capable of reading the eight words used in the study. There were roughly equal numbers of boys and girls.

Apparatus

Fig. 1 gives a schematic representation of the experimental arrangement. Transparencies size 2" x 2" were made of line drawings of the following objects: cat, boy, tree, dog, man, book, car, and ball. Transparencies were also made of pages on which one of these words had been printed with Transfer Types #3851. The slides were projected by a Kodak Carousel projector (model #800), and were so arranged that they alternated with blank slides. The stimulus slides had a hole punched in the top which passed a shaft of light above the screen to activate a photocell. The photocell started

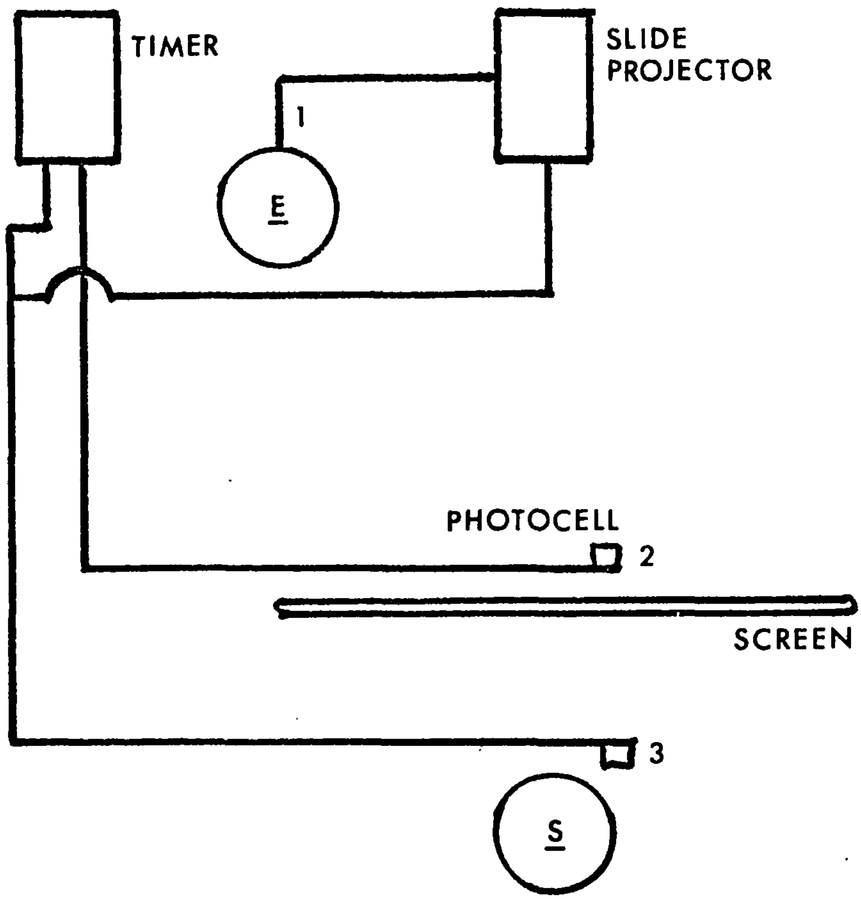

Fig. 1. A graphic representation of the experimental arrangement. At point 1, E depresses telegraph key, advancing slide projector. At point 2, the photocell is activated by the slide, starting timer. At point 3, S responds, stopping timer and advancing slide projector.

an electric timer (Standard, Type S1) which ran until S spoke into the voice key (Marietta, Model * 14 10 4), which stopped it. The slide projector was also automatically advanced to the next slide (a blank) by S's response. E initiated each trial with a telegraph key which advanced the slide projector.

Procedure

The experiment entailed three variables: A) mode of stimulus presentation, printed words (A_1), and pictures (A_2); B) grade in school, first (B_1), second (B_2), and third (B_3); C) set size, 2 (C_1), 4 (C_2), and 8 (C_3). The C variable may also be expressed in bits, 1, 2, and 3. A and B were between Ss variables, while each S received all three levels of the C variable. The order of presentation of the C conditions was randomized between Ss.

Each C level consisted of 32 stimulus presentations alternating with 32 blank slides. In the 2 stimulus conditions, each stimulus appeared 16 times. In the 4 stimulus conditions, each appeared 8 times and in the 8, each appeared 4 times. The pictures or words "cat" and "boy" appeared in all levels and the data were collected on trials in which "cat" appeared. The data analysis was performed on the means per condition of the median recognition time per S for the word or picture, cat. There were thus 16, 8, and 4 data points determining the medians in the 2, 4, and 8 stimulus conditions respectively and 10 medians determining the means in each ABC cell.

The slides for each ABC condition were arranged in different trays. The order of stimuli was determined by a table of random numbers. Before the 32 stimulus slides and blanks, a number of practice slides were placed in order to familiarize S with the sub set and to give him practice with the apparatus.

The experimental routine was as follows: S was introduced to the task as a game or contest in which his task was to make the picture or word go away just as fast as he could. S was then shown a slide which he named and which then left the screen. Several practice trials were given to reduce S's variability. This usually took about four minutes. S was then shown the first sub set. This was done twice and the condition was verbally explained, i.e., "This time, each picture (word) you will see will be one of these 2 (3, 4), so be ready to say one of these. Let's go through them." This was repeated several times to insure S's comprehension.

The trials went for 32 consecutive stimulus presentations alternating with 32 blanks, or for one C condition. Then S was given a rest before starting the next C condition. The first trial began when S indicated that he was ready. E pressed the telegraph key, advancing the slide projector, presenting the first slide, and starting the timer by means of the photocell. When S made his naming response, the slide projector was advanced by means of the voice key and the timer was stopped. E then recorded the RT. The coming of a slide was cued to S by the sound made by the slide projector as it advanced. Noncontingent encouragement and exhortations to try hard were liberally presented after trials by E.

RESULTS

In Table 1 appears a summary table of the analysis of variance. The exact probabilities for the F ratios are given. As can be seen, all of the main effects and interactions are significant save for variable A, mode of stimulus presentation. The data are given graphically in Fig. 2. In Table 2, the means for each level of each variable are given after collapsing across all others. In Table 3, the means for each ABC cell are given.

TABLE 1

A SUMMARY OF THE DATA ANALYSIS

ANOVA Summary Table

Source	SS	df	MS	F	P
Between Ss	3.731	59	.063		
A	.001	1	.001	.048	.822
B	1.791	2	.895	31.630	.000
AB	.410	2	.205	7.244	.002
SS WG	1.529	54	.028		
Within Ss	1.537	120	.013		
C	.196	2	.098	11.785	.000
AC	.056	2	.028	3.394	.036
BC	.138	4	.035	4.153	.004
ABC	.248	4	.062	7.462	.000
C SS WG	.898	108	.008		

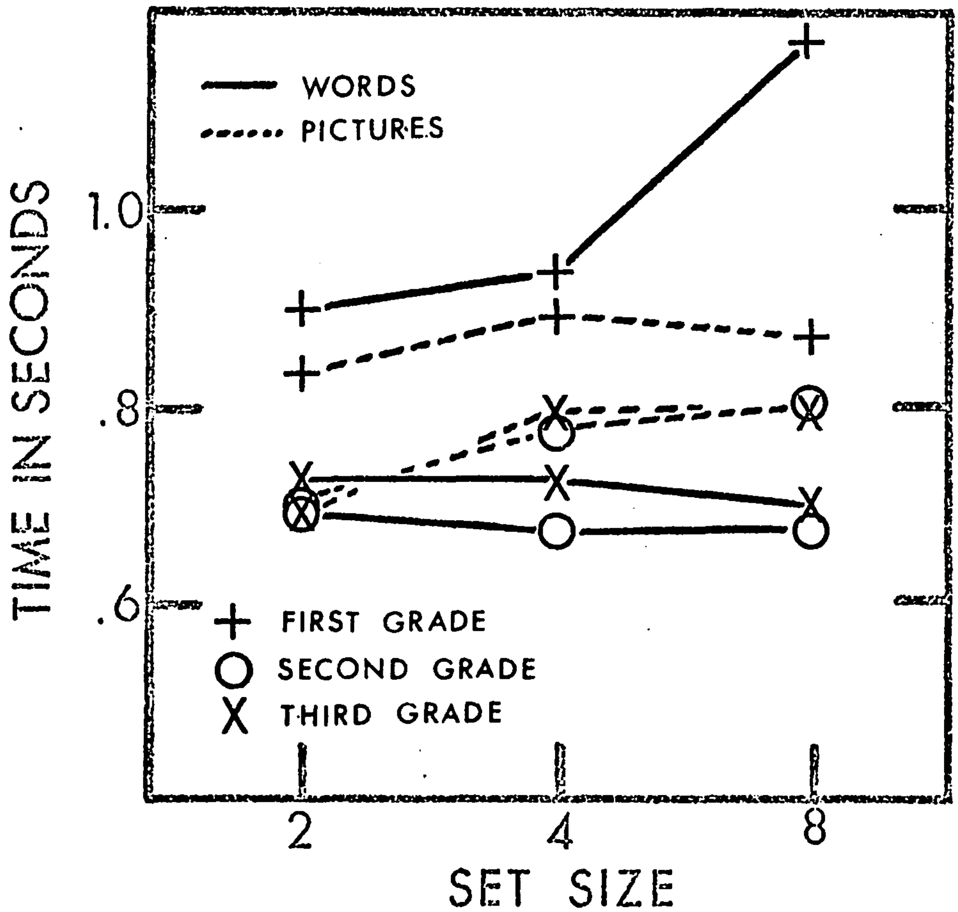

Fig. 2. A graphic representation of the mean reaction time for each ABC cell.

TABLE 2

MEANS FOR EACH CATEGORY OF EACH VARIABLE,
COLLAPSING ACROSS ALL OTHER VARIABLES

		Category		
		All values are given in seconds		
		Words	Pictures	
	A Mode	.804	.799	
		First	Second	Third
Variable	B Grade	.942	.724	.738
		Two	Four	Eight
	C Set Size	.762	.801	.842

TABLE 3

MEANS FOR EACH CELL IN THE FACTORIAL

		Words Number of Stimuli			Pictures Number of Stimuli		
		All values are given in seconds					
		2	4	8	2	4	8
	First	.912	.932	1.192	.835	.900	.883
Grade	Second	.697	.679	.680	.704	.776	.807
	Third	.725	.725	.697	.696	.794	.795

DISCUSSION

The first thing to be noted is the highly significant ($p < .0009$) effect of age on recognition time. This appears mainly to be due to the gross difference between grade 1 and the other two, .942 sec. being the mean for grade 1 as opposed to .724 for grade 2 and .738 for grade 3. It is to be noted that the grade 2 and 3 means are in the opposite direction from what one would expect. This overall difference is not large, however, and examination of Fig. 2 reveals that the grade 2 sample was faster than grade 3 in all levels of the words condition. The pictures conditions are quite similar for both grades, with third graders being slightly faster in 2 conditions (1 and 3 bits) and the second graders being faster in the other. Perhaps this group of second graders happened to be exceptionally good readers.

The overall C effect (set size) is also highly significant ($p < .0009$). There is an orderly, .041 sec. increase in recognition time with each increasing level of C. That is, the recognition time for 4 stimuli is .041 sec. slower than is the recognition time for 2 stimuli, while, with 8 stimuli, there is a further .041 sec. increase. This orderliness, however, is more apparent than real as is shown by examination of the also significant AxC interaction ($p < .03$).

This interaction is plotted in Fig. 3. As can be seen, in the words condition, there is no increase in RT with 4 stimuli relative to 2, but there is a large jump at 8 stimuli of .780 sec. In the pictures condition, on the other hand, a similar large increase occurs at 4 stimuli with essentially no difference thereafter (.050 sec.). A return to Fig. 2 reveals the structure of this interaction between mode of stimulus presentation and stimulus information value. It is clear that, in level A_1, words, the C slope is due to the large set size effect in grade 1, with the second and third graders showing a slight <u>decrease</u> in RT with increasing information. In the pictures (A_2) condition, on the other hand, the trend for increasing RT with increasing information is present with only the one exception of a fairly small (.170 sec.) shift down in RT from 4 to 8 sub set size conditions for group B_1, the first graders. The significant grade by set size interaction is similarly explicable as due to the steep slope of the words conditions for the first graders, this slope elevating the whole B_1 slope relative to those for groups B_2 and B_3, whose slopes are nearly even as can be seen in Fig. 4.

The nature of the highly significant mode of presentation by grade level interaction ($p < .002$) is obvious from Fig. 2. For first graders, words take longer to identify than do pictures, 1.012 as opposed to .872 sec. For the other two age levels, smaller but clearly significant differences

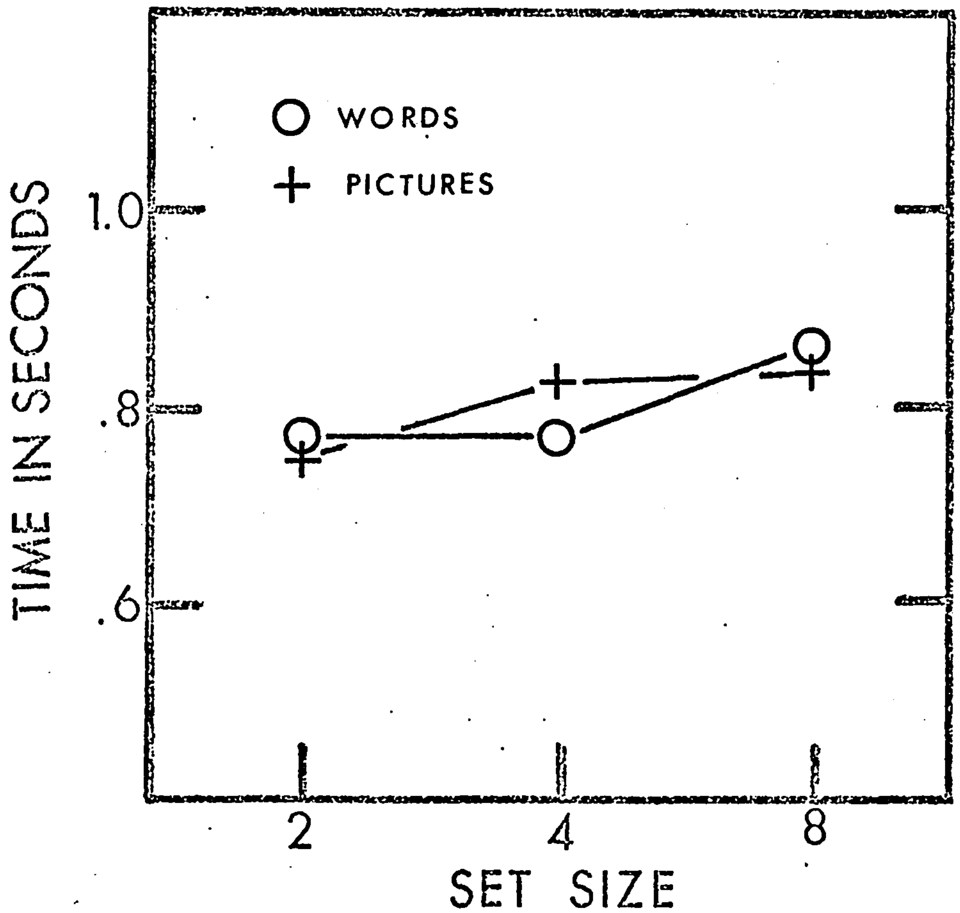

Fig. 3. A graphic representation of the mean reaction times for words and pictures at different set sizes, collapsing across grade levels.

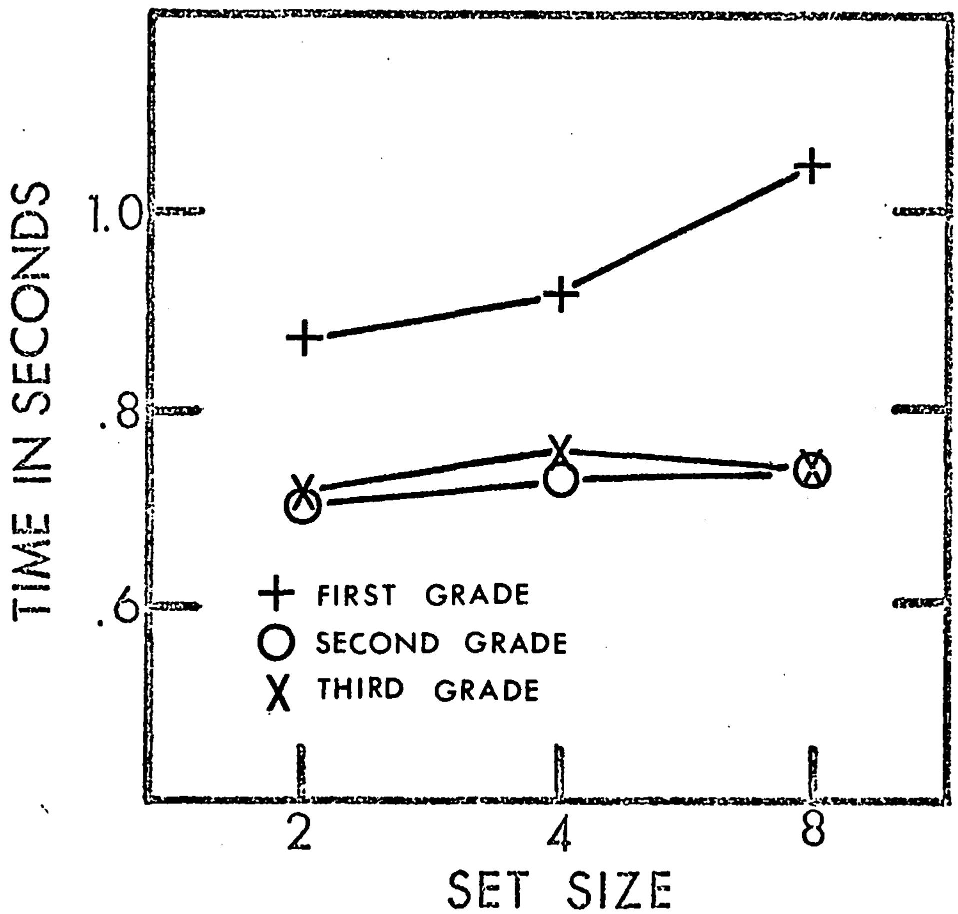

Fig. 4. A graphic representation of the mean reaction times for each grade group at each set size, collapsing across modes of presentation.

in the opposite direction are seen. For second graders, words take .685 sec. as compared to .762 for pictures. The corresponding figures for third graders are .715 and .761 sec. respectively. This dramatic reversal also explains the failure to find a significant overall A effect. There is essentially no difference between conditions A_1 (words) and A_2 (pictures) collapsing across all other conditions, the A_1 mean being .804 as compared to .799 sec. for condition A_2.

It is difficult to express the nature of the very significant AxBxC interaction ($p < .0009$), except to say that the structure of each of the two way interactions differs with levels of the other variable. The grade by set size interaction, for example, is of a different nature in the words and pictures conditions. With words, the slope for the first graders is steeply increasing, while for second and third graders, it is slightly decreasing. For pictures, on the other hand, the slopes are much more similar for all age groups, being increasing.

Relating these results to those of other studies is straightforward in some cases. The mode of presentation by age level interaction, for example, is perfectly consistent with Lund's (1927) report, but it conflicts with that of Ligon (1932). As was noted above, this effect is mainly due to _S_s' reading ability, which is only partially age related.

The finding in the upper two grades of faster recognition times for words than for pictures fits well with the report by Morin and Forrin (1965) that numerals are recognized faster than are geometric figures. It likewise relates to Morin, Konick, Troxell and McPherson's (1965) finding with adults that letters are more quickly recognized than are faces, pictures, colors, or symbols at higher information levels. In a sense, this study renders this result more convincingly than do the earlier ones, since the responses here were the same in both conditions with only the stimuli varying. One could argue that, in the other two studies, the numeral and letter responses were more prepotent and that this accounts for the difference, rather than a difference in the processing of stimuli. In the present study, however, stimulus processing must play a role, since the responses were the same.

The results with regard to variable C, information value, bear considerable comment. First, the finding of a large set size effect among first graders identifying words is striking. Usually, symbolic verbal stimuli tend to show independence of recognition time and set size or information. This is, in fact, what occurred in the two older samples in this study, their time actually decreasing with increasing information in the words condition. How, then, is the first grade finding to be accounted for?

Perhaps the reason is pointed to by the AxB interaction. For the first graders, word reading is slower than picture naming, and this is true at all levels of information value. The reverse is true for the other groups. Might it not be argued, therefore, that, for first graders, word "reading" is functionally analogous to concrete picture naming? For these young Ss, the automatic, highly overlearned characteristic of reading responses to these stimuli is not yet present. They must search out the meaning of the configuration "cat," then utter the appropriate response. For the older Ss, on the other hand, the appropriate utterance comes to the fore, even before the meaning response is excited. The utterance "cat" is made to "cat" or "kat" for the same phonetic reasons, antecedent to any processing of the stimulus for meaning. In picture naming, on the other hand, it is the meaning response which excites the utterance. Thus, the explanation being offered for the gross slope seen in Fig. 2 for first graders identifying words is that, for these Ss, the meaning of the stimulus configuration "cat" must be generated before the word comes to be uttered. This sequence of events is paradigmatic for picture naming in all groups. The paradigm for reading, on the other hand, is stimulus--verbal response--internal meaning response, the last being essentially irrelevant to the task. For first graders, reading has not reached this level of proficiency.

Lumping the groups together with regard to picture naming, it is clear from Fig. 4 that the relationship between RT and information is increasing, but not linear. In fact, for first and third graders, there is a slight decrease in

RT from 4 to 8 stimuli, while for second graders, though there is an increase from 4 to 8 stimuli, its magnitude is less than that occurring from 2 to 4. The model of a binary search among equiprobable alternative responses does not seem appropriate. An examination of the Morin, Konick, Troxell, and McPherson (1965) data reveals that here also, a break in the curves occurs at 4 stimuli in every case except for letters where there is a linear but very small increase in RT as a function of information. In the Morin and Forrin (1965) study, there were only two data points in the symbols condition, hence calling the relationship linear is a bit superfluous. One might conjecture that the curves would have levelled off to some degree at 8 stimuli, since, extending the first grade data linearly would yield an RT for 8 stimuli of something near 1.250 sec.

The linear relationship predicted by information theory is based on several assumptions about what S does in the identification process. It assumes, first, that all the responses are treated as equiprobable, and secondly, that S does, in fact, make a binary search of the E defined sub set. Furthermore, it must also be the case that the search time increases equally with each bit of information. That is, three binary decisions must take exactly three times as long, on the average, as one for searching. The present data, as well as those of Morin, Konick, Troxell, and McPherson (1965) do not lend support to all these assumptions.

On the other hand, a number of studies (e.g., Hyman, 1953; or Davis, Moray, and Treisman, 1961), do report linear increases in RT with increasing information. The question to be answered, then, is why is linearity found in some RT studies and not in others, such as the present one?

Perhaps the answer lies in part in the demand characteristics of the experiment. The strategy which S employs is only partly a function of E's instructions. The nature of the task also exerts an influence, and some tasks make more sense given an information processing paradigm than do others. In Hyman's (1953) study, for example, the task was an utterly unfamiliar one in which preexisting response potencies were quite irrelevant. Presumably S had almost no experience in making nonsense naming responses to combinations of lights. In such a case, a sub set presented before the task could be employed very usefully in restricting the range of alternatives. That the relationship turns out to be a linear one between recognition time and log n, argues that S does, in this situation, make a binary search. On the other hand, in the present study, or in Morin, Konick, Troxell, and McPherson's (1965) account, the task is a familiar one, hence the E defined sub set is only one of many factors which might effect recognition time. Clearly, in normal recognition of objects in the natural environment, a person does not make a binary search of the universe of possible objects in finding a label. If he did, he would require some considerable time in naming things. A binary search strategy is useful only in some circumstances.

Perhaps, then, the bend in the Rt x information functions found in this and other studies reflects a shift in recognition strategy. That is, with 2 or 4 alternatives, making some attempt to keep the sub set in mind is of use, i.e., it leads to lower recognition times. With more alternatives, however, S implicitly decides to ignore the E defined sub set and simply names the objects as he would on opening a picture book. He brings to the situation figure recognizing techniques which are only partly responsive to E's instructions.

One might speculate, in fact, that the degree of linearity of the relationship could be varied by changing instructional conditions. That is, one could give one group minimal sub set relevant verbalizations, perhaps simply stating that this is the sub set, then beginning the trials. With a second group, E might talk at some length about the importance of keeping the sub set in mind, telling S how that will improve his times, and thus make him a more efficient processor of information. One might predict greater increases from 4 to 8 stimuli conditions in the latter group relative to the former.

In sum, the importance of the information variable depends on what S is doing, and what S does is partly dependent on setting events or instructions, and partly a function of the nature of the task. If his task is presented as being simply "to name the object as fast as possible," S's processing steps may be different from what they would be if his task is defined as "to say which of these two stimuli appears as fast as possible." In the limiting case, we may tell S that the stimulus will be one of the following 250 with fairly complete confidence that he will essentially ignore instructions to keep the 250 in mind. Here the real nature of the task supersedes instructional effects.

Some support for these speculations might be garnered from the finding, averaging second and third graders, of slight decreases in RT with increasing numbers of word stimuli. In Morin and Forrin's (1965) study, a clear downward trend occurred on the first grade sample with approximately .100 sec. difference between 2 and 8 stimuli conditions, while the third grade sample dipped slightly from 2 to 4 numerals, then went up again to about the 2 stimuli level at 8 stimuli. It could be argued that attempting to retain the sub set served to retard performance at the 2 stimuli level. The S's attempt to maintain two responses in mind leads to interference which is absent in normal reading without expectation for the words or, in this case, numbers. At higher information levels, S does essentially that--he ignores the sub set and reads the words as fast as he can. The result is a decrease, up to a point, in RT with increasing information.

The finding here of independence of RT and bit value for words appears to be in conflict with the report by Fraisse (1967) of increases in threshold for words of roughly equal Lorge-Thorndike type frequency with increasing information. This conflict, however, is completely illusory. The threshold task and the RT task are different in many important respects, and there is no reason to expect similar outcomes with the two methods. In the threshold experiment, S's task is really to construct the stimulus given decreasingly inadequate cues. Here, obviously, maintenance of the sub set is of considerable help; it tells S what cues to look for in the brief exposure of the stimulus. Also, speed of response is of no consequence. S can identify the stimulus, then search for the label at his leisure. In the RT task, the stimulus is given and it is only the response which must be generated. Speed of response is the critical task and, as has been argued above, in reading, sub set maintenance is of no particular help. Thus, one would expect an information value effect in the threshold task but not necessarily in the RT task, and this is, in fact, the case. Subject is being asked to do different things and his strategy varies appropriately.

In their paper, Morin and Forrin (1965) argue that the difference between numeral reading and symbol identifying is due to the fact that there are competing responses evoked with the concrete stimuli, but not with the verbal.

That is, "cat" leads only to the verbalization "cat," while a picture of a cat is also associated with "kitty," "Tabby," "feline," etc. The argument seems to be that it is the elicitation of these competing responses which retards generation of the correct one. If this were the major factor, however, one would expect the picture naming task to be slower than the word reading in all conditions in the present study. Such was not the case. At 1 bit of information, the mean RTs for second and third graders are about equal for pictures and for words. Furthermore, if response competition were an important factor, one might expect at least an occasional intrusion of a competing response. Yet, in over 2,880 trials with pictures in the present study, not a single case of S naming a picture by other than its assigned name occurred.

There was allusion to an alternative form of explanation above in connection with the discussion of the difference between reading words and naming pictures. In that context, it was argued that the elicitation of an utterance by the printed word is direct, while the elicitation of the same response by a picture is mediated by what was there termed an internal meaning response, part of which was the label. Thus, in contrast to Morin and Forrin's (1965) conceptualization, the two types of stimuli differed not merely in the number of associations they elicit, but rather, they differed in the way they elicit them.

The internal meaning response is similar to what Evans (1967) has called a schema and it has the status of a hypothetical construct. It entails the entire complex of associations S has with the pictured object, one of which is the verbal label. This entity is only secondarily involved in the reading response, since, in older Ss, reading is mediated by a highly overlearned phonetic system which functions independent of, and in this case, temporally prior to, the meaning or schema associated with the word read. The common experience of reading aloud with complete disregard for content offers some introspective support for this analysis, as does the facility with which adult Ss "read" nonsense syllables. There is no hesitancy in coming up with a label for "trug," though it is obviously unfamiliar and meaningless. The connection between S and R is of a one to one sort, and any "meaning" associated with "trug" accrues to it later, perhaps while S attempts to devise a way of retaining it.

It is therefore necessary to take issue with Lund's (1927) conclusion quoted above. Though it is true that the associations between the utterance "green," and the color and printed word, green, are arbitrary, the latter is arbitrary in a different way. It is arbitrary in the way mathematics is arbitrary. Granting, arbitrarily, the rules of the decimal system, 2 and 2 must total 4. Likewise, granting also arbitrarily the less consistent rules of phonetic reading, "green" must lead to the utterance "green." There is no analogous relationship between the hue and the word. That is, no rule which makes the hue green lead to the utterance "green," will generate another hue which must lead to the utterance "red." But, the word "red" must lead to the utterance "red," by the same family of rules which make the word "green" lead to the utterance "green," or the word "trug" lead to the utterance "trug." Acquiring reading skill, then, may be thought of as precisely this, making the shift from arbitrary to systematic relating of Ss to Rs.

To summarize, the common finding of longer RTs for concrete than for verbal stimuli is due to the necessity of mediation by an internal meaning response in the former case. The finding of RT slopes with increasing set size in the concrete case is due to the fact that S must keep a number of these mediators prepotent, then select the correct one from among them. This tactic, however, is decreasingly useful as set size increases, hence S abandons it and his RTs level off. In the verbal case, on the other hand, there is no reason to keep the mediators prepotent and to do so, in fact, may impede performance. In the present study, it will be recalled, increasing set size led to decreasing RTs in the older samples.

Finally, in the first grade sample, the "reading" responses appear not to be that at all, but rather to be more like the picture recognition task. For these Ss, there is no one-to-one, phonetic connection between the printed word, "cat," and the appropriate utterance. Rather, the first graders must search their memories for associations with the printed word and this takes time. Knowing the sub set ahead of time is helpful here, and, as the data indicate, there is a gross sub set size effect with first graders reading words. As these Ss get older and learn to read, their performance will shift, with picture naming remaining responsive to sub set size manipulations and reading becoming independent of information value.

REFERENCES

Brainard, R. W., Irby, T. S., Fitts, P. M., and Alluisi, E. A. Some variables influencing the rate of gain of information. J. exp. Psychol., 1962, 63, 105-114.

Brown, W. Practice in associating color-names with colors. Psych. Rev., 1915, 22, 45-55.

Bruner, J. S., Postman, L., and Rodrigues, J. Expectations and the perception of color. Amer. J. Psychol., 1951, 64, 216-227.

Cattell, J. McK. The time it takes to see and name objects. Mind, (1886), 11, 63-65. (Cited in) Oldfield, R. C. Things, words, and the brain. Quart. J. exp. Psychol., 1966, 18, 340-353.

Davis, R., Moray, N., and Treisman, A. Imitative responses and the rate of gain of information. Quart. J. exp. Psychol., 1961, 13, 78-89.

Evans, S. H. A brief statement of schema theory. Psychonom. Sci., 1967, 8, 87-88.

Fraisse, F. Recognition time measured by verbal reaction time to figures and words. Percept. Mot. Sk., 1960, 11, 204.

Fraisse, P. Le rôle de l'incertitude et de la discriminabilité dans la reconnaissance perceptive. Anée Psychol., 1967, 67, 61-72.

Fraisse, P. Motor and verbal reaction times to words and drawings. Psychonom. Sci., 1968, 12, 235-236.

Fraisse, P., and Bancheteau, M. The influence of the number of alternatives on the perceptual recognition threshold. Quart. J. exp. Psychol., 1962, 14, 52-55.

Gibson, E. J. Principles of Perceptual Learning and Development. New York: Appleton-Century-Croft, 1969.

Gibson, J. J. The Senses Considered as Perceptual Systems. Boston: Houghton Mifflin, 1966.

Hartline, H. K. The receptive fields of optic nerve fibers. Amer. J. Physiol., 1940a, 130, 690-699.

Hartline, H. K. The effects of spatial summation in the retina on the excitation of fibers of the optic nerve. Amer. J. Physiol., 1940b, 130, 700-711.

Hartline, H. K., and Ratliff, F. Inhibitory interaction of receptor units of the eye of Limulus. J. gen. Physiol., 1957, 40, 357-376.

Howes, D., and Solomon, R. L. Visual duration threshold as a function of word probability. J. exp. Psychol., 1951, 41, 401-410.

Hubel, D. H., and Wiesel, T. N. Receptive fields, binocular interaction and functional architecure of the cat's visual cortex. J. Physiol., 1962, 160, 106-154.

Hyman, R. Stimulus information as a determinant of reaction time. J. exp. Psychol., 1953, 45, 188-196.

Klein, G. S. Semantic power measured through the interference of words with color-naming. Amer. J. Psychol., 1964, 77, 576-588.

Kolers, P. A. Some psychological aspects of pattern recognition. In: Kolers, P. A., and Eden, M. (Eds.) Recognizing Patterns: Studies in Living and Automatic Systems. Cambridge: The M.I.T. Press, 1968, 4-61.

Leonard, J. A. Tactual choice reactions: I. Quart. J. exp. Psychol., 1959, 11, 76-83.

Lettvin, J. Y., Maturana, H. R., McCulloch, W. S., and Pitts, W. H. What the frog's eye tells the frog's brain. Proc. Inst. Radio Engr., 1959, 47, 1940-1951.

Ligon, E. M. A genetic study of color naming and word reading. Amer. J. Psychol., 1932, 44, 103-122.

Lund, P. H. The role of practice in speed of association. J. exp. Psychol., 1927, 10, 424-433.

Luria, A. R. The Higher Cortical Functions in Man. New York: Basic Books, 1966.

Merkel, J. Die zeitlichen Verhaltnisse der Willensthatigkeit. Phil. Stud., 1885, 2, 73-127. (Cited in) Morin, R. E., Konick, A., Troxell, N., and McPherson, S. Information and reaction time for "naming" responses. J. exp. Psychol., 1965, 70, 309-314.

Morin, R. E., and Forrin, B. Response equivocation and reaction time. J. exp. Psychol., 1963, 66, 30-36.

Morin, R. E., and Forrin, B. Information processing: Choice reaction time of first and third-grade students for two types of associations. Child Devel., 1965, 36, 713-720.

Morin, R. E., Konick, A., Troxell, N., and McPherson, S. Information and reaction time for "naming" responses. J. exp. Psychol., 1965, 70, 309-314.

Mowbray, G. H. Choice reaction times for skilled responses. Quart. J. exp. Psychol., 1960, 12, 193-202.

Mowbray, G. H., and Rhoades, M. V. On the reduction of choice reaction times with practice. Quart. J. exp. Psychol., 1959, 11, 16-23.

Neisser, U. Cognitive Psychology. New York: Appleton-Century-Croft, 1967.

Oldfield, R. C. Things, words and the brain. Quart. J. exp. Psychol., 1966, 18, 340-353.

Polyak, S. L. The Vertebrate Visual System. Chicago: University of Chicago Press, 1957.

Posner, M. I. Representational systems for storing information in memory. In: Talland, G. A., and Waugh, N. C. (Eds.) The Pathology of Memory. New York: Academic press, 1969, 173-194.

Ryan, T. A., and Schwartz, C. B. Speed of perception as a function of mode of representation. Amer. J. Psychol., 1956, 69, 193-199.

Seibel, R. Discrimination reaction time as a function of the number of alternatives and of the particular S-R pattern. American Psychologist, 1959, 14, 396.

Sternberg, S. Memory-scanning: Mental processes revealed by reaction-time experiments. American Scientist, 1969, 57, 421-457.

Suci, G. J., Davidoff, M. D., and Surwillo, W. W. Reaction time as a function of information and age. *J. exp. Psychol.*, 1960, 60, 242-244.

Wingfield, A. *The Identification and Naming of Objects.* D. Phil. Thesis, Oxford, 1966. (Cited in) Oldfield, R. C. Things, words and the brain. *Quart. J. exp. Psychol.*, 1966, 18, 340-353.