DOCUMENT RESUME

ED 074 692 EC 051 885

AUTHOR Kaufman, Herbert; Smith, Jerome
TITLE Perceptual Capacities of Retarded and Normal Children. Final Report.
INSTITUTION Connecticut Univ., Storrs.
SPONS AGENCY Bureau of Education for the Handicapped (DHEW/OE), Washington, D.C.
BUREAU NO BR-00-601
PUB DATE Sep 72
GRANT OEG-1-70-00601-0101(508)
NOTE 160p.

EDRS PRICE MF-$0.65 HC-$6.58
DESCRIPTORS *Discrimination Learning; *Exceptional Child Research; Identification; *Memory; *Mentally Handicapped; *Perception; Recall (Psychological); Stimulus Behavior

ABSTRACT

Eight experiments using as Ss either retarded children, normal children, or normal adults studied the relations of retardation and normal development to the perceptual process of identification. Two experiments were reported on the identification of stimuli varying in either one, two, or three dimensions. Retardates did not perform as well as normals of equal chronological or mental age. Multidimensionally varying stimuli were easier to identify than those varying undimensionally. In three experiments efficiency in identification and discrimination tasks was evaluated. The effects of dimensional combination and stimulus distinctiveness were similar both in normal adults and retarded children. Success was reported in increasing the efficiency of retardate performance by first presenting a less demanding memory task (discrimination) and moving to a more demanding task (match-to-sample identification). Three experiments evaluated short term memory coding. Memory effects were found in all studies in which delay between stimulus presentation and response was varied. Explicit coding was not found to be effective at very short presentation times when the code was in octal form. The coding involved in remembering word-like material as opposed to non-word-like material was effective at even ten milliseconds presentation time. The rapid coding appeared to be under the subject's conscious control. (Author/DB)

ERIC

ED 074692

FILMED FROM BEST AVAILABLE COPY

Final Report

Project No. 00601
Grant No. OEG-1-70-006-1-0101(508)

Perceptual Capacities of Retarded and Normal Children

Herbert Kaufman

and

Jerome Smith

University of Connecticut

Storrs, Connecticut

September 1972

The research reported herein was performed pursuant to a grant with the Office of Education, U.S. Department of Health, Education and Welfare. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official Office of Education position or policy.

ED 074692

Final Report
Project No. 00601
Grant No. OEG-1-70-000601-0101(508)

PERCEPTUAL CAPACITIES OF RETARDED AND NORMAL CHILDREN

Herbert Kaufman and Jerome Smith
Department of Psychology
University of Connecticut
Storrs, Connecticut 06268

September 1972

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
OFFICE OF EDUCATION
THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL OFFICE OF EDUCATION POSITION OR POLICY.

EC 051 885

CONTENTS

ILLUSTRATIONS

ACKNOWLEDGEMENTS

The authors are indebted to Patricia Ching, Susan Dutch, Raymond Frost, Joel Kleinberg, Judith Prizer, and Kent Williams, all of whom served as graduate assistants at some time during the project period and carried out the hard work which made the conduct of the project possible. We are also indebted to Mr. William Lang, Superintendent of the Willington school system and Mr. William Nelligan, Superintendent of the Willimantic school system for their aid in providing the normal school children who served as experimental subjects. Finally we thank Drs. David Zeaman and Betty House in whose laboratory the retarded children were run.

SUMMARY

The research described in this report centers about the perceptual process of identification and its relation to retardation and normal development. Eight experiments are reported using as subjects either retarded children, normal children or normal adults. The capacity to identify stimuli which vary in either one, two or three dimensions was examined for retardates and their equal mental age and chronological age normal controls. Retardates do not perform as well as either normal control group, demonstrating both an IQ and an MA correlate of the identification process. A developmental factor was uncovered as well in that normal sixth graders outperform normal first graders.

The primary identification procedure employed was a delayed match-to-sample task. This technique minimized verbal responding while still permitting investigation of the determinants of the stimulis distinctiveness which forms the basis for identification. However, the match-to-sample task does differ from the conventional identification or absolute judgment task in ways other than the presence or absence of verbal response. The differences among types of identification and the discriminative paradigm were also investigated. The effects of dimensional combination and stimulus distinctiveness were similar among the various procedures both in normal adults and retarded children. Differences among the types of judgment appeared to center upon the memory demands of each task. Indeed, great success in increasing the efficiency of retardate performance was obtained by first presenting a less memory-demanding task (discrimination) and subsequently moving to a slightly more demanding task (match-to-sample identification).

The effects of dimensional combination were studied in several experiments. It was repeatedly demonstrated that multidimensionally varying stimuli were easier to identify than those varying unidi-densionally. In most studies multidimensional stimuli were varied in a correlated or redundant fashion, however one study convincingly demonstrated that dimensions combined in an independent or non-redundant fashion were not only as distinctive but even more distinctive than redundant combination.

Memory effects were found in all of the studies in which delay between stimulus presentation and response was varied. Some evidence that these effects were greater for retardates than for normals was uncovered in one study but this was not the case in a second. Memory effects were further studied with normal adults with the emphasis upon the effects of coding in short term memory. Explicit coding was not found to be effective at very short presentation times when the code was in octal form. However, the coding involved in remembering word-like material as opposed to non-word like material was extremely effective at even ten milliseconds presentation time. Moreover, this coding was to some extent, at least, under the subject's control as demonstrated by the effectiveness of instructions to either use or ignore the word code.

GENERAL INTRODUCTION

Although there is general agreement that the retarded child exhibits behavioral deficiencies of many kinds, the precise nature of these deficiencies has not yet emerged from the considerable body of research on retardation. Indeed, available evidence does not support qualitative retardate-normal differences in such basic functions as discrimination (Zeaman and House, 1963), short term memory (Belmont and Butterfield; Scott and Scott, 1968), long term memory (Belmont, 1966) and sensory acuity (Kodman, 1963).

Of the basic psychological processes, those which have been conventionally labeled perceptual have received relatively little experimental attention from researchers in the area of retardation (Spivack, 1963), although a few studies in the area of retardate information processing have recently become available (Olsen, 1971; Spitz, 1966; Spitz and Borland, 1971).

Our basic approach is to view the retardate as an information processing system (Miller, 1956; Fitts and Posner, 1967) and to examine his channel capacities as compared to both MA and CA normal controls. Both CA and MA controls are included because not only is information concerning retardate perceptual capacity scarce, but developmental changes in such capacities remain unknown.

To attack all problems that might fall under the heading of "perceptual capacity" and "perceptual process" would be unwieldly and impractical. As is the case in any research strategy, a judicious selection of problems must be made. We have chosen the recognition or identification process as a focal point of our project. In the most general terms we have sought to uncover the developmental and intellectual correlates of the perceptual mechanisms which lead to stimulus distinctiveness. By distinctiveness we refer to those stimulus characteristics which determine the ability to identify or recognize a given object. The reasons for choosing identification are compelling to us: 1) it is unquestionably a very fundamental perceptual process (Miller, 1956), 2) there is considerable evidence about capacity at the human adult level (Attneave, 1959), 3) there is great regularity in the capacity findings (Miller, 1956), 4) it is possible to study recognition while minimizing verbal responding, thus making retardate-normal comparisons more meaningful.

It is commonplace that the human can identify quickly and accurately a vast number of stimuli in many sense modalities. The remarkable thing about this capability is that it is achieved despite the fundamental limitation on human identification capacity pointed out by Miller in his article, "Magical Number Seven" (1956). The limitation, since verified many times, is that the number of stimuli differing along a <u>single perceptual dimension</u> which can be identified without error is about seven, or from five to nine. In slightly different terms, the channel capacity for uni-dimensionally varying stimuli is somewhat under three bits. It follows evidently that the efficiency of the human information transmission system, in the sense of high channel capacity, is determined by the extent to which stimuli vary along many dimensions simultaneously. Not so obvious are the rules of dimensional combination; what are the characteristics of component dimensions in multi-dimensional stimulus sets which make for distinctive elements; are some subsets of the total number of combinations better than others? These important questions of perception have been given hardly any experimental consideration.

Within the framework of the identification process in retarded and normal subjects we address ourselves to the following questions:

1. What are the identification capacities for uni-dimensional stimuli?
2. How do these capacities change when dimensions are combined?
3. Are there any systematic changes in capacity as a function of the way the dimensions are combined?
4. How is identification capacity affected when dimensional information must be stored for varying periods before the response is made?

This final question is, of course, a matter of memory. However, we feel that the separation of perception and memory is at best an arbitrary one. Perceptual responses are measured by recording the subject's overt response. A small but finite time period exists between the presentation of the stimulus to be perceived and the response indicating perception. That this time period may be considered within the context of memory has been recognized with increasing frequency in recent years (Kintsch, 1970; Lindsay and Norman, 1972).

The most direct way to study identification capacity is by increasing the number of stimuli to be identified until errors begin to occur. The changes in identification become extremely interesting when viewed in terms of the information transmission characteristics of the subject. As the stimulus pool is increased in size (increased stimulus information) the subject transmits information (identifies) perfectly up to a certain point. At that point he continues to transmit the same amount of information or less, even though the stimulus information (size of the pool) may increase. This asymptotic value of transmitted information is referred to as channel capacity. The invariance of identification acros[illegible] which Miller pointed out becomes even clearer wh[illegible]ms of channel capacity. We know that channel capacity [illegible] a function of whether the stimuli to be identified vary unidimensionally or bidimensionally (Eriksen and Hake, 1955), and as a function of the manner in which dimensions are combined in multi-dimensionally varying stimuli (Kaufman & Levy, 1971). We know little about the relation of channel capacity to subject differences.

The experiments included in this report represent an attempt to shed light upon the basic perceptual process of retarded and normal children. The purpose of the project is not only the furthering of our knowledge about retardation but also a clearer specification and understanding of perceptual responding per se. Therefore, experimental subjects included college students as well as retarded and normal children, and in one experiment members of the faculty and graduate students were used.

Eight experiments were conducted during the project period, and are discussed in three sections: I. Identification of uni- and multi-dimensionally varying stimuli; II. Comparisons of identification and discrimination, and III. Coding in short-term memory.

I. Identification of uni- and multi-dimensionally varying stimuli

The two studies in this section deal with the identification capacities of retarded children and their normal mental age and chronological age controls for stimuli varying along one, two or three physical dimensions. Both normal MA and CA controls were used in these experiments to provide information not only about the intellectual (MA and IQ) correlates of identification, but also about possible developmental differences. The latter information is obtained through comparison between the normal control groups which differ only in chronological age.

In addition to questions about identification capacity, both studies include manipulations designed to look at the role of memory in identification. These manipulations involve instituting varying delays between the presentation of the stimulus to be identified and the overt response made by the child. As was the case with identification capacity, memory effects are also examined in light of possible intellectual and developmental differences.

II. Comparisons of Identification and Discrimination.

The conventional identification situation requires the subject to provide a distinctive verbal label for a particular stimulus presented to him. Because retardates often exhibit problems with verbal tasks, we sought to provide a situation in which identification could be measured and verbal responding minimized. The identification experiments reported in section I made use of a technique customarily called delayed match to sample or recognition. The stimulus to be identified was presented to the subject and then removed. Instead of being required to provide a verbal label, the child was shown a matrix or display of all the possible experimental stimuli including the one to be identified on that trial and was asked to point to the one he had just seen. We felt that our procedure and the conventional identification procedure were similar in the fundamental sense that the basis for response is provided by the distinctiveness of the original stimulus. The fact that a verbal label was not necessary in our procedure made it much more attractive for use with our retarded subjects and younger normal controls.

Despite our feelings that the match-to-sample procedure and conventic 'entification provide similar information about stimulus distinct , we did recognize that differences other than the presence or absence of a verbal response may exist. These differences revolve around the demands made upon the memory systems of the subjects. In conventional identification the subject w o has seen a particular object in the past, has stored information about it and similar objects in what has now become to be known as long-term memory (Kintach, 1970). When he is presented the stimulus for identification he must recover or retrieve that information (which includes a verbal label) to make the correct response. In the match to sample procedure the information provided by memory in the identification situation is provided by the experimenter. A matrix including the stimulus to be identified and similar stimuli is presented to the subject and he selects from these. In this case the matrix might be considered a memory aid. The extent to which the matrix does aid memory was investigated in the first experiment reported in section II.

Further consideration of the relation of memory to the match to sample and identification situation led to the second experiment of section II. Consideration of the memory demands of the two paradigms, led us to the following line of reasoning: in the identification task the subject looks at a stimulus and must compare it with his memories of past similar stimuli before making a response; in the delayed match to sample task, the subject looks at a stimulus which is then removed and he must compare the memory of that single recently seen stimulus with the display which offers him as it were a pre-fabricated memory store for comparison. In the first case a single visible stimulus must be compared to a large memory store, while in the second, a single unit in recent memory must be compared to a large, but visible display.

ge for match to sample should not be too surprising. Further consideration of the relative memory demands of the two procedures led us to the conclusion that the situation in which almost no memory demands were placed upon the subject should produce the best performance. The situation would require the simultaneous presentation of the test stimulus with the display which includes that same stimulus along with those similar objects which make up the pool of experimental stimuli. Here the subject need only compare the visibly present test stimulus with the visibly present display stimuli. We call this situation a discrimination situation. The bulk of discrimination literature with retarded children includes study of two choice discrimination learning (House and Zeaman, 1963; Shepp & Turesi, 1968; Zeaman & House, 1963). In these studies the major emphasis has been upon the mechanism which permits the child to discover which of two stimuli is "correct" as designated by the experimenter. The perceptual problem of the discriminative distinctiveness of the two stimuli is handled by attempting to make the two choices as distinctive as possible. In our discriminative situation the focus of attention is on the perceptual distinctiveness of the test stimulus which must be isolated from its comparison stimuli in the display.

The second experiment of section II compared discrimination, identification, and delayed match to sample with a fourth condition which logically followed from our treatment of the first three paradigms in terms of memory. This fourth condition involved presentation of the display matrix before each trial, that is the matrix was presented, removed, and then the test stimulus presented and a verbal identification response requested. Here the subject was required to do precisely what he had to do in the identification situation but his memory was "refreshed" before each trial by presentation of all the experimental stimuli.

The third experiment of section II represents an attempt to tie together many of the findings of the experiments which preceded it. In the early experiments of section II the comparisons of identification and discrimination were made with college students as subjects. In this experiment the comparison is made with retarded children. In the identification experiments of section I retardates proved not only less proficient than did normal children but demonstrated the unexpected characteristics of depressed performance at even the simplest levels of the task. These findings were unexpected in light of our consideration of identification in terms of the information transmitting capacity of the subject. It was expected that retardates would transmit small amounts of information perfectly but reach channel capacity at a point earlier than did normals. Channel capacity is an asymptotic level of information transmission above which no further information is transmitted despite increases in the stimulus information or task demands. Our retarded subjects in the experiments of section I did not show signs of reaching early asymptote but instead performed generally poorly at all levels of stimulus information. We therefore attempted to maximize the information transmission of our retardates with a shaping procedure in the third experiment of section II. We always preceded our identification task with the same stimuli in the less demanding discrimination task to find if possible the function which would reveal a channel capacity level for the stimulus dimensions under study.

A third line of investigation in the experiment dealt with the types of dimensional combination for multidimensional stimuli. In all the experiments of section I and II identification of stimuli varying either unidimensionally or multidimensionally were studied. In all the studies save the one under consideration, the multidimensional stimuli were constructed in only one way, in a perfectly correlated one to one fashion. If for example, there were nine points along each of two dimensions, point one of dimension A would be paired with point one of dimension B, point two of A with point two of B and so on. However, it is clear that identification might be differentially affected by set of stimuli consisting of the same two varying dimensions combined in an uncorrelated or differently correlated fashion. Therefore in addition to the identification, discrimination comparison and the attempt to maximize identification, the experiment included a comparison of three types of multidimensional combination.

Section III - Coding in Short Term Memory

The effects of memory upon the perceptual process of identification were investigated in the experiments of section I and II. Indeed, it was our feeling that a crucial difference among the three types of identification paradigms, and the discrimination paradigm lay in the demands made upon the subject's memory. One type of memory system which stores information for a time period ranging from approximately one second to one minute has been called short term memory (Kintsch, 1970; Lindsay & Norman, 1972; Norman, 1970). It was clear to us that the short term memory system played an important role in the type of information transmission we considered in the first five experiments we reported. The three experiments in section III deal more specifically with short term memory, particularly with questions concerning the effects of coding or transforming stimulus information upon short term memory capacity.

Miller (1956) pointed out that while the capacity of short term memory was limited, this limitation was on the number of items which would be retained not upon the amount of information. For example, if a subject were rapidly presented a series of binary digits he would accurately retain approximately seven of them. If however, the subject were taught a technique of arranging these digits into groups or "chunks" and he were given enough <u>time</u> he could retain about seven chunks and hence many more digits. Two aspects of Miller's discussion were of interest to us: firstly that "chunking" or coding improves short term memory, at least in terms of increased information capacity, and secondly that this coding process is time consuming. That fact that coding takes time has received experimental support elsewhere (Klineberg & Kaufman, 1972), but we wished to look further into the matter. In the first experiment of section III we presented subjects with strings of the letters S and Z at various presentation times and asked for recall. The subjects were then taught to group these letters in an octal code and similar strings were presented for recall. Our feeling was that at brief presentation times no superiority for the code performance would exist because not enough time was available to do the work of coding, but at longer presentation times we might see the effects of coding.

The second experiment of section III dealt with a seemingly paradoxical state of affairs arising from the conclusion that coding in short term memory required time. Since the early experimentation of Wundt it has been known that words are more easily recognized than non-words even at very brief exposure times. But a word differs from a non-word of equal number of letters only because it is organized or chunked in one unit. Clearly this kind of coding does not appear to take much time. Recognition studies differ from the kind of short term memory study which Miller discussed in that the latter seeks to tap capacity of the memory system rather than just pointing to a difference between two types of material each containing a small number of units. To combine the two types of experiments we presented subjects with varying combinations of groups of word-like and non-word-like stimuli at different exposure times and asked them to recall as many letters as possible. If word coding was operating to increase capacity even when little time was available for coding, our procedure should have revealed it.

The third experiment of section III followed directly from the first two. Here we extended the range of presentation times to get a fuller picture of the relation of coding to time available for processing the stimuli and further, looked at the case with which word coding could be manipulated by instruction as well as how dependent was capacity upon the type of response which the subject was required to produce.

ERIC

SECTION I

IDENTIFICATION OF UNIDIMENSIONALLY AND MULTIDIMENSIONALLY VARYING STIMULI

Experiment 1.

Identification by retarded and normal children of stimuli varying unidimensionally and bidimensionally

In the history of perceptual investigations those questions dealing with the discriminative capacities of organisms have long held an honored position. Dating from Weber's and Fechner's work in the nineteenth century, data concerning difference thresholds have been collected in laboratories all over the world. In contrast to discrimination, an equally fundamental perceptual process, that of identification, has received a great deal of experimental attention only in relatively recent history. Attention was focused on the identification process by Miller's influential article "The magical number seven, plus or minus two" (Miller, 1956). While the Weber fraction may vary considerably across a group of selected physical dimensions, Miller pointed out that the number of identifications possible within each of these dimensions was fairly invariant. This invariance has been demonstrated for many dimensions in many studies (Fitts & Posner, 1967).

The experiment to be described was designed to discover whether identification capacity varies with the intellectual and/or developmental level of the subject. The question seems a reasonable one to ask, expecially with respect to possible differences between retarded and normal children. Identification is a process which has not been carefully studied in either retarded or normal children, while other basic processes have received considerably more attention, for example: discrimination learning (Zeaman & House, 1963), short term memory (Belmont & Butterfield, 1969; Scott & Scott, 1968), long term memory

(Belmont, 1966), and sensory acuity (Kodman, 1963).

Identification capacity is studied by increasing the number of stimuli to be identified until errors begin to occur. The changes in identification become extremely interesting when viewed in terms of the information transmission characteristics of the subject. As the stimulus pool is increased in size (increased stimulus information) the subject transmits information (identifies) perfectly up to a certain point. At that point he continues to transmit the same amount of information or less even though the stimulus information (size of the pool) may increase. This asymptotic value of transmitted information is referred to as channel capacity. The invariance of identification across dimensions which Miller pointed out becomes even clearer when viewed in terms of channel capacity. We know that channel capacity varies as a function of whether the stimuli to be identified vary unidimensionally or bidimensionally (Eriksen & Hake, 1955), and as a function of the manner in which dimensions are combined in multi-dimensionally varying stimuli (Kaufman & Levy, 1971). We know little about the relation of channel capacity to subject differences. Recently, Olson (1971), has suggested that channel capacity may be related to mental age. Our study examines channel capacity differences in identification in retarded children and their normal mental age equivalents in first grade as well as their normal chronological age equivalents in sixth grade.

The conventional identification situation requires the subject to provide a previously acquired verbal label to the stimulus presented. For example: "This is a green square," or "That is number five." The identification procedure we use has been conventionally described as

ERIC

delayed match-to-sample or recognition. We present the stimulus object, remove it, and then offer the entire pool of objects for that experimental condition, enabling the subject to point to the one he just saw. We feel that our procedure and the conventional identification procedure are similar in the fundamental sense that the distinctiveness of the original stimulus provides the basis for response. One important difference between the two procedures lies in the necessity for having a well learned verbal lable for the stimulus in the conventional identification situation. In dealing with young children and retardates in particular, verbal responses may pose a problem. The absence of or difficulty with verbal labels does not necessarily mean that the child cannot recognize the unique characteristics of the stimulus. The use of our procedure is further justified by the fact that it produces regular data when used with such non-verbal subjects as monkeys (Kaufman & Wilson, 1970).

In addition to the intellectual and developmental level of the subjects, the independent variables of this study include stimulus information load (size of the stimulus pool to be identified), number and types of dimensions along which the stimuli vary, and the delay between removal of the stimulus to be identified and the production of the pointing response. The information load variable provides the key to possible channel capacity differences among our subject groups; the number of dimensions variable tells us about possible differential effects of redundancy, and the delay variable may point to normal-retardate memory differences.

METHOD

Subjects

Six retarded children, six normal first graders and six normal sixth graders served as subjects. The retardates, five male and one female,

ERIC

were residents of the Mansfield State Training School, Mansfield, Connecticut. There were mixed diagnostically, including three familial, two mongoloid and one brain damaged child. None of the children exhibited gross sensory or motor impairment, all attended public school classes at the training school and all had previously served as subjects in discrimination learning experiments. Their mental ages ranged from 56 to 75 months (mean = 62) while their CA ranged from 140 to 164 months (mean = 145). The normals, three boys and three girls at each grade level were selected by their teachers as "average" students in the Hall Memorial and Willington Center public schools, Willington, Connecticut. The CA range for the first graders was 73 to 83 months with a mean of 76, with a CA range for six graders of 142 to 150 and a mean of 147 months.

Since MA levels for the normals were not available, the selection of "average" students was requested of the teachers. Average was defined as neither above nor below grade level, but doing reasonable work in the opinion of the home room teachers.

The discrepancy in sex distribution between the normals and retardates resulted from the feeling that any possible sex effect would be minimal in comparison to CA and MA effects. The retardates were therefore chosen to reflect the best possible matches on the latter two variables and sex balance was sacrificed to this end.

Materials

The stimuli to be identified were squares which varied in size or brightness or both size and brightness in different conditions. Size variations were from 2/8 inch to 11/8 inch increments. Ten shades of grey selected from a set of 16 Color Aid greys represented the degrees of brightness variations. Two sets of the 100 possible combinations of size and brightness were constructed by centering each square on a 2-1/4 inch white display card and spraying with a clear plastic preservative coating. One of the two sets of cards served as stimuli while the others were mounted by hinges on a response matrix board.

The response matrix board contained 1-- --1/4 deep circular depressions one inch in diameter, arranged in a ten by ten matrix. Each depression could be covered by a hinged display card. The board was mounted almost perpendicular (at an angle of approximately 85 degrees) on a turntable, to permit easy access for both the experimenter and the subject.

Procedure

On each trial the experimenter held a stimulus display card up to the subject for approximately two seconds with instructions to look at it carefully. The card was then removed and after the appropriate delay interval the response matrix was turned toward the subject with instructions to point to the card he had just seen. The pool of cards for that particular condition were arranged in natural order on the board (smallest to largest, darkest to lightest), with the empty depressions covered by a white cardboard mask.

The experimenter provided knowledge of results with a verbal "good" or "no." In addition, retarded subjects were permitted to lift the display card on the response board and found "M&M" candy in the well when correct.

Experimental Design

One between group variable (retarded, first or sixth graders) and three within group variables (dimensionality, number of alternative, and delay) made up the overall experimental design. The levels of the dimensionality variable were unidimensional (size or brightness) and bidimensional (size and brightness combined in a perfectly correlated fashion). The number of alternatives variable had levels of 2, 4 or 6 for unidimensional stimuli and 6 or 8 for bidimensional stimuli. Since better performance was expected in the bidimensional case we felt that the smaller number of alternatives would not be necessary in the bidimensional case but that a larger number of alternatives might be required to test bidimensional capacity. The delay between the presentation of the stimulus for identification and the response matrix was set at 0, 10 or 20 seconds.

All subjects were run on all combinations of the three variables with eight daily sessions of 90 trials each required of each child. A daily session was divided into the 3 blocks of 30 trials each. Within each block the delay levels and particular stimuli chosen for identification were varied randomly with the restriction that each value appeared an equal number of times. The unidimensional conditions were presented on the first six days with two days each of two, four and six alternatives in that order. The bidimensional conditions were presented on the last two days with the six alternative ones preceding the eight. The size and brightness dimensions were completely counterbalanced across the unidimensional sessions. If a child performed at the 90% correct level in any block of 30 trials the daily session was terminated after that block.

Specific values for a given set of stimuli were chosen from the complete pool of 100 stimuli to maximize the separations among the set, and as was previously stated were randomly assigned to a given trial in a daily session.

The response measure used was amount of information transmitted (T)

ERIC

in each experimental condition. Transmitted information is calculated from a stimulus-response matrix. The number of responses made to a given stimulus is recorded in each cell with the column totals providing the frequency with which each stimulus was presented and the row totals the frequency with which each response was made. Information transmitted is given by the sum of the stimulus information and the response information minus the cell information. The transmitted information indicates the degree of overlap of stimulus and response information. When the number of response categories is the same as the number of stimulus categories and the subject is responding on a purely random basis, T = 0. If the subject is performing perfectly stimulus and response information will be equal and T will equal the stimulus information.

RESULTS

Because the amounts of stimulus information (number of alternatives) differed in the unidimensional and bidimensional conditions (2, 4 and 6 alternatives for size or brightness, 6 and 8 alternatives for size and brightness combined), three variance analyses were performed. The first included unidimensional data only, the second bidimensional data only, and the third compared unidimensional and bidimensional performance at the point of maximum stimulus information (6 alternatives for the unidimensional case and 8 for the bidimensional).

Sex

The performance of males and females was very similar in all phases of experimentation. The overall Fs for sex in first and sixth graders were not significant and there were no indications of any interactions.

Stimulus information

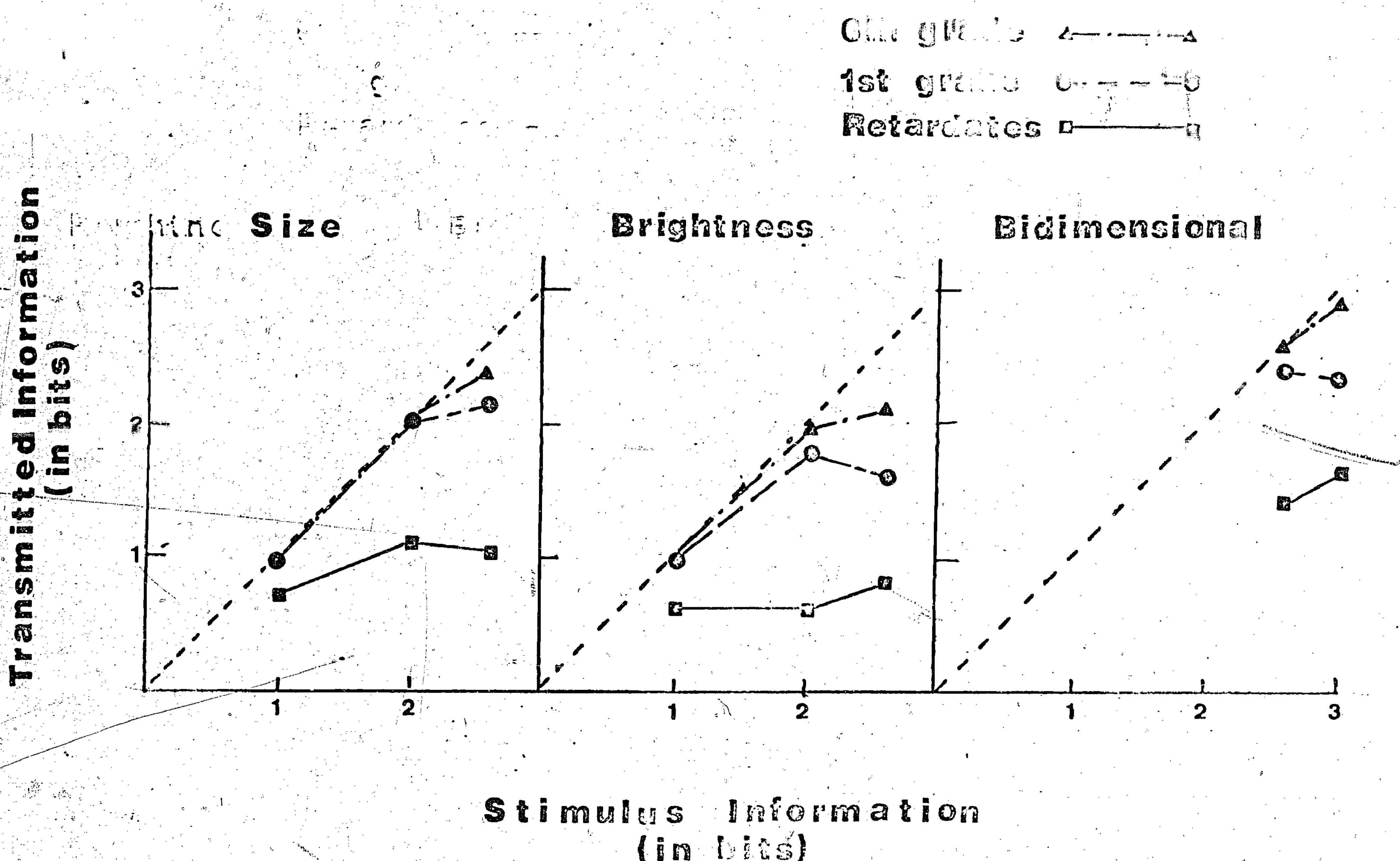
The effects upon the three subject populations of increasing stimulus information and type and number of dimensions available for identification are presented in Fig. 1. The figure illustrates the expected increase in transmitted information with increasing stimulus information, an increase statistically substantiated by the two appropriate variance analyses. The main effect for number of alternatives in the unidimensional analysis was reliable ($F = 16.01$, $df = 1,255$, $p < .001$) as was the case in the bidimensional analysis ($F = 17.08$, $df = 1,75$, $p < .001$). More interesting were the significant differences in information transmitted between the retardates on the one hand and the first and sixth graders on the other (Unidimensional $F = 67.47$, $df = 1,15$, $p < .001$; bidimensional $F = 37.1$, $df = 1,15$, $p < .001$).

Although it is clear from Fig. 1 that the retardates were transmitting some information at each stimulus information load, the gain in information transmitted with increasing loads is clearly much smaller than the gain for normals. A test of the gain for retardates along however, does produce an F of 6.76 with $df = 1,25$ and $p < .05$. The discrepancy between the gain for retardates on the one hand and normals on the other is emphasized by a significant interaction of intellectual level and number of alternatives ($F = 7.04$, $df = 1,255$, $p < .01$) in the unidimensional analysis.

While the intellectual parameter clearly affected the amount of information transmitted, the effects of the developmental parameter were not so evident. Although sixth graders always performed at a somewhat higher level than first graders, the difference reached statistical significance only in the analyses comparing uni- and bidimensional conditions at the point of maximum stimulus information ($F = 5.52$, $df = 1,15$, $p < .05$).

Figure 1

Information transmitted by the three experimental groups as a function of the amount of stimulus information (number of alternatives) and type of stimulus variation.



1st grade
Retardates
Size
Brightness
Bidimensional
Transmitted Information (in bits)
Stimulus Information (in bits)
1
2
3

Dimensionality

Figure 1 illustrates the fact that performance was superior for all groups when two dimensions were available for identification than when only one dimension was available. This fact was statistically substantiated in the uni- and bidimensional analysis ($F = 228.9$, $df = 1,120$, $p < .001$). This analysis also revealed the effects of the intellectual parameter, with normals outperforming retardates ($F = 44.66$, $df = 1,15$, $p < .001$) overall. In this analysis again an interaction involving intellectual level was found. The interaction was between the normal-retardate comparison on the one hand and dimensionality on the other ($F = 4.10$, $df = 1,120$, $p < .05$). In the unidimensional analysis increasing stimulus information load (greater demand upon the subject) produced increasing retardate-normal differences. In this analysis, the two-dimensional case (a lesser demand upon the subject) produced a <u>smaller</u> retardate-normal difference than did the one-dimensional case. However, it should be pointed out that the closeness of the two normal groups to the informational ceiling in the bidimensional condition make the smaller difference difficult to interpret.

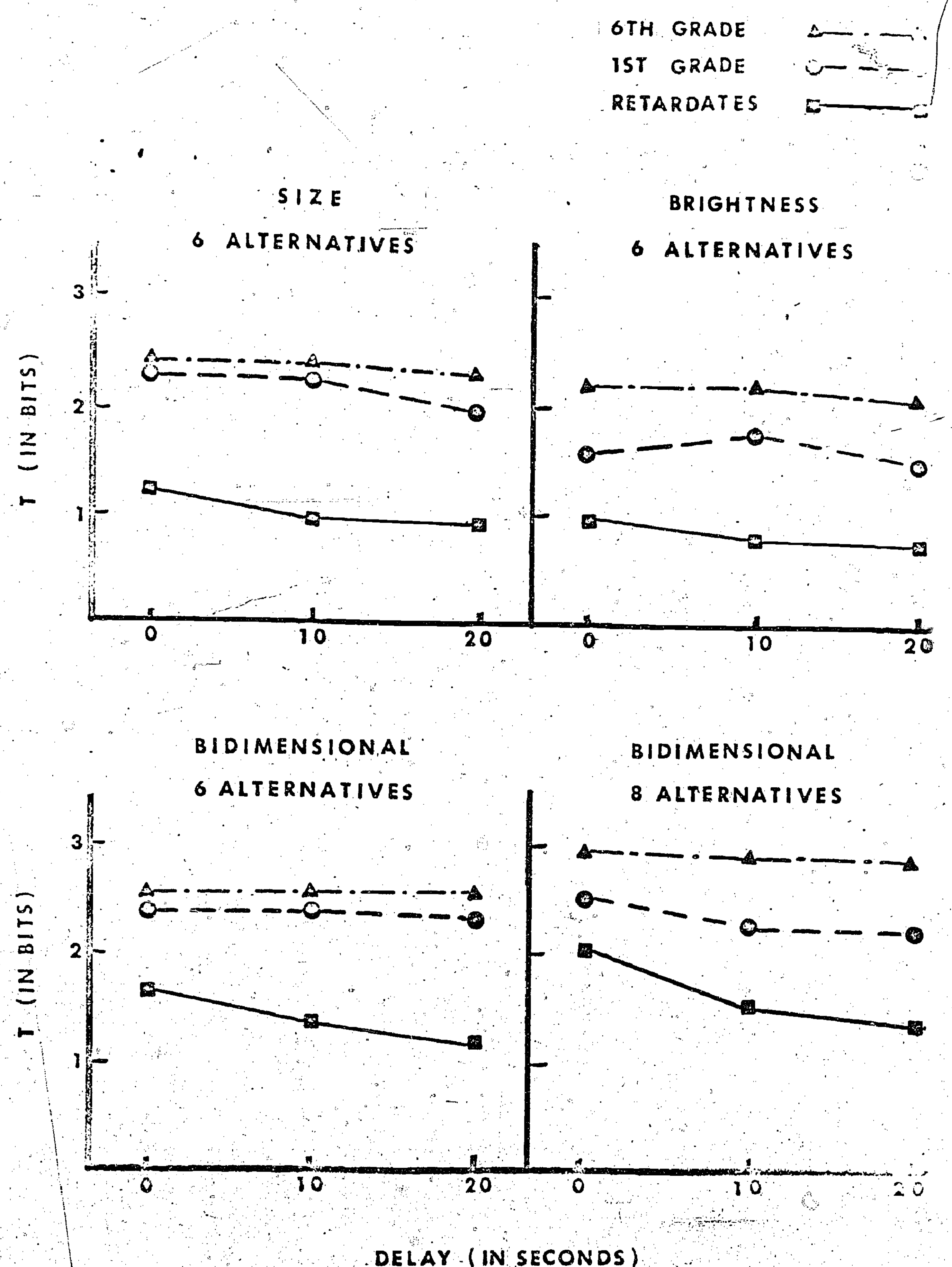
Another type of dimensionality effect is illustrated by the unidimensional analysis. Size proved to be an easier dimension than did brightness ($F = 2.47$, $df = 1,255$, $p < .05$) for all groups.

Delay

Figure 2 illustrates the delay effects for the 6 alternative unidimensional conditions and the 6 and 8 altervative bidimensional conditions. The effects of delay between stimulus presentation and response matrix presentation seen in the figure was found with smaller information loads as well (2 and 4 alternatives in the unidimensional situation). All

Figure 2

Information transmitted (T) by the three experimental groups a s a function of delay between the stimulus and the response matrix and type of stimulus variation.


6TH GRADE
1ST GRADE
RETARDATES
SIZE
6 ALTERNATIVES
BRIGHTNESS
6 ALTERNATIVES
BIDIMENSIONAL
6 ALTERNATIVES
BIDIMENSIONAL
8 ALTERNATIVES
T (IN BITS)
1
2
3
0
10
20
DELAY (IN SECONDS)

three variance analyses revealed reliable delay effects (Unidimensional $F = 7.86$, $df = 1,255$, $p < .01$; Bidimensional $F = 23.58$, $df = 1,75$, $p < .001$; maximum information load $F = 26.17$, $df = 1,120$; $p < .001$). Not only did increasing delays result in decreasing information transmission overall, but they did so differentially with respect to intellectual level. Retardate-normal differences increased as delay increased, a fact statistically substantiated by reliable interactions in all three variance analyses (Unidimensional $F = 7.04$, $df = 1,255$, $p < .01$; Bidimensional $F = 8.71$, $df = 1,75$, $p < .005$; maximal information load $F = 4.62$, $df = 1,120$, $p < .05$).

Although there is a greater effect of delay upon retardates, the normal children are not immune to the effects of delay. While the delay functions for first and sixth graders in Fig. 2 do not show marked decrease an overall test of delay for normals alone did reveal the decrement to be a significant one ($F = 4.73$, $df = 2,110$, $p < .025$).

DISCUSSION

The data of our experiment clearly support the inference that intellectual level plays a role in the ability to transmit information in the identification situation as we have defined it. In all comparisons made, retarded children performed at a significantly lower level than both their MA and CA controls. This retardate deficit is further emphasized by the interactions of intellectual level with increasing information load (number of alternatives) and with increasing delays between presentation of the stimulus and presentation of the response matrix. In general, as greater demands are put upon the subject the retardate deficit increases.

ERIC

The effect of a developmental parameter of identification is not as clear as the intellectual parameter effect. While sixth graders consistantly perform at a level equal to or higher than first graders, the differences are small, and reach a level of statistical significance only in comparisons involving maximum stimulus information in the uni- and bi-dimensional conditions. It is possible that a developmental factor is operating but requires a higher information load to reveal its effect. A parametric study including closer examination of the developmental factor would appear warranted.

Given the retardate deficit in identification, the question of the nature of that deficit remains. Our original conjecture was that Miller's magical number in terms of channel capacity (Miller, 1956) might be lower for retardates than for normals. That is, with unidimensional stimulus sets on all (or at least many) perceptual dimensions, retardates should reach asymptotic information transmission at a lower level than normals. Such capacity difference should include not only a lower retardate asymptote, but equal retardate-normal ability to transmit smaller amounts of information before asymptote is reached. Our data do not point unambiguously to such a capacity difference. Figure 1 reveals a retardate deficit even when stimulus information is only one bit. Furthermore, as stimulus information increases, retardates do transmit more information but still far below normal performance. It is possible that the notion of a channel capacity deficit is inapproapriate. However, our data do not force rejection of a capacity difference but may point to the contribution of other factors as well. One such factor is the context effect, the effect of preceding trials upon an identification response. An analysis of such context effects in the performance by monkeys of a task similar to ours, has been outlined by Kaufman and Wilson (1970). This analysis identifies three types of error based upon the trial immediately preceding the reference trial:

1. An R error which entails repeating the response made in the preceding trial when the stimulus has been changed and the previous response was incorrect. This type of error may be thought of as response perseveration independent of the stimulus.
2. An S error, which is making the response appropriate for the previous trial stimulus when the previous trial response was incorrect. This error may be thought of as a correction of the preceding response.
3. As S-R error which is making the response which was correct for the previous trial. This type of error may be thought of as response perseveration dependent upon the preceding stimulus. Errors other than the three described are considered errors of identification independent of context.

The analysis of context effects in our experiment is contaminated by the fact that intervals between stimulus presentations were not equal, since delays were randomly assigned within blocks of trials. However, mindful of the delay problem, we did analyze errors to find that the most common context effect was the incorrect response perseveration (R error), with the correct response perseveration (S-R) error made less frequently. Very few corrections (or S) errors were made by our subjects. However, more S, R and S-R errors were made by retardates than normals, indicating greater susceptibility to context effects as defined by the preceding trial.

Our study has produced what we feel are convincing data pointing to a retardate identification deficit. It seems clear that this deficit is to some extent influenced by the tendency of our retarded subjects to be more greatly influenced by the preceding trial than normals. Whether the effects of preceding trials upon the retardates result from the tendency to revert to such strategies when faced with a difficult task or whether they enter all tasks with such strategies is not determinable from our data.

It is not clear that the form of the identification deficit may be described in terms of channel capacity differences. The asymptotic levels of information transmission required for such a description are not readily seen in our data. It is possible to speculate about the mechanism underlying the deficit. It might be suggested that the difference between our retarded and normal children represents a simple discrepancy in the ability to attach verbal labels to stimuli. However, our matching task was chosen not only because such verbalizations were not an integral part of the process but because they were <u>unnecessary</u>, as evidenced by the success of such nonverbal subjects as monkeys in comparable situations. The effects of delay upon matching also argue against a purely verbal mechanism. It does not seem to be the case that normals mediate their choice by a verbal label, rehearse it and then make the match as well after longer delays as they would after shorter delays. The normals were subject to delay decrements even though they were not as large as the retardate decrements. If one were to appeal to a verbal mediator one would have to postulate not only differential effects of unfilled rehearsal periods in normals and retardates but also a rehearsal decrement over time in normals. What does appear to be true is that the trial by trial strategies for retardates differ from those of normals. Response perseveration and correction errors are more characteristic of the retarded group than either the first or sixth graders. These context effects would tend to depress performance over all levels of stimulus information. They would also tend to obscure channel capacity differences, that is differential asymptotic levels of information transmission.

ERIC

Experiment 2.

Identification by retarded and normal children of stimuli varying along one, two or three dimensions

The data of experiment one revealed a retardate identification deficit when compared to both CA and MA normal controls. However, despite the fact that sixth graders appeared to perform more effectively than did first graders the difference was not statistically reliable. A difficulty with experiment one was the high level of identification performance for both normal control groups. We hypothesized that a possible developmental difference was obscured because the task was not sufficiently demanding to differentiate the normals despite the fact that it clearly revealed retardate-normal differences. One of the purposes of the present study was to provide a sufficiently demanding task to tap developmental as well as intellectual effects. All subjects were therefore presented with a ten alternative identification task, and once again groups of retardates, sixth grade CA and first grade MA controls were run.

Replication of some of the effects found in the first experiment was another goal of this study. Two levels of delay between presentation and removal of the stimulus card and presentation of the matrix display were included to determine the reliability of the memory effects of the previous study. As was the case in experiment one the effects of redundancy upon stimulus distinctiveness were investigated by requiring identification of stimuli which varied not only along one dimension but along two dimensions as well. An extension of the redundancy question involved the inclusion of stimuli which varied along three dimensions along with the one and two dimensional stimuli.

ERIC

An additional perceptual question posed by this experiment centered about the type of dimensions used and their combinations. In experiment one the stimuli consisted of squares varying in size and/or brightness. The physical dimensions of this study included length of a line, orientation of that line, and the brightness of the background upon which the line was placed. The use of these three dimensions permitted investigation of not only the distinctiveness of stimuli varying along each of these dimensions and stimuli in which they were combined but also made possible a comparison of different dimensional combinations. If one considers the line as a figure upon a background varying in brightness, one may ask whether distinctiveness differs when one varies both dimensions of the figure, e.g., length and orientation with the baskground (brightness) held constant, from the case in which a two-dimensionally varying stimulus has as its dimensions of variation one from the figue (length or orientation) and one from the background. This figure-ground question was the final one toward which experiment two was addressed.

METHOD

Subjects

Twenty six normal first graders, 26 sixth graders and nine retarded children served as subjects. The normals were students in the public school system of Willimantic, Connecticut and the retardates were residents of the Mansfield State Training School, Mansfield, Connecticut. The retarded children were undifferentiated diagnostically with a mean CA of 12.15 years (range 10.3 to 14.6), mean MA of 6.67 (range 6.05 to 7.74) and mean IQ of 51.7 (range 43 to 72). None of them exhibited gross sensory or motor impairment, all attended public school classes at the training school, and all had previously served as subjects in discrimination learning experiments. The normal children were selected by their teachers who were instructed to choose pupils who were of average age and average ability for their respective grade levels.

Materials

The stimuli to be identified consisted of 3 in. x 3 in. cards upon which a line made of 1/16 in. red charting tape was placed. The brightness of the background of the card was varied by the use of color-aid gray paper. Ten brightness levels were obtained using Color-aid values 1A, 1, 2A, 3A, 4A, 5A, 6A, 7A, 8 and 9A. Ten values of length of line were used with a range of 14 mm. to 57.7 mm. Each step along the length dimension was 1.17 times the size of the preceding one. Ten orientations were obtained by varying the line with respect to the horizontal from 6^{0} to 87^{0} in 9^{0} steps. Thirteen sets of 10 cards each were constructed to provide stimuli which varied along one, two or three dimensions. The 13 sets consisted of: three unidimensional sets in which one of each of the three dimensions varied while the other two were held constant, six bidimensional sets in which two dimensions varied in a perfectly correlated fashion while the third remained constant, and four tridimensional sets in which all three dimensions varied in a correlated fashion. There were six and four bi- and tridimensional sets rather than three and one respectively because for each of the bidimensional sets value one on a variable dimension was combined with value one or ten on the other variable dimension, while in the tridimensional sets value 10 on one dimension was combined with both one values on the other two dimensions, along with a set in which all dimensions were combined starting with value one.

Both the stimulus for identification and the display matrix were presented on a 30" x 30" display board. The identification stimulus was inserted in a holder mounted in the center of the board, with the response matrix arranged in a circle around the stimulus. The board was placed on an easel facing the subject and covered with a mask. The mask required an excursion of six inches to cover and uncover the response matrix. Figure three illustrates the display board, mask and relation of the display to S and E.

Experimental Design and Procedure

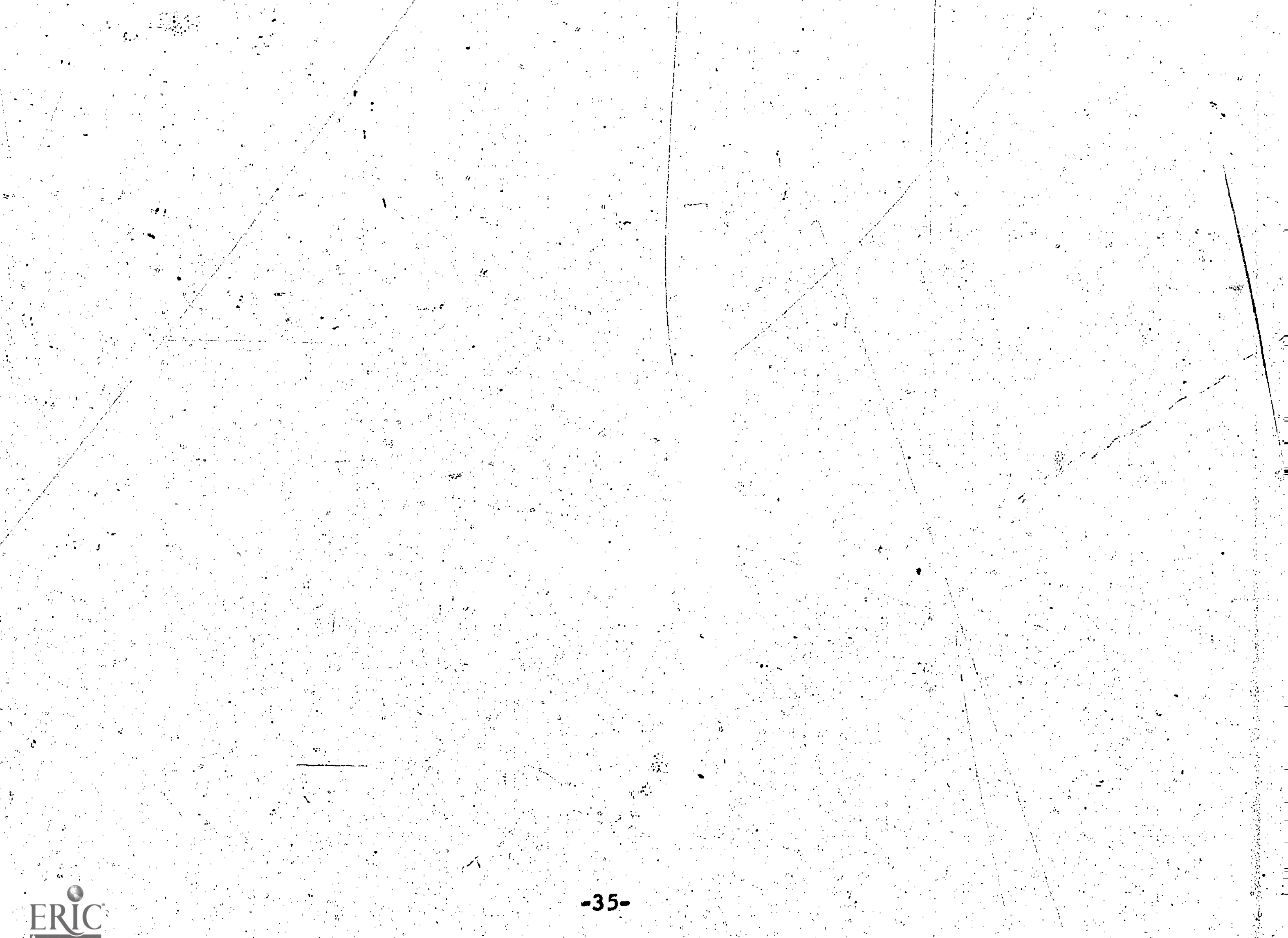
The independent variables of the study were Groups (retardate, first graders and sixth graders) identification delay (zero or 15 seconds) and dimensionality (uni-, bi- or tridimensional stimuli). The delay conditions were presented as a within subjects variable in all three groups, but the dimensionality condition was presented as a between subjects variable in the normal groups and as a within variable with the retarded subjects.

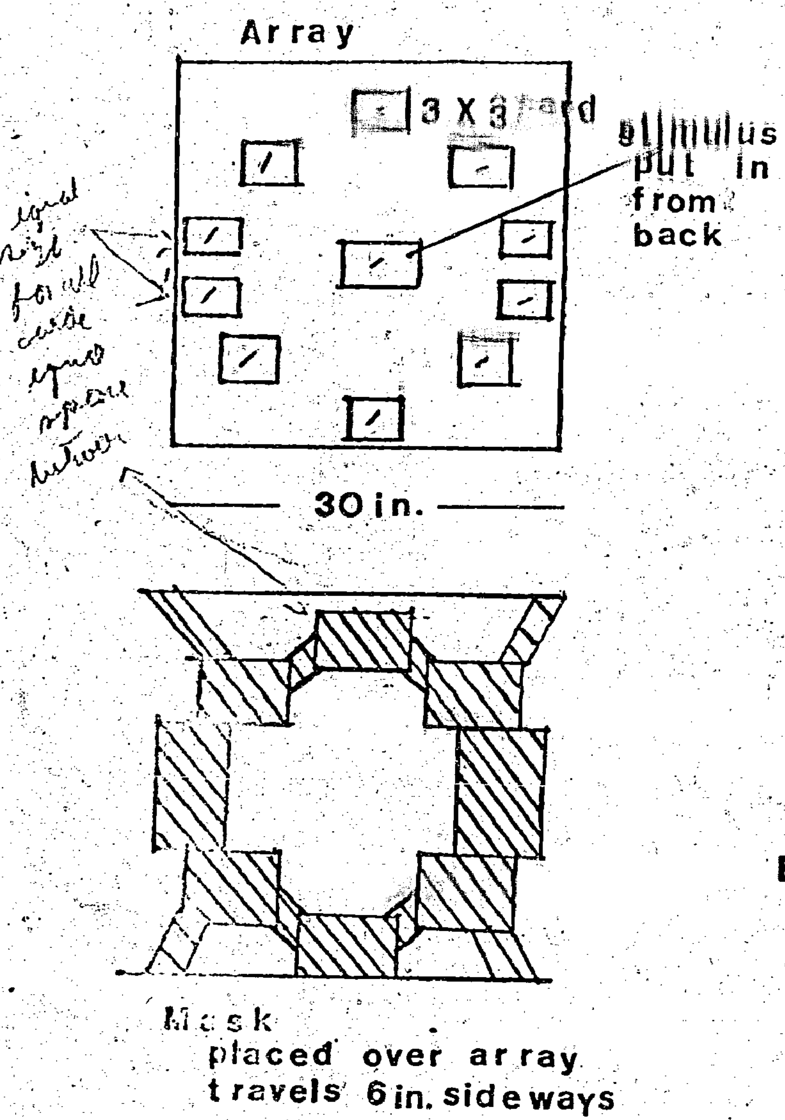
Each of the retarded Ss were run for three hourly sessions. Within each session the two delay conditions were imposed in a balanced fashion across subjects. The dimensionality conditions were balanced across session and subjects as were the stimulus sets within each dimensionality condition. In an hourly session the 10 stimuli to be identified were presented 100 times, 50 under the 0 delay condition and 50 under the 15 sec. delay. Ten practice trials preceded the experimental trials and Ss were given regular verbal reinforcement. Candy and/or toy reinforcements followed each daily session.

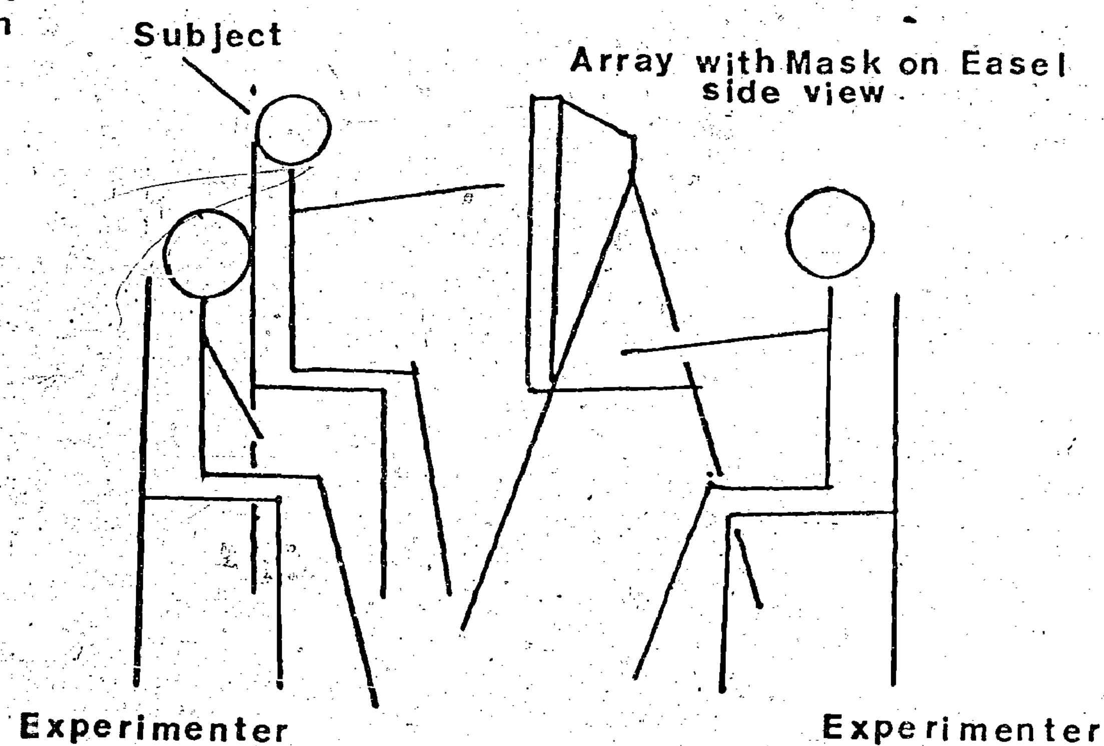
The procedure for the normal Ss was similar to that for the retarded children, but for the fact that only one hourly session per S was held

Figure 3

Sketch of display board, mask, and subject and experimenter arrangement.




Array
3 X 3 card
stimulus put in from back
30 in.
Mask
placed over array
travels 6 in. sideways


Subject
Array with Mask on Easel
side view
Experimenter
Experimenter

because each $\underline{S}$ served in only one dimensionality condition. Each of the 13 sets of stimulus cards was used for two normal $\underline{S}$s.

RESULTS

Since the experimental design included different arrangements of the independent variables for retarded and normal subjects several analyses were carried out. These will be presented in three sets: analyses for normals, analyses for retardates and retardate-normal comparisons. As was the case in experiment 1, the response measure analyzed was transmitted information (T).

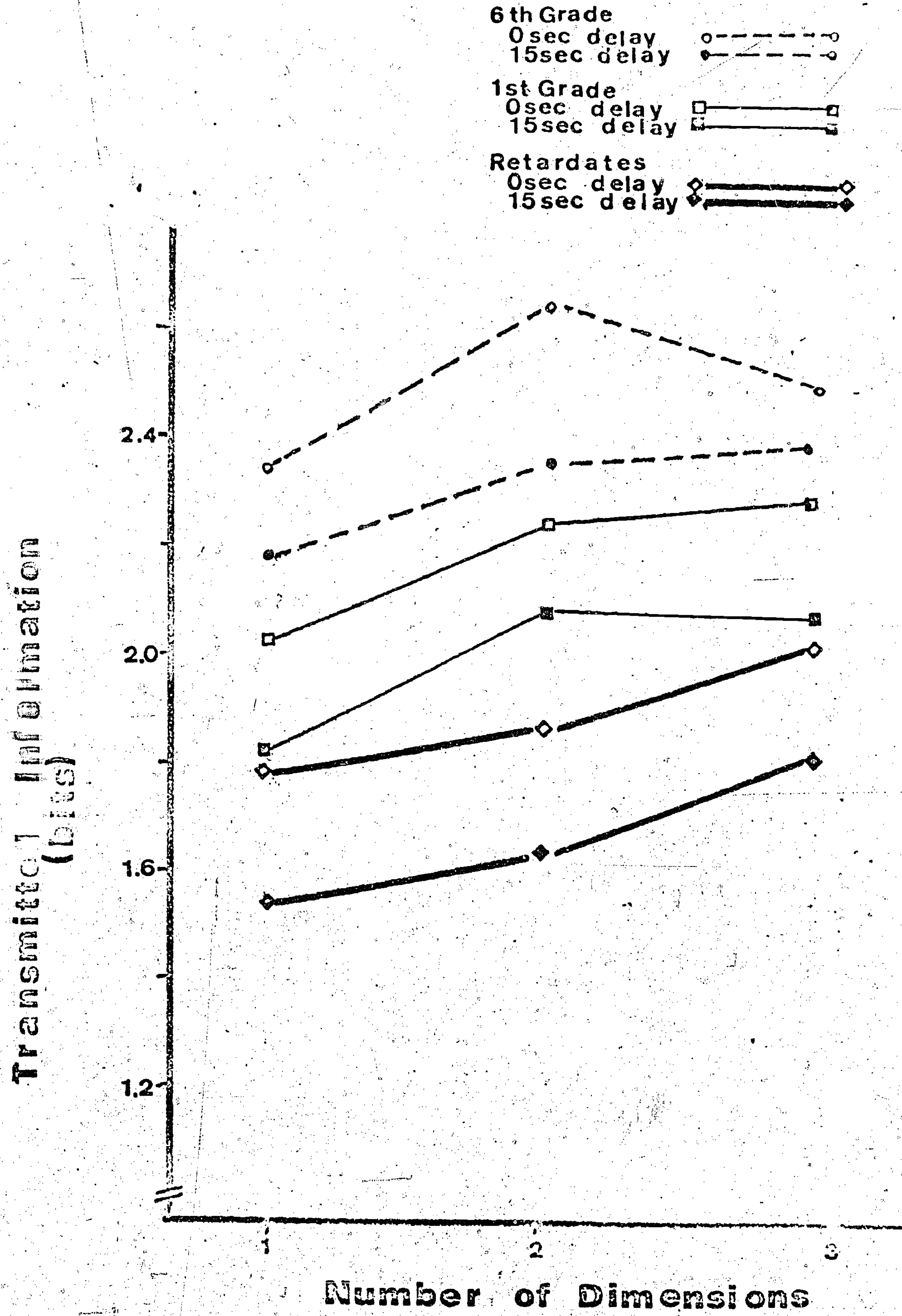
First and Sixth Graders

As can be seen in figures four and five, the sixth graders transmitted consistantly greater amounts of information than did the first graders. This difference was statistically reliable below the .001 level ($F = 40.27$, $df = 1,38$). Dimensionality effects illustrated in Figure 4 include more information transmitted for the bi- and tridimensional conditions than for the unidimensional condition ($F = 17.40$, $df = 1,38$, $p < .001$) but no significant increment for tridimensional stimuli over bidimensional ones. None of the three unidimensional conditions differed significantly from the other, but the bidimensional combinations did. When the two figure dimensions (length and orientation) were combined, significantly more information was transmitted ($F = 8.27$, $df = 1,38$, $p < .01$) than when either of the figure dimensions were combined with the background dimension (brightness).

Delay effects were clear and consistant as illustrated by figure 5. Performance was degraded by the 15 second delay at both grade levels ($F = 36.8$, $df = 1,38$, $p < .001$).

Figure 4

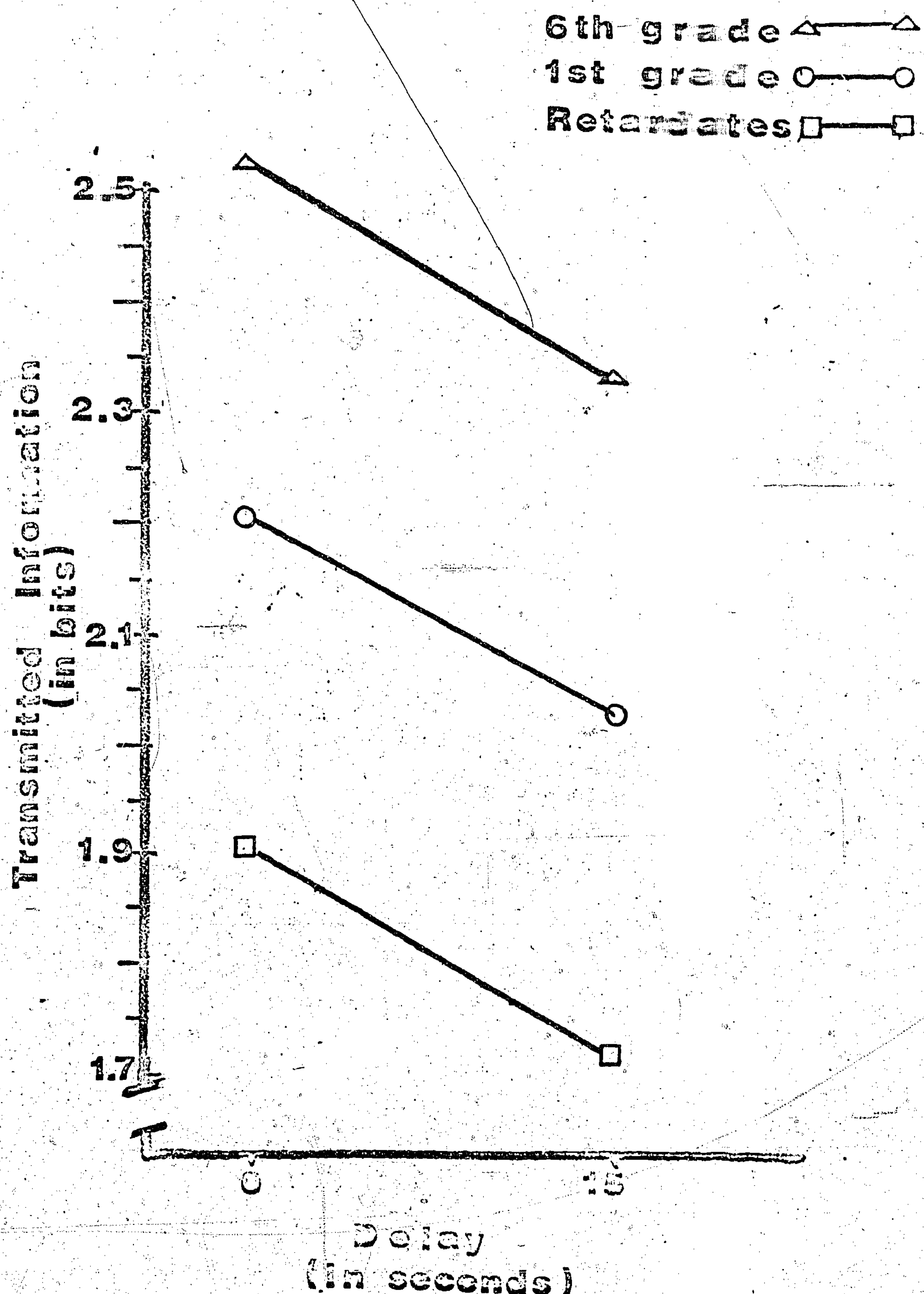
Information transmitted by the three experimental groups as a function of delay and number of redundant dimensions.



6 th Grade
0 sec delay
15 sec delay
1st Grade
0 sec delay
15 sec delay
Retardates
0 sec delay
15 sec delay
2.4
2.0
1.6
1.2
Transmitted Information (bits)
1
2
3
Number of Dimensions

Figure 5

Delay effects among the three experimental groups.



6th grade
1st grade
Retardates
Transmitted Information
(in bits)
2.5
2.3
2.1
1.9
1.7
0
15
Delay
(in seconds)

ERIC

Retardates

Dimensionality effects within the retarded Ss differed somewhat from those found with the normal controls. While there were no differences among the unidimensional sets of stimuli as was the case with the first and sixth graders, the bidimensional figure combinations as opposed to figure-ground combinations were not reliable different though they were with the normals. Another retardate-normal dimensionality difference can be seen in Figure 4. The greatest effect of redundancy is seen by looking at the tridimensional stimuli as opposed to the uni- and bi-dimensional sets ($F = 21.3$, $df = 1,35$, $p < .001$). The uni- and bi-dimensional conditions do not differ greatly from each other.

Retardate delay effects were similar to those found with normals (see Figure 5) and were highly reliable ($F = 28.3$, $df = 1,35$, $p < .001$).

Normal vs. Retardate Comparisons

In comparing retardates and normals directly two analyses were carried out. The first and sixth grade Ss who had unidimensional conditions were compared to the retardate unidimensional performance, while those first and sixth graders who performed in the bidimensional conditions were compared to the same retarded children but only in terms of their bidimensional performance.

For unidimensional sets, sixth graders transmitted significantly more information than did either first graders or retardates ($F = 10.98$, $df = 1,12$, $p < .01$), but the difference between first graders and retardates were not significant ($F = 2.07$, $df = 1,12$, $p > .05$). Although delay effects were significant as may have been expected from the other analyses, no interaction of subject differences and delay were found.

In the bidimensional analysis once again sixth graders transmitted more information than did first graders and retardates ($F = 39.7$, $df = 1,24$, $p < .001$), but in this instance first grade performance was significantly better than that of retardates ($F = 19.5$, $df = 1,24$, $p < .001$). Once again significant delay effects but no interaction of delay and subject differences were found.

DISCUSSION

The results of experiment one revealed a retardate identification deficit and a hint of a developmental correlate of identification. We reasoned that the developmental effect was not clear because the high level of performance in both normal groups may have resulted from too simple a task. Support for this hypothesis comes from the reliable sixth and first grade differences of the present study in which task demands were higher. In this study as was the case in the first, retardates did not perform as well as did normals. However while both first and sixth graders outperformed retardates in the first study, only our sixth graders did so in all cases in this study. With the unidimensional stimuli of experiment two, retardate and first grade performance was not significantly different. While it is possible that the particular dimension employed might attenuate the differences found with other dimensions and dimensional combinations, we do not favor such an hypothesis. The differences that did exist (see Figure 4) were in the appropriate direction, the bidimensional stimuli did produce significant retardate-first grade differences, and one of the single dimensions, brightness, used in this study was similar to the brightness dimension of the first study; all of which leads us to favor the first grade-retardate difference we found as real despite its failure to reach a conventional level of statistical significance.

The effects of redundancy resulting from dimensional combinations, upon stimulus distinctiveness were consistent with the first experiment but not as straightforward as we might have liked them to be. Once again more information was transmitted when dimensions were combined than when unidimensional stimuli were identified. However the benefit gained from increased dimensionality was not only not linear, but perhaps not even monotonic. For the normals the gain for two dimensions over one was clear and expected, however the addition of a third variable dimension in some cases improved performance slightly over two dimensions, but in others depressed performance. For the retardates the three dimensional identification produced by far the best performance. It may be that the effects of dimensionality upon distinctiveness do indeed interact strongly with developmental and intellectual level as our data seem to suggest, but if this is so the interaction is a strange one indeed. The results of this study and the first study would indicate that retardates benefit <u>increasingly</u> from added redundancy, but that our normal controls cease deriving benefit after two dimensions of variation. This by itself is not very strange, but when countered in light of the fact that college students seem to benefit from increasing redundancy up to three dimensional stimuli with the very same dimensions of variation (see experiment four, section II), the interaction becomes at best a very complex one.

The overall effects of delay in this study were identical to those found in experiment one. In all cases imposing a delay between the stimulus to be identified and the response matrix decreased performance. This clear indication of the importance of memory to our task forms the basis for the investigations reported in section II and III. While the overall delay effects in this study were similar to those found in experiment one, there was no indication of an interaction of delay with groups of the sort found in that early study. In that experimental delay seemed to affect retardates more adversely than it did normals, while here, delay decrements (see Figure 5) were similar for all subject groups.

ERIC

SECTION II

COMPARISONS OF IDENTIFICATION AND DISCRIMINATION

Experiment 3

A comparison of two types of identification

The match-to-sample procedure used in experiments one and two was selected to minimize verbal responding and yet still provide a vehicle for measurement of the identification process. The conventional identification procedure requires the labeling of a particular stimulus in the absence of any other comparison stimuli; it became clear to us that our match-to-sample procedure by providing comparison stimuli might be doing more than just avoiding the problem of retardate verbal deficiency. We reasoned that the matrix was providing information which was otherwise required of the subject's memory in the identification situation. This "memory aid" function of the matrix could be seen in its optimal form in the conventional discrimination situation in which all stimuli for comparison are available at the same time and no memory demands for the characteristic of those stimuli are required at all. The differential requirements for memory in the discrimination paradigm and the match-to-sample paradigm which we consider a type of identification led us to the experimental consideration of identification and discrimination described in this and the following two experiments.

As our analysis of the major theoretical question of the discrimination-identification distinction proceeded, a number of iables could be isolated for experimental investigation. Our procedure of matching to sample provides operational distinctions in the comparison of the two processes. In terms most natural to the procedure, discrimination is a process involving the successive comparisons of a very short term trace (i.e., a "present" stimulus) with one of a number of other traces, subject to certain conditions, e.g., that there is a "closest" match, or that the stimulus is "identical" to one (and only one) of the designated set. Identification can be said to differ from this in a quasi-qualitative, or nearly quantitative way, in that a) the stimulus trace is old b) the response set traces are old c) both.

Perhaps, we reasoned, part of the retardate deficiency is in the way in which the two kinds of stimulus traces are stored or retrieved. Reserving for later the comparison with the temporal effects on retardates, we investigated in the present experiment the way in which normal adults process information when, in our standard identification task, the temporal relation between the stimulus and the response matrix is varied. This was done in a 2 x 2 design in which the sub-variables were:

1) presence-absence of a response-matrix (the set of all stimuli used in that condition).

2) Zero or 20 sec. delay of response following the offset of the sample stimulus

The response consisted of a choice of one of the stimuli in the response matrix (matching the sample) when the sample was present, or naming the sample stimulus when the matrix was absent.

Since one of the major purposes of the program is to assess the effects of varying dimensional complexity in sets of stimuli on identification and discrimination processes we incorporated another variable, dimensional-type, into the design. There were three levels of this factor:

1) One-dimensional size

2) One-dimensional brightness

3) Two-dimensional size and brightness

In summary: this experiment was designed to measure the effects on information transmission capacity of the presence of a recognition display, the response matrix, with or without a "retention" delay; the type of dimensional variation; and their interaction. We expect that recognition-identification will be better when the display is present, giving the observer a set of values against which to match the trace of the sample. At the longer delay, performance could be expected to fall off with the matrix present at about the same level as matrix absent, depending perhaps on the dimensional complexity of the stimuli.

METHOD

Subjects

The Ss consisted of six volunteer (paid) undergraduate students, three male and three female, from the University of Connecticut.

Materials

The stimuli consisted of two identical sets of squares selected from the 10 size by 10 brightness orthogonal set used in the first experiment. Each set consisted of stimuli of ten different sizes (S_1, S_2, ...S_{10}) with uniform brightness, ten different brightnesses (B_1, B_2, ...B_{10}) with uniform size, and ten different bidimensional completely redundant squares (S_1B_1, S_2B_2, ...$S_{10}B_{10}$, a "linearly correlated" set). The 10 values of each dimension (or bidimension) in one of the sets were singly centered on reddish colored tachistiscope "field cards." The 10 values of each dimension in the other set were collectively mounted in two rows of successively increasing values on reddish colored "field cards." These three collectively mounted dimension cards were the "display cards" from which the subject had to identify the test stimulus.

A two-field tachistoscope was used to present the test stimulus and display. Either a blank red field, a single test stimulus against a red field, or a display of ten alternative stimuli against a red field could be seen in the tachistiscope at any given moment during the course of the experiment.

Design

Three independent variables were studied in a factorial design: Display type at two levels (presence vs. absence of a display following the test stimulus presentation); dimension type at three levels (one-dimension size, one-dimension brightness, and two-dimension size-brightness); and the length of the retention interval at two levels (0, or 20 seconds).

All subjects were run under all conditions; thus they acted as their own controls. The Ss were tested over six experimental sessions, each session consisting of 120 trials. Only one combination of display, and dimension type or number was used during a given session. Delay and correct stimulus value orders were randomly arranged over the 120 trials, while the order of experimental conditions was completely counterbalanced across subjects. Dimensional types occurred in succession.

The dependent measure, which was manually recorded by the experimenter, was the number of errors made by Ss under each condition. This error measure was subsequently transformed into the amount of information transmitted by each S under each condition.

Procedure

Upon entering the experimental lab Ss were seated in front of the tachistiscope and explained its use. They were then instructed as to the nature of the tasks they had to perform, and given several practice trials with the tachistiscope.

The test stimuli were presented for a period of one second. In the display-absent condition the display was shown only once for a period of one minute at the beginning of the session. In the display-present condition it was shown after each test stimulus for a sufficient amount of time for the S to make his identification response.

The S had full control over the time of test stimulus presentation. By pressing a button on the tachistiscope control box at any time after a signal given by the experimenter, he could cause the test stimulus to appear. The experimenter had full control over the length of the delay interval preceding the identification response. During this delay the S was told to continue looking into the tachistiscope in order to keep his eyes at the same level of light adaptation.

RESULTS

Figure 6 shows the mean number of bits of information transmitted under each of the experimental conditions.

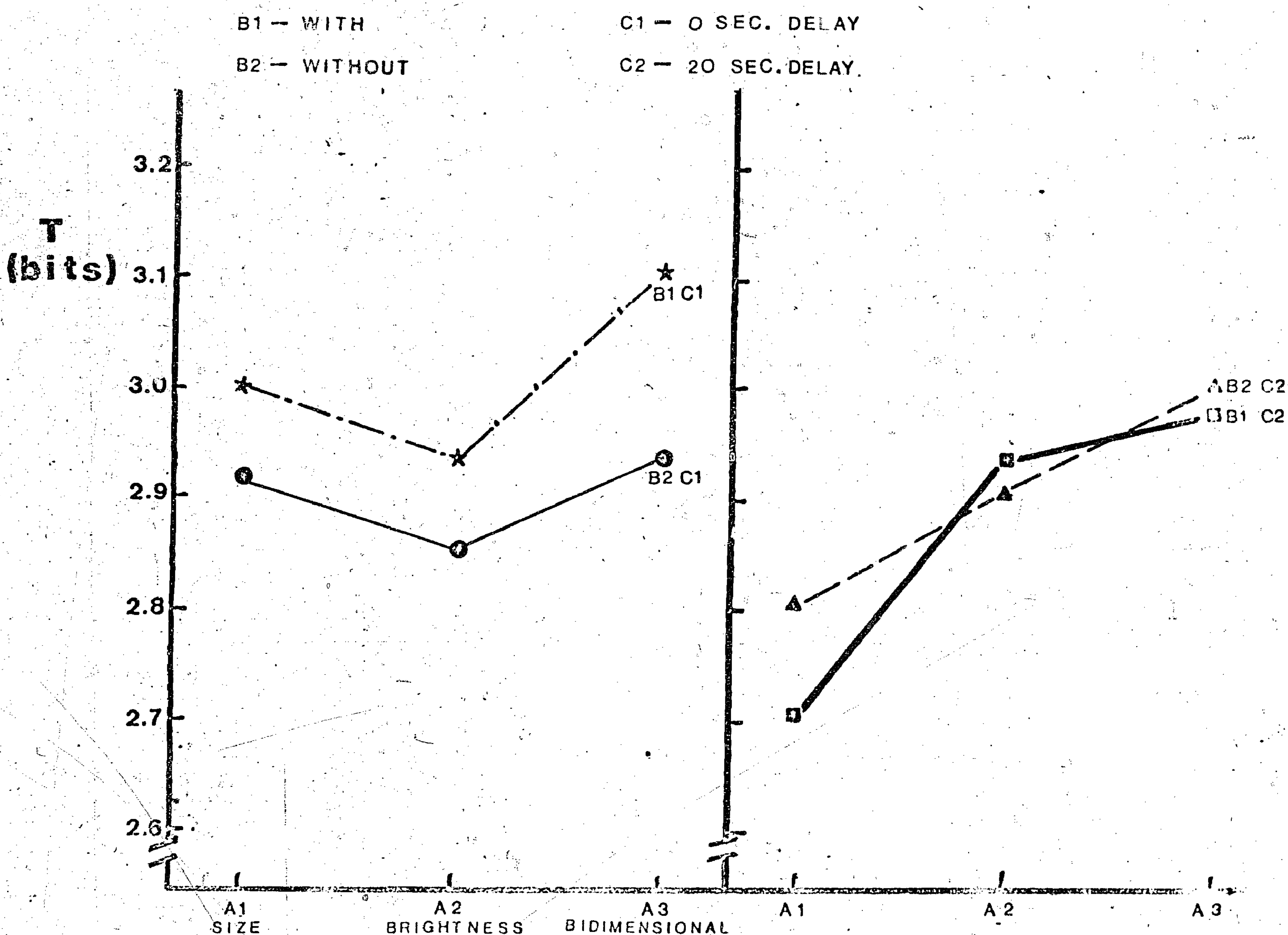
The analysis of variance showed that only one effect was significant in the present data; unidimensional stimuli resulted in less information transmission than bidimensional stimuli ($F = 6.81$, $df = 1,44$, $p < .05$). Other effects which approached significance were: (1) Delay x Display ($F = 2.67$, $df = 1,44$, $p < .10$), in which less information was transmitted under conditions of increasing delay and no-display than under conditions of decreasing delay and display present; and (2) Delay x Unidimensional type ($F = 3.72$, $df = 1,44$, p . 10), in which delay had a more detrimental effect upon brightness than upon size.

The results were noteworthy chiefly in their lack of confirmation of the intuitive hypotheses concerning the major variable, the presence of the matrix. There was no effect of the presence of the display, and as

Figure 6

Information transmitted with and without matrix as a function of dimensic i condition (Size, Brightness, Bidimensional) and delay.

ERIC


B1 — WITH
B2 — WITHOUT
C1 — O SEC. DELAY
C2 — 2O SEC. DELAY
T (bits)
3.2
3.1
3.0
2.9
2.8
2.7
2.6
B1 C1
B2 C1
B2 C2
B1 C2
A1
SIZE
A2
BRIGHTNESS
A3
BIDIMENSIONAL
A1
A2
A3

might be expected from this, no effect of delay. There was a delay effect only as a part of the interaction of delay with the type of 1-D task (Size vs. Brightness). With size stimuli there was a definite drop off in performance at the 20 sec. delay, while the delay had no deleterious effect on performance in the brightness condition. This suggests strongly that the uses to which a reference display can be put may depend on the type of coding (in turn a function of the dimension of variation). The trace for a Size stimulus has a "spatial" quality which makes it accessible to comparison with a present stimulus. This trace decays rapidly; in the meanwhile it is converted into some relatively permanent form, so that a considerable amount of the information is preserved. This meachnism is, of course, essentially what we have hypothesized as a general effect of the matrix delay. With the brightness stimuli, no such effect occurs at all. There is, in fact, a slight increase in performance with the 20 sec. delay. Presumably Brightness is immediately coded into its permanent form, so that the comparison with the display stimuli is not really helpful. An alternative possibility is that the trace for Brightness stimuli is much longer lasting than that for Size, but this seems, in light of the present data, a less plausible explanation.

Similarly the results for Display are not simple. The reason why a main effect for Display does not appear may be because of a Display x Delay interaction: in each of the three dimension conditions there is an advantage to use of a display presented immediately but this advantage disappears, and even seems to be slightly reversed when the response and display presentation is delayed for 20 sec. The latter result is unexpected but, after the fact, not completely uncomprehensible. In the no-display condition, the task of the subject is to identify the stimulus presented, comparing it to a set of remembered standards. He must "make up his mind" either instantly (0 delay) or sometime before 20 seconds. The requirement of immediate responding can only work to reduce accuracy. The net result of the combination of this effect and that of the display when presented is to cancel out the main effects of both Display and Delay, leaving the interaction to carry the burden of analysis.

One interesting result is that the lowest point is a matrix 20" point. The no-matrix condition, which could be expected to be worse, is not. This suggests that Ss use different strategies for matrix than for no-matrix conditions. They are operating close to capacity for no-matrix. They drop at 20 sec. delay when matrix is there. They don't learn or don't care to identify (work as hard) in the matrix-with-no-delay. Or maybe they're simply trying to be "good" subjects. We tell them to wait 20 seconds for the matrix and they wait, even though they lose more by waiting than by an immediate response.

The only clear main effect is that of dimensionality, with the 2-D stimuli, as expected, more distinctive than either of the single dimensions.

These results support an encoding, or attentional, interpretation of retardate perceptual deficit, rather than a trace persistancy interpretation. The fact that an identification aiding display following test stimulus presentation does not significantly aid recall indicates that the possibility of the Ss "matching perceptual traces" during identification is of little importance. It might be argued that the S can satisfactorialy match perceptual traces under both conditions of display presentation, but the fact that the S would have to maintain a separate trace for each of the ten altervatives over the duration of the 120 trial session in the no-display condition is highly unlikely. With a display present after each test stimulus presentation, on the other hand, the S would have only to maintain a single trace for a short duration. Thus, in experiment 3 it appears that the significant effects which were found were primarily the result of the S's ease of encoding (possibly involving anchors and labeling) under the different conditions.

The trend toward significance of the display x delay interaction suggests that maybe at very short intervals of delay the S can satisfactorily maintain the perceptual trace and subsequently use it to aid recall, while after a long delay interval the S may no longer be able to utilize the trace, presumably because it has had time to decay. While this finding might be given as support for trace decay theory, it must be remembered that it was only a "non-significant trend."

The reason for finding such a general lack of comparable results between this and the retardate studies is not clear but points to some factors of potential importance. It seems unlikely that the significant dimension type and delay effects found in experiment 1 and 2 would disappear as a result of using an adult sample of subjects in experiment 3. In any event, a clearly significant bidimensionality effect was found in both experiments, thus lending strong support to the contention that adding dimensions to stimuli is a tremendous aid in perceptual identification.

Experiment 4

Comparisons among three types of identification and a discrimination

The results of the previous experiments made it clear that the process we had called identification was, at least on the operational level, resolvable into subprocesses defined on the basis of such factors as the number of stimuli in the set, whether a comparison set (display) is available, the times of presentation of stimuli and display, delay of display presentation, etc.

In the present experiment we attempted to extend the range of "identification" processes by manipulating the temporal relations between the presentation of a stimulus for identification and the display matrix. The four logical combinations were used:

no matrix; replicating one of the conditions of a previous experiment.

matrix first: the display was presented, then removed before the presentation of the stimulus.

matrix last: again replicating the previous experiment. The sequence was: present stimulus, remove stimulus, present matrix.

simultaneous: stimulus and display presented together.

In this way we included a range of conditions from what can be interpreted as a discrimination (simultaneous) through a short-term recognition-identification (matrix last) to a short-term recall-identification (matrix first) and finally the "pure" or long term identification, (no-matrix). To get the simplest forms of these processes the matrix first and matrix-last delays were set at 0 sec., i.e., the termination of one and the onset of presentation of the other were simultaneous.

Again consistent with our concern for the interaction of various identification-discrimination processes with conditions of dimensional variation, we devised our stimulus sets so that every redundancy combination of three separate stimulus dimensions were included. Redundancy was always constructed through "linear" correlation, i.e., the values of the dimensions being A_1, A_2 ...; B_1, B_2 ...; C_1, C_2 ... the 2-D sets were: A_1B_1, A_2B_2 ... or A_1C_1, A_2C_2 ... or B_1C_1, B_2C_2 ...; the 3-D sets were $A_1B_1C_1$, $A_2B_2C_2$ ....

METHOD

Subjects

There were eight paid Ss recruited from undergraduate classes in Psychology at the University of Connecticut. All Ss served in all conditions.

Materials and apparatus

The basic apparatus was a large board on which were mounted the stimulus cards appropriate to one of the seven conditions (the "matrix"). The cards were arranged in a sequence of 16 ordered values according to the dimension(s) varied in a circle with the sequence starting and ending at the vertical. In half the cases the order (according to a given definition of increasing) was clockwise, the other half counter-clockwise.

In the center of the display there was an opening through which the stimulus was presented.

Matrix Conditions:

I No-matrix: the matrix board was covered after the entire stimulus set was shown, and not uncovered throughout the session. Stimuli were presented in the center opening and responses coded by the position on the board of the corresponding matrix card, now covered. Since the matrix cards were arranged in a known quantitative sequence it can be (and is) assumed that any mistakes reflected the lack of resolving ability and not a failure of naming.

II Matrix first (0 sec. delay): at each trial onset, S was presented with the matrix of 16 stimulus cards mounted (in sequence) on the matrix board. After about 5 sec., the cards were covered by pulling a screen in front of the board, and at the same instant the center stimulus card was uncovered. Responses were indicated by naming the corresponding matrix card (now covered).

III Matrix last (0 sec delay): at each trial onset, S was presented with the center stimulus card, the matrix cards being covered. After about 5 sec, the center card was covered and at the same instant the entire set of 16 matrix cards was uncovered.

IV Simultaneously: at each trial onset the center stimulus and set of matrix cards were simultaneously exposed and left for about 5 sec., then all covered.

Stimulus conditions: there were 7 different stimulus conditions

1. Length (A). The sequence of 16 cards, clockwise or counter-clockwise from A_1 to A_{16} in roughly equal j.n.d. units of length (determined on the basis of pilot psychophysical testing) the "lines" being made of 1/8" tape all of the same brightness and orientation (horizontal).
2. Orientation (B) was varied as the angle of a line (1/8" tape of fixed length and brightness) with the vertical axis of the stimulus card. There were 16 roughly equal angle steps from the vertical to the horizontal.
3. Brightness (C) varied as 16 shades of grey in lines of constant length and orientation.

4. Length and Orientation, redundant two-dimension. There were four possible matrix arrangements. The two series, numbered A_1, A_2 ..., A_{16} and B_1, B_2 ..., B_{16} were covaried either as A_1B_1, A_2B_2, ..., $A_{16}B_{16}$ or as A_1B_{16}, A_2B_{15}, ...$A_{16}B_1$ and each of these could be ordered either clockwise or counter clockwise on the display board.
5. Brightness-Orientation redundant two-dimension, also four possible series.
6. Length-Brightness redundant two-dimension, four sets
7. Length-Orientation-Brightness, eight possible arrangements

   $A_1B_1C_1$, ..., $A_{16}B_{16}C_{16}$

   $A_1B_1C_{16}$, ..., $A_{16}B_{16}C_1$

   $A_1B_{16}C_1$, ..., $A_{16}B_1C_{16}$

   $A_{16}B_1C_1$, ..., $A_1B_{16}C_{16}$

   each in a clockwise or counter-clockwise order.

The particular arrangement (1, 2, ... 16 or 16, 15, ... 1) of any given dimension was balanced across the 8 subjects, but for each S was the same in 1D, 2D and 3D, and under all matrix conditions. Thus, the 5 stimulus conditions for S_5 were

1. A_{16}, ..., A_1
2. B_1, ..., B_{16}
3. C_1, ..., C_{16}
4. $A_{16}B_1$, ..., A_1B_{16}
5. B_1C_1, ..., $B_{16}C_{16}$
6. $A_{16}C_1$, ..., A_1C_{16}
7. $A_{16}B_1C_1$, ..., $A_1B_{16}C_{16}$

and were the same in all matrix conditions.

A summary of the experimental conditions is given in Table 1.

Instructions: The Ss were told that there are two identical sets of cards.

1. one is set up in a matrix (showing matrix board), cards numbered 1-16 which correspond to the data sheet given.
2. the other set will be presented one at a time in the center of the matrix board (showing where stimulus card appears).

You will be asked to indicate on the data sheet and orally to which matrix card the center card corresponds. Please respond as quickly as possible. Only one answer should be recorded in each block.

You will first be given 8 trials in which the matrix and stimulus will be visible at the same time. This will help you become familar with the cards.

Procedure

After giving subject 8 practice trials (using the simultaneous matrix condition), the experimenter explained which matrix condition would be used. A correction procedure was used, the experimenter giving the correct response or saying "correct" immediately. The matrix or stimulus card (depending on the matrix condition) was left exposed until after the correction was given.

There were 80 trials in each experimental condition. The 16 cards were presented in random order, 5 times each; the same card was not presented more than two successive times.

No-matrix condition

The S was given 3 minutes to study the matrix board after the practice trials, then the board was covered for the remainder of the session.

TABLE I

EXPERIMENTAL CONDITION

MATRIX CONDITION

I no matrix condition

II matrix first with 0 delay

III matrix last with 0 delay

IV simultaneous condition

1. orientation and brightness constant, vary length
   A1, A16

2. brightness and length constant, vary orientation
   B1, B16

3. length and orientation constant, vary brightness
   C1, C16

4. brightness constant, vary length and orientation
   A1B1, A1B16, A16B1, A16B16

5. length constant, vary brightness and orientation
   B1C1, B1C16, B16C1, B16C16

6. orientation constant, vary length and brightness
   C1A1, C1A16, C16A1, C16A16

7. vary length, orientation and brightness
   A1B1C1, A1B1C16, A1B16C1, A16B1C1, A1B16C16, A16B16C1, A16B1C16, A16B16C16

Subject 1:	A1, B1, C1, A1B1, B1C1, C1A1, A1B1C1	Subject 5:	A16, B1, C1, A16B1, B1C1, C1A16, A16B1C1
Subject 2:	A1, B1, C16, A1B1, B1C16, C16A1 A1B1C16	Subject 6:	A16, B16, C1, A16B16, B16C1, C1A16, A16B16C1
Subject 3:	A1, B16, C1, A1B16, B16C1, C1A1, A1B16C1	Subject 7:	A16, B1, C16, A16B1, B1C16, C16A16, A16B1C16
Subject 4:	A1, B16, C16, A1B16, B16C16, C16A1, A2N16C16	Subject 8:	A16, B16, C16, A16B16, B16C16, C16A16, A16N16C16

Matrix-first condition

The matrix board was exposed for 3 seconds, then covered and the stimulus card presented at the same time.

Matrix-last condition

The stimulus card was presented for 3 seconds, then removed and the matrix board exposed at the same time.

Simultaneous matrix condition

The matrix board was available at all times, open. The stimulus card being presented for 3 sec. at each trial.

RESULTS AND DISCUSSION

The basic analyses were performed on transmitted information scores calculated for each S in each of the 28 conditions.

Matrix Conditions (see Figure 7) Analyses confirmed the major hypotheses about thematrix conditions.

1) The simultaneous (discrimination) condition is significantly better than any of the other three.

2) The matrix-last or recognition-identification condition is superior to matrix-first or no-matris but not as high as the simultaneous condition

3) There is no difference between the matrix-first and no-matrix condition. (I, II) vx. (III, IV) $F = 10.89$; $df = 1,189$; $p < .001$ (I) v (II) $F < 1$ (III) v (IV) $F = 4.91$; $df = 1,189$; $p < .05$.

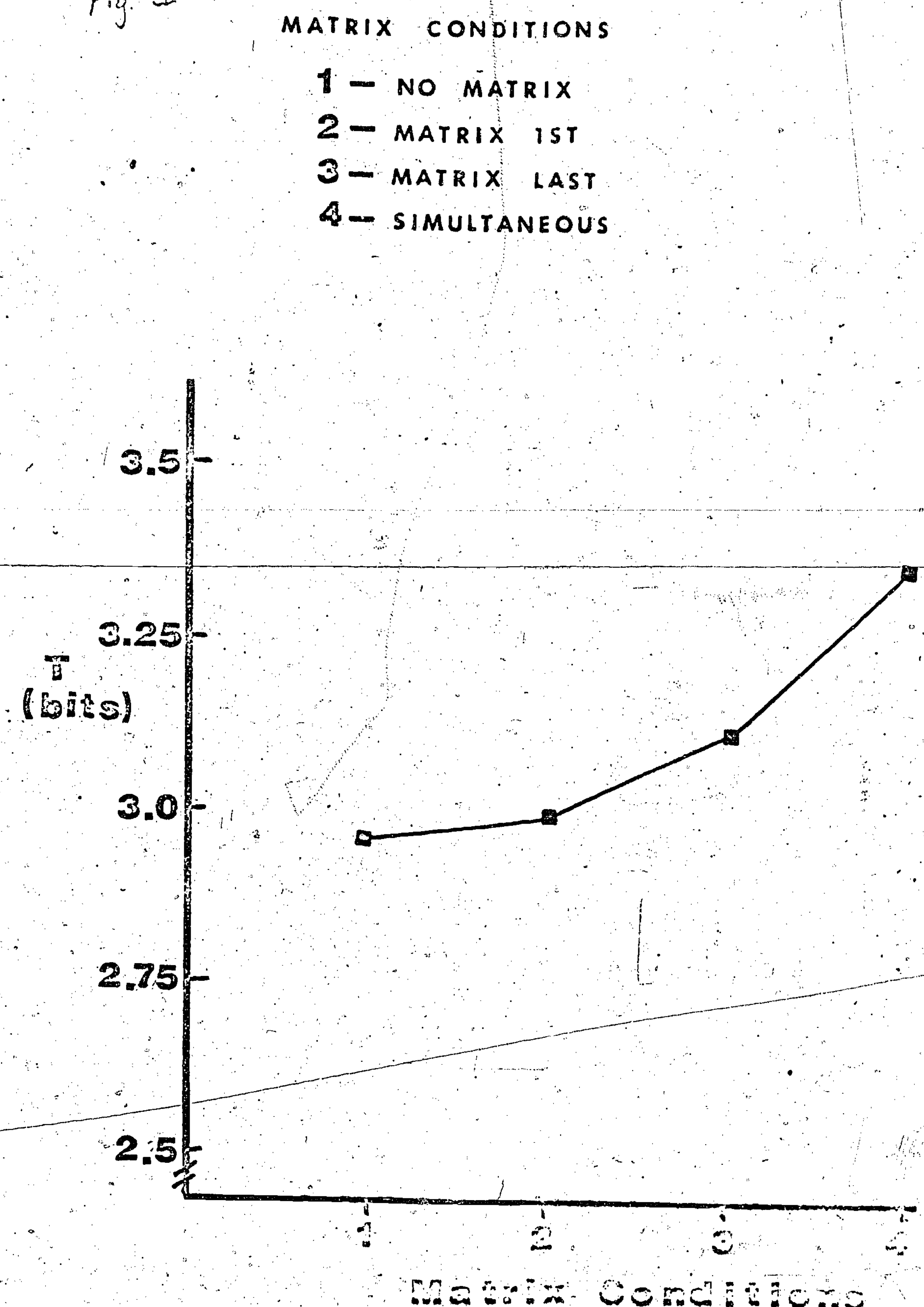
These results confirm and considerable extend the conclusions emerging from the previous experiment:

i) The process-dimension whose end points are discrimination and identification can be operationalized in our delayed matching-to-sample

Figure

Transmitted i nation as a func of the x condition.

Exp. 3
Fig. 1


MATRIX CONDITIONS
1 — NO MATRIX
2 — MATRIX 1ST
3 — MATRIX LAST
4 — SIMULTANEOUS
3.5
3.25
3.0
2.75
2.5
T
(bits)
1
2
3
4
Matrix Conditions

procedure, with the critical parameter being the temporal relation between stimulus and response matrix.

ii) In identification some sort of short term trace of the judged stimulus is involved in the perceptual decision.

iii) The judgment process in identification does <u>not</u> make use of any kind of short-term trace of the set of possible stimulus values. This is a rather surprising result. Evidently, at least when the number of response categories is large, the organism cannot effectively use the <u>short</u> term information available from the whole set. The present results suggest, although not conclusively, that <u>S</u> cannot even use the display to strengthen a smaller number (as few as two?) of anchor points as an aid to categorizing the stimulus.

A major conclusion from this is that the identification process involves the construction of an ordered set of long term representations, nor affected by incoming consistent information (although it may be by new inconsistent information). The relative stability of the judgment standards suggests a number of difficulties in reconciling the judgment data with the general findings of adaptation-level research, for example. It also, to the point of the present project, suggests the dimensions along which retardate-normal and developmental parameters of identification may be explored.

Dimension Conditions. (See Figs. 8 and 9)

The main Dimensional effects again demonstrated their importance in identification.

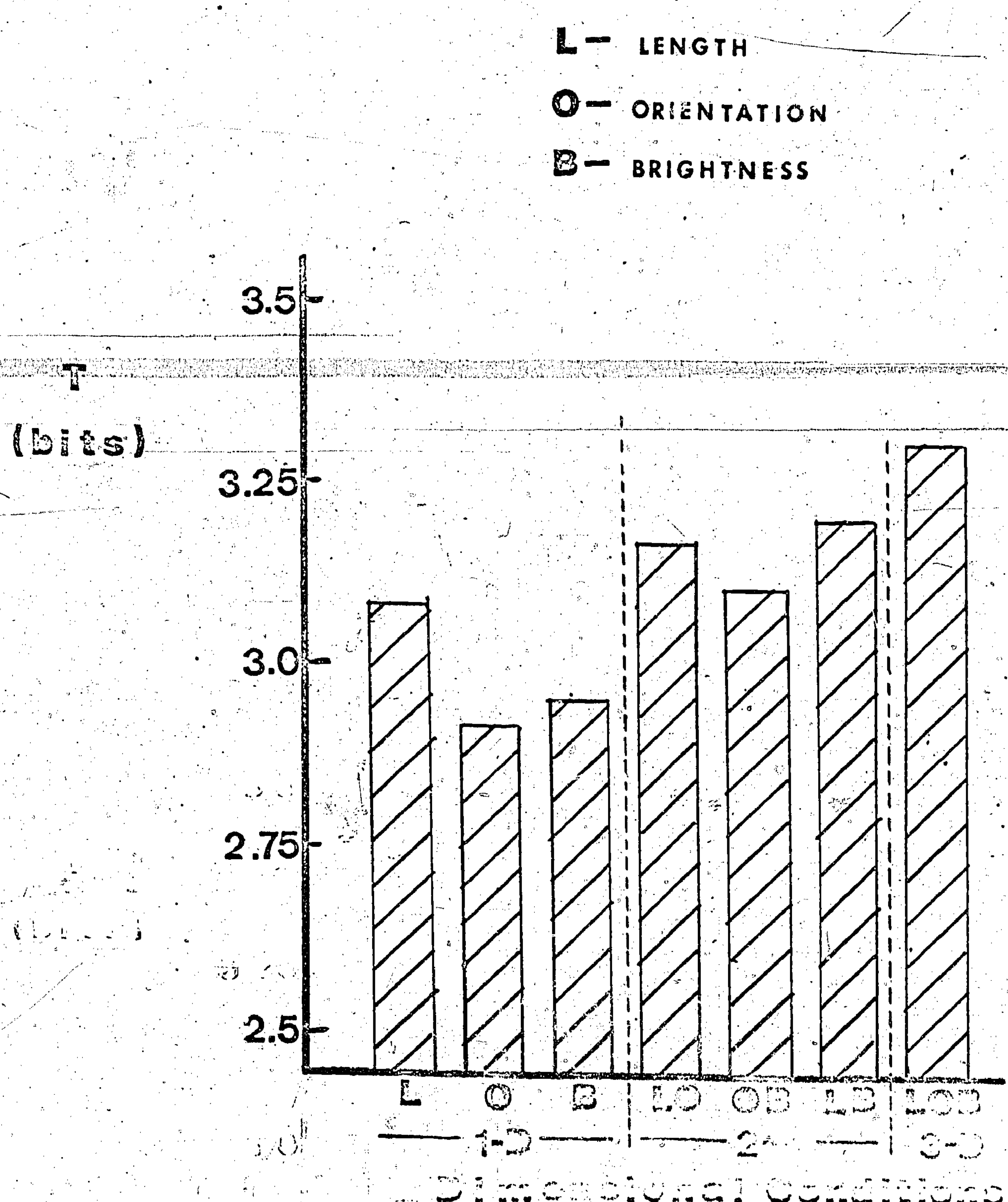
1) The 3-D condition was significantly better than the one- or two-D ($F = 19.92$; $df = 1,189$; $p < .001$).

2) The 1-D was significantly worse than others ($F = 72.27$; $df = 1,189$; $p < .001$)

Figure 8

Information transmitted under conditions of dimensional variation.

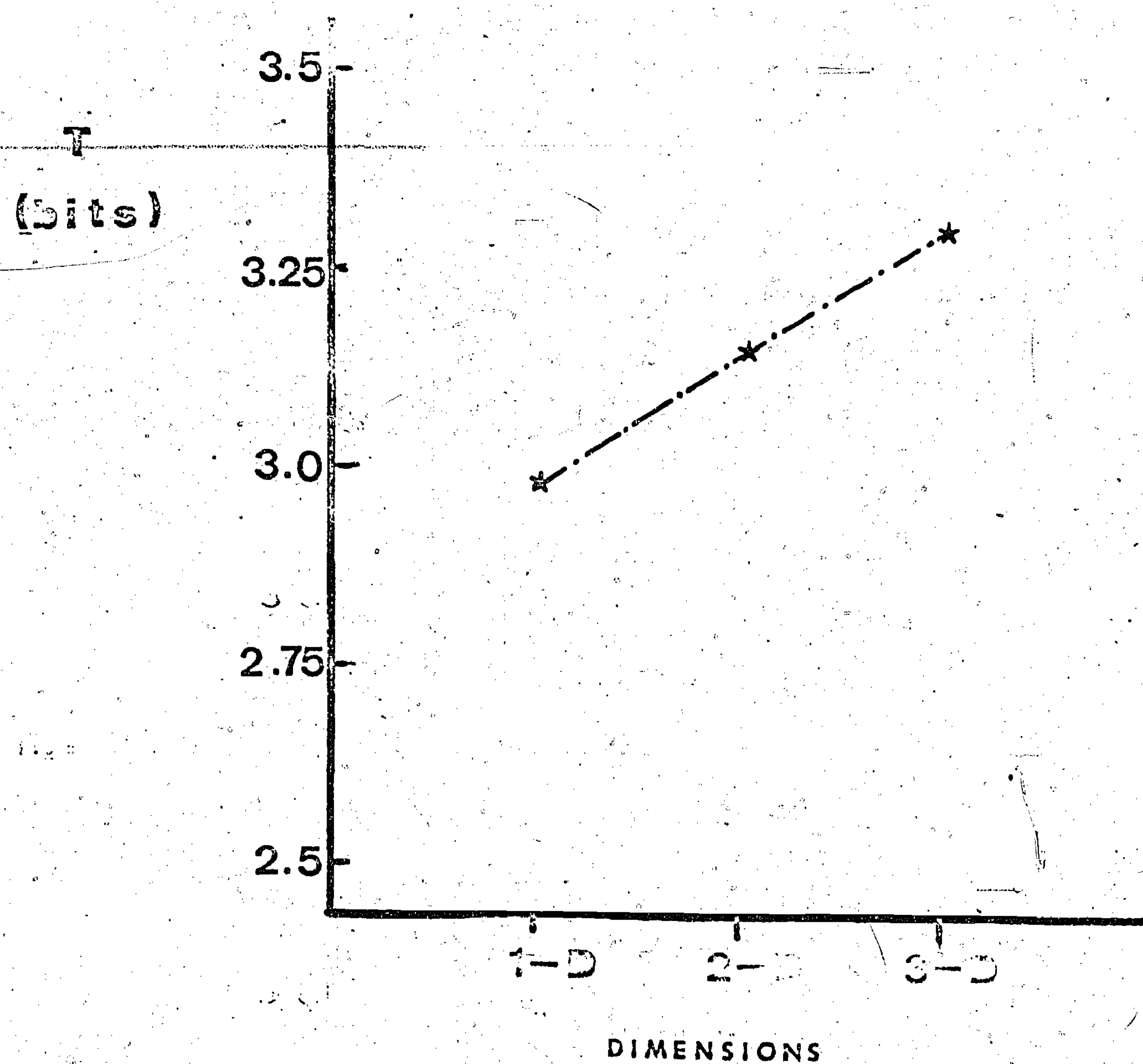
Exp. 1
Fig. 2



L— LENGTH
O— ORIENTATION
B— BRIGHTNESS
T
(bits)
3.5
3.25
3.0
2.75
2.5
L
O
B
LO
OB
LB
LOB
1-D
2-D
3-D
Dimensional Conditions

Figure 9

Transmitted information as a function of number of dimensions.


T
(bits)
3.5
3.25
3.0
2.75
2.5
1-D
2-D
3-D
DIMENSIONS

Redundant information of the kind in this experiment makes stimuli more distinctive, over all conditions of judgment.

3) Within 1-D conditions, results of earlier studies were verified in that information capacity for Length was much better than for Orientation and Brightness ($F = 10.51$; $df = 1,189$; $p < .005$). This is probably not a result of much intrinsic interest, i.e., it may not reflect so much the qualities of the dimensions, as the limitations of the stimulus material. The question is worth pursuing, but needs better equipment and a refinement of experimental techniques to get to a definite conclusion.

4) Consistent with the above is that the 2-D results differed mainly in that the combination not involving Length (OB) was marginally lower than the two 2-D conditions which did ($F = 3.35$; $df = 1,189$; $p < .10$).

Interactions. (See Figure 10)

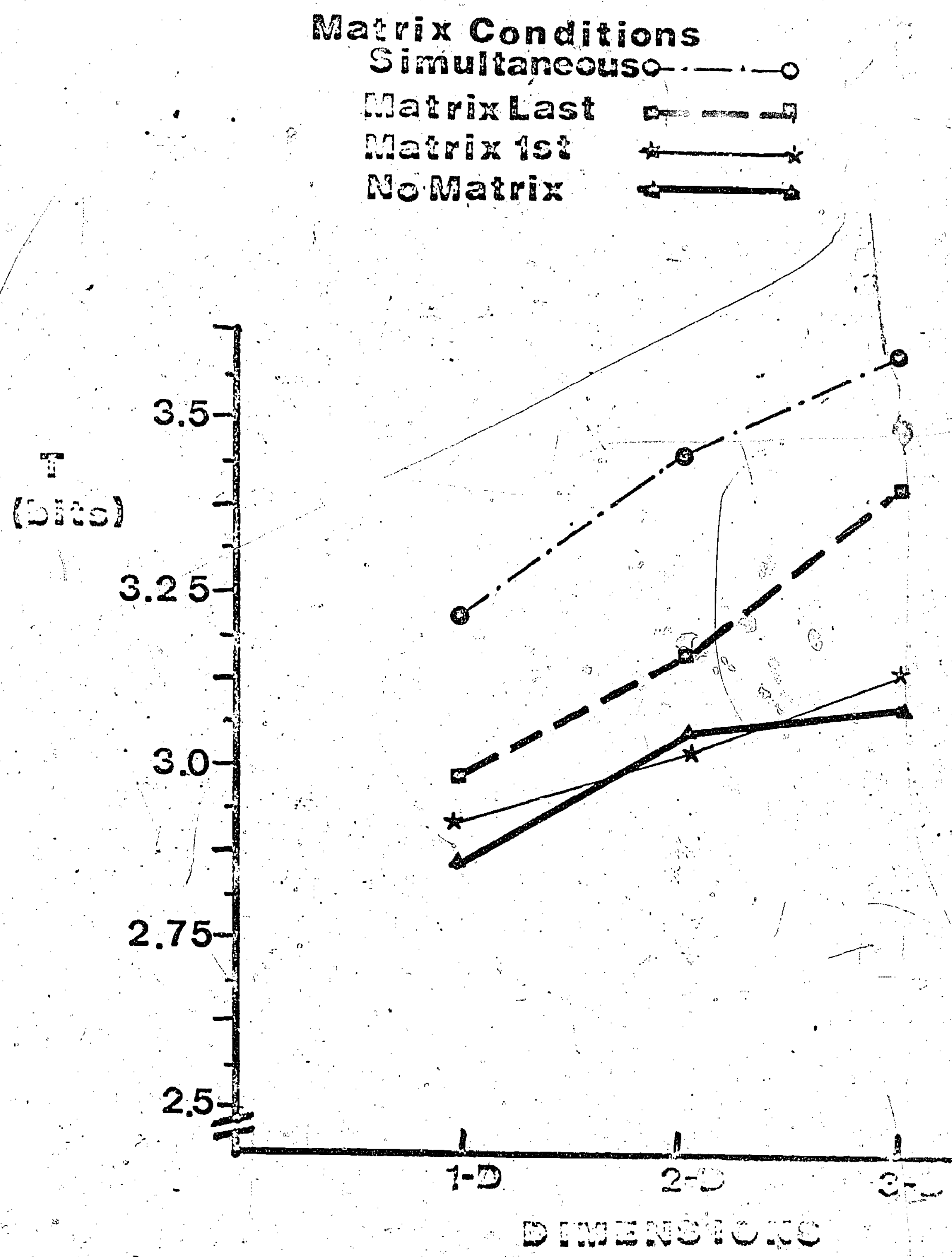
The only surprising result was that there were no significant interactions between the Matrix and Dimensional conditions. The only mariginal result ($F = 3.62$; $df = 1,189$, $p < .10$) was that the difference between 1-D and 2- or 3-D was different for the two best matrix conditions (I, II) than for the two worst (III, IV) corresponding roughly to a difference in the slopes of the two upper as compared to the two lower curves in Figure 10. The result, if replicable, is noteworthy in that the 3-D redundancy effects are greater in the better conditions (where ceiling effects might be expected to cause a smaller increase) than in the poorer ones. This is another result which should be followed up with more research.

ERIC

Figure 10

The effects of dimensionality on transmitted information, as a function of matrix condition.

Fig. 4



Matrix Conditions
Simultaneous
Matrix Last
Matrix 1st
No Matrix
T
(bits)
3.5
3.25
3.0
2.75
2.5
1-D
2-D
DIMENSIONS

Experiment 5

Comparisons of identification, discrimination and type of dimensional combination with retarded children

In this study we extended the ideas developed in earlier studies about the identification-discrimination continuum and the effects of combinin perceptual dimensions to a retardate population. The chief aims of the study :

1) Determine the channel capacity of our retardate group for stimuli encoded in one-dimensionally varying sets and in various two-dimensional sets. We hoped that improved equipment and techniques would yield higher and more stable information transmission rates than we had been able to achieve in our earlier studies.

2) Obtain basic parametric data relating to the discriminative and identification capacities of our population. Our earlier analysis had pointed to the delay, d, between the offset of a stimulus and the onset of the response matrix set as a crucial parameter; with $d \geq 0$ defining the condition identification and $d < 0$ (implying some overlap of stimulus and response matrix on-time) defining discrimination. These two conditions were the first of the major variables in the study.

3) Verify the 1-D, 2-D effects, expecting that multidimensional variation makes for more distinctive stimuli. To this end we included two 1-D sets, one for color, the other for size

4) Discover the effects of varying the two-dimensional information redundantly and non-redundantly. Two redundant sets and one non-redundant (orthogonal) set were used.

5) Compare the two most extreme forms of redundant 2-D encoding (linearly correlated and "sawtooth" sets)

6) In a less formal way, try to develop an effective shaping procedure to bring the S population to the point where their performance could reasonably be interpreted as reflecting their perceptual capacities and not any of a myriad of extraneous factors.

METHOD

Subjects

There were 5 independent groups of 5 Ss each, 25 Ss in all, drawn from the population of the Mansfield Training School. Ss were undifferentiated diagnostically but showed no evidence of gross sensory or motor impairment. MA levels were balanced across groups within the range of six to eight years. All the children had previously served as subjects in discrimination learning experiments and all attended classes at the Longley public school.

Procedure

Apparatus. The matrix board described in experiment two was used such that the stimulus matrix was presented in a circle with the target stimulus presented in the center of the circle.

Stimuli consisted of circles of various diameters and colors depending upon the condition. There were a total of 5 conditions, 2 uni-dimensional conditions; (size, color), and 3 bi-dimensional conditions; (diagonal, orthogonal, sawtooth).

Each subject was presented a stimulus while the matrix was covered by a sliding door and then presented with a matrix of 2, 3, 5, 7, or 9 alternatives, one of which exactly matched the target stimulus. The S's task was to point to the stimulus in the matrix which exactly matched the target stimulus: in this way, no verbal communication was necessary on the part of the S.

Design. A between subject design was used, where each S was run in only one stimulus condition in a series of 3, 4, or 5 experimental sessions, depending upon the performance of each S in each condition. Two temporal conditions were also employed, a "discrimination" condition (in which S was shown the target stimulus immediately followed by the stimulus matrix in time and both were shown simultaneously until S made a response or 5 sec. had elapsed); and the "identification" condition (in which S was shown the FS for 3 sec. at the end of which the TS was taken away, after which the stimulus matrix was shown immediately (zero-second delay): S then had 5 sec. in which to respond. Reinforcement was administered verbally and in the form of M & M candies which were administered periodically, and with the choice of a toy which was administered at the end of each experimental session. All Ss were first presented with the smallest stimulus matrix with the discrimination condition presented first, followed by the identification condition before moving on to a larger stimulus matrix in ascending order.

Order of presentation

$\longrightarrow$

No. of alts in stimulus matrix	2	2	3	3	5	5	7	7	9	9
temporal sondition	D	I	D	I	D	I	D	I	D	I

Stimulus Conditions. Stimulus sets were made up with ordered values on the two dimensions: A_1, A_2, ... A_9; B_1, B_2, ... B_9 determined by a preliminary pilot study.

The full (n = 9) orthogonal bidimensional set was taken as the numbered values below. In the orthogonal condition with n = 3, 5, 7 the values were taken in the order indicated. Note that the subsets of size < 9 are not themselves arranged as orthogonal combinations.

	B1	B2	B3	B4	B5	B6	B7	B8	B9
A1	1				6				3
A2									
A3									
A4									
A5	9				5				7
A6									
A7									
A8									
A9	4				8				2

The linear correlated sets were obtained according to the following schedule

1								
	7							
		5						
			8					
				3				
					9			
						4		
							6	
								2

and the sawtooth as follows

	B1	B2	B3	B4	B5	B6	B7	B8	B9
A1							2		
A2				8					
A3	4								
A4								9	
A5					5				
A6		7							
A7									3
A8						6			
A9			1						

RESULTS AND DISCUSSION

A transmitted information measure (T) was calculated for each S in each condition. The mean T over Ss for each group by process (Discrimination vs. Identification) as a function of Stimulus Information (the "channel capacity" curve) are plotted in Figures 11-15. The dotted line (slope of 1.0) represents the upper limit or perfect transmission.

A most impressive feature of the whole set of data is that relating to points 1) and 6) in the introduction. As compared for example to the same kinds of functions calculated on a comparable subject population with comparable stimulus dimension, performance in the present experiment is much better (more information transmitted) and more reliable, almost to the point where the upper limit was being approached. Over all it is clear that the first question, is the shaping procedure adequate, can be answered affirmatively. Certain Ss in certain conditions from time to time showed lapses of attention and susceptibility to distraction from extra-experimental sources, but these were considered minor and

Figure 11

Discrimination and identification channel capacity function for the color dimension.

1-Dimension – Color

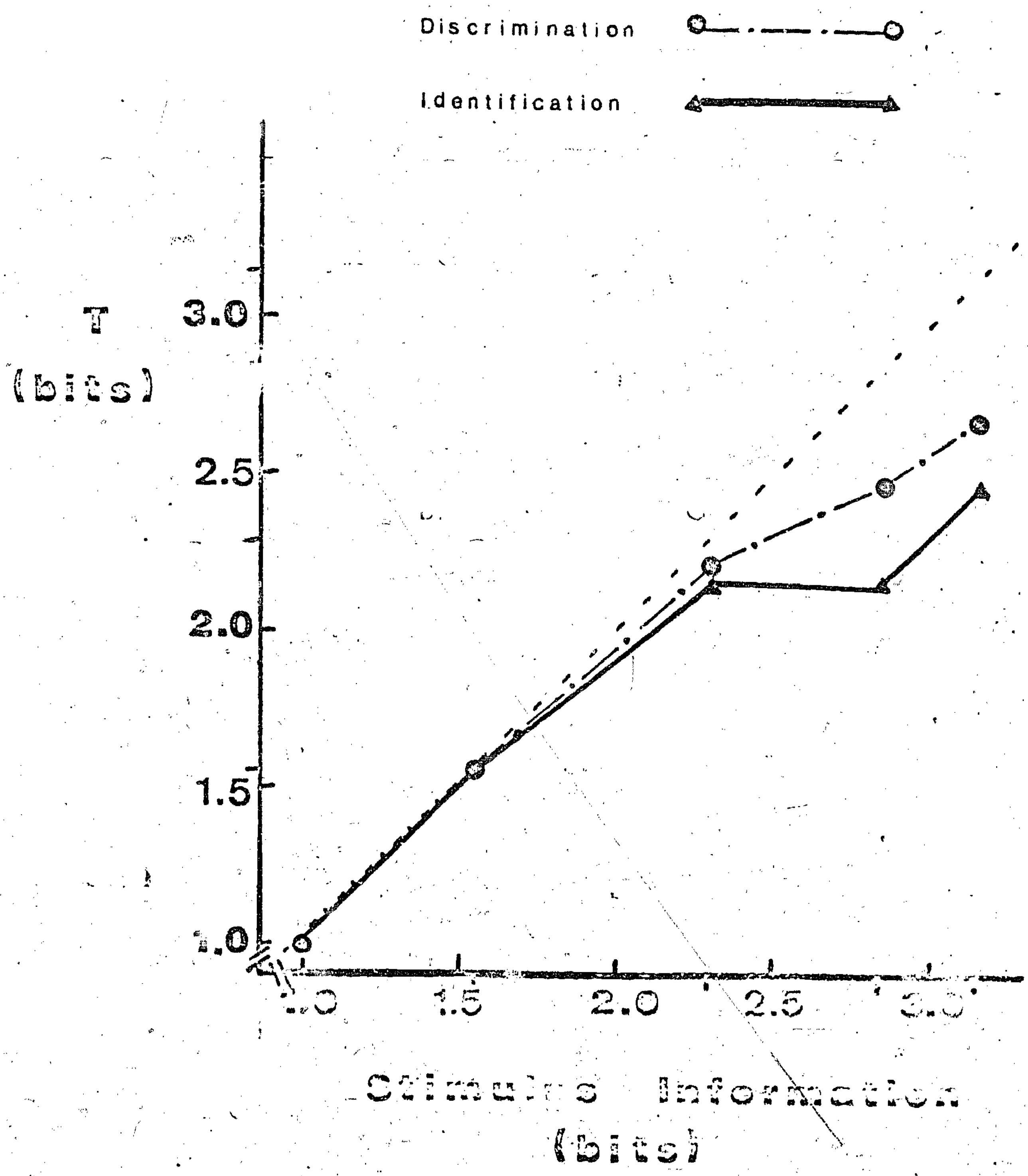


Figure 12

Discrimination and identification channel capacity functions for the size dimension.

1-Dimension - Size

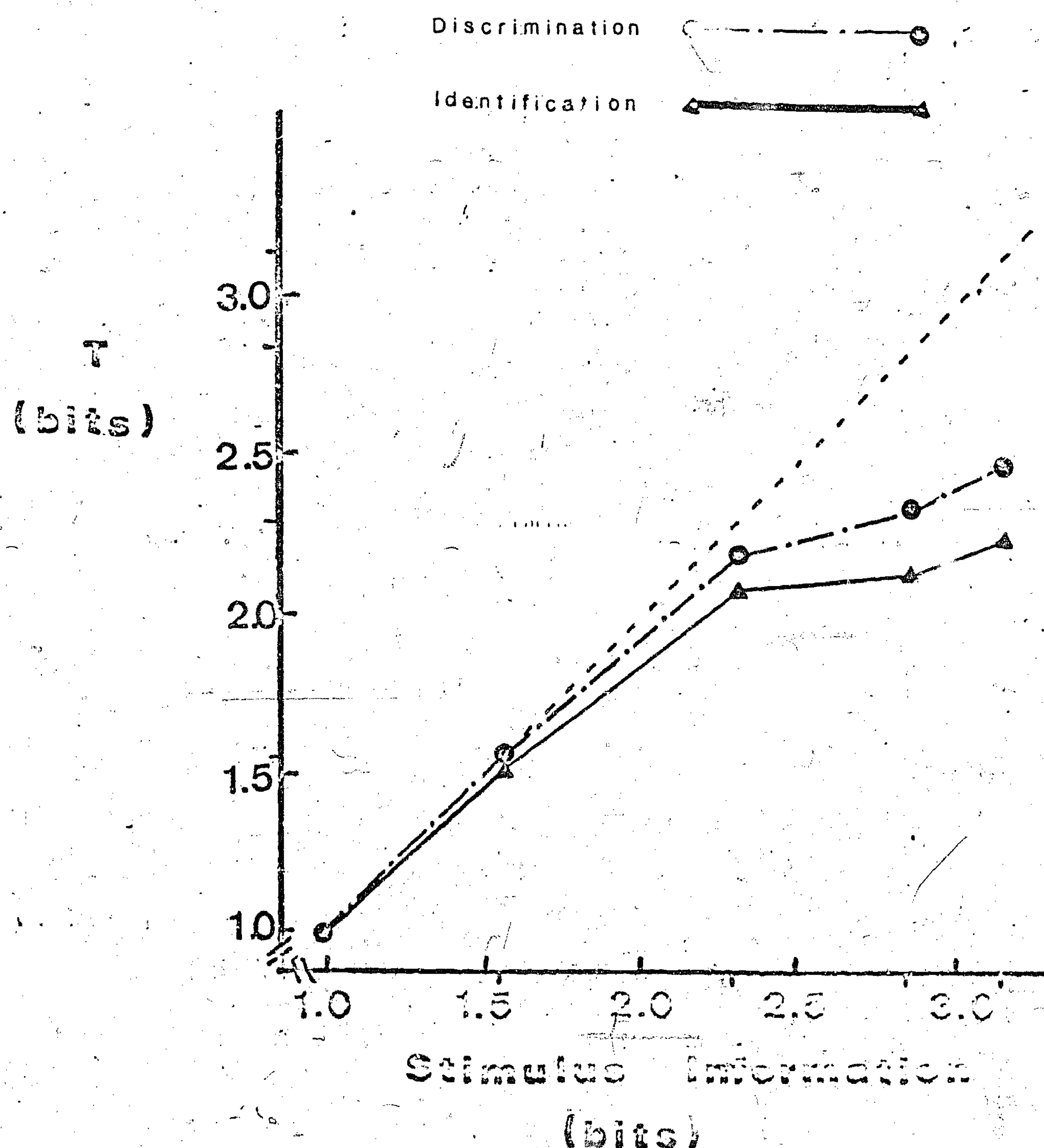


Figure 13

Discrimination and identification channel capacity functions for the orthogonal bidimensional combination.

2-Dimensions — Orthogonal

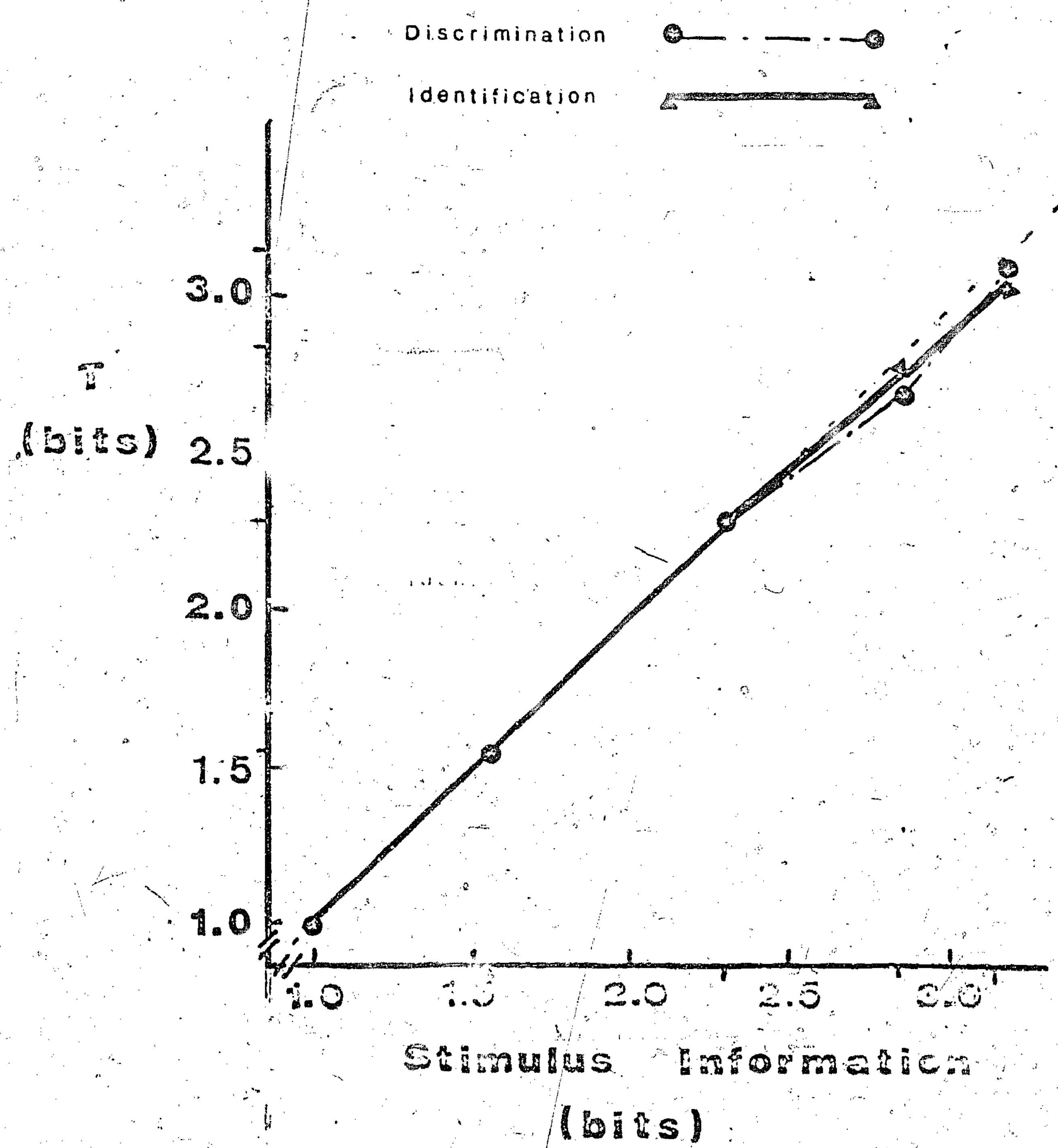


Figure 14

Discrimination and identification channel capacity functions for the diagonal bidimensional combination.

ERIC

2-Dimensions – Diagonal

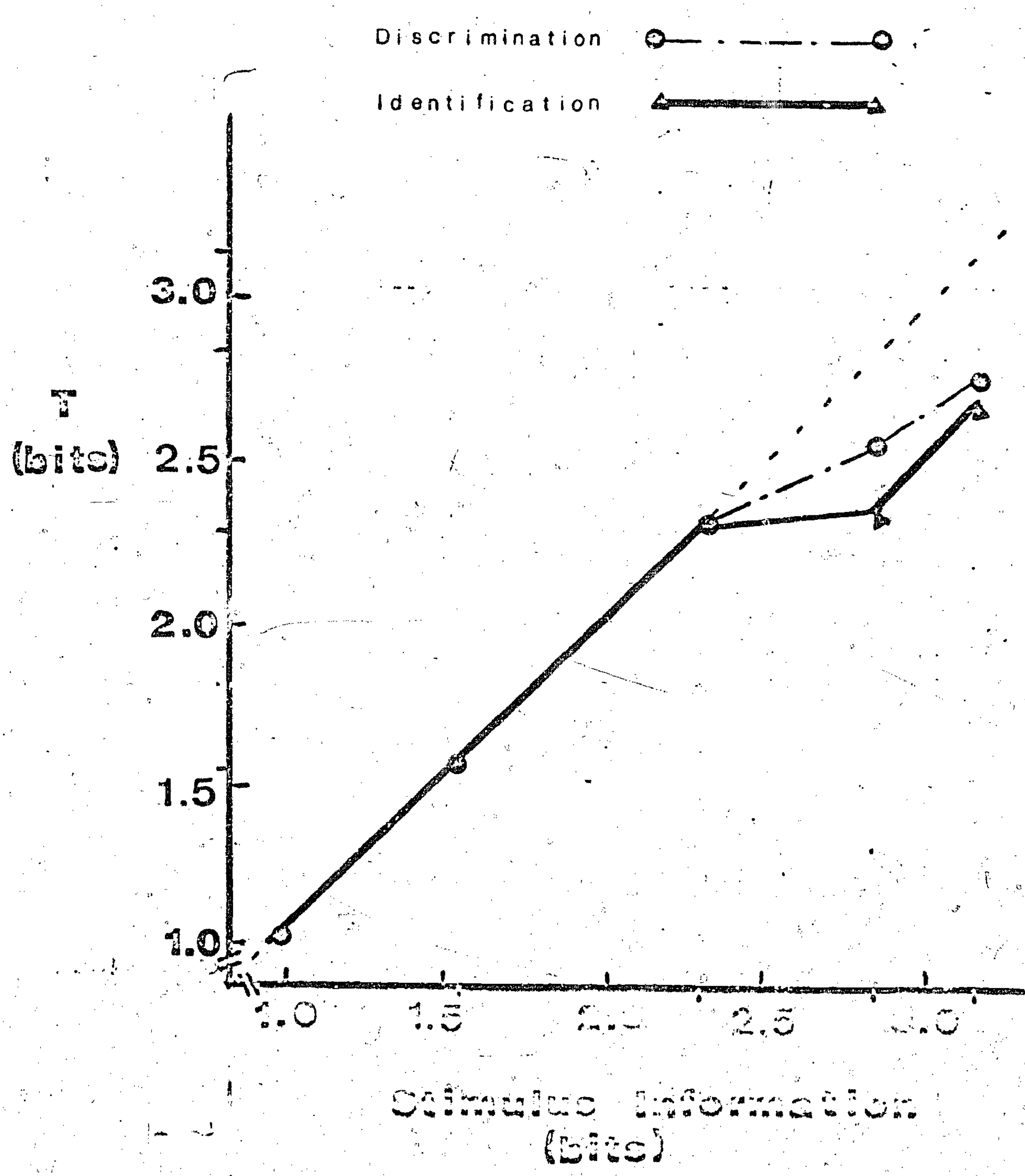
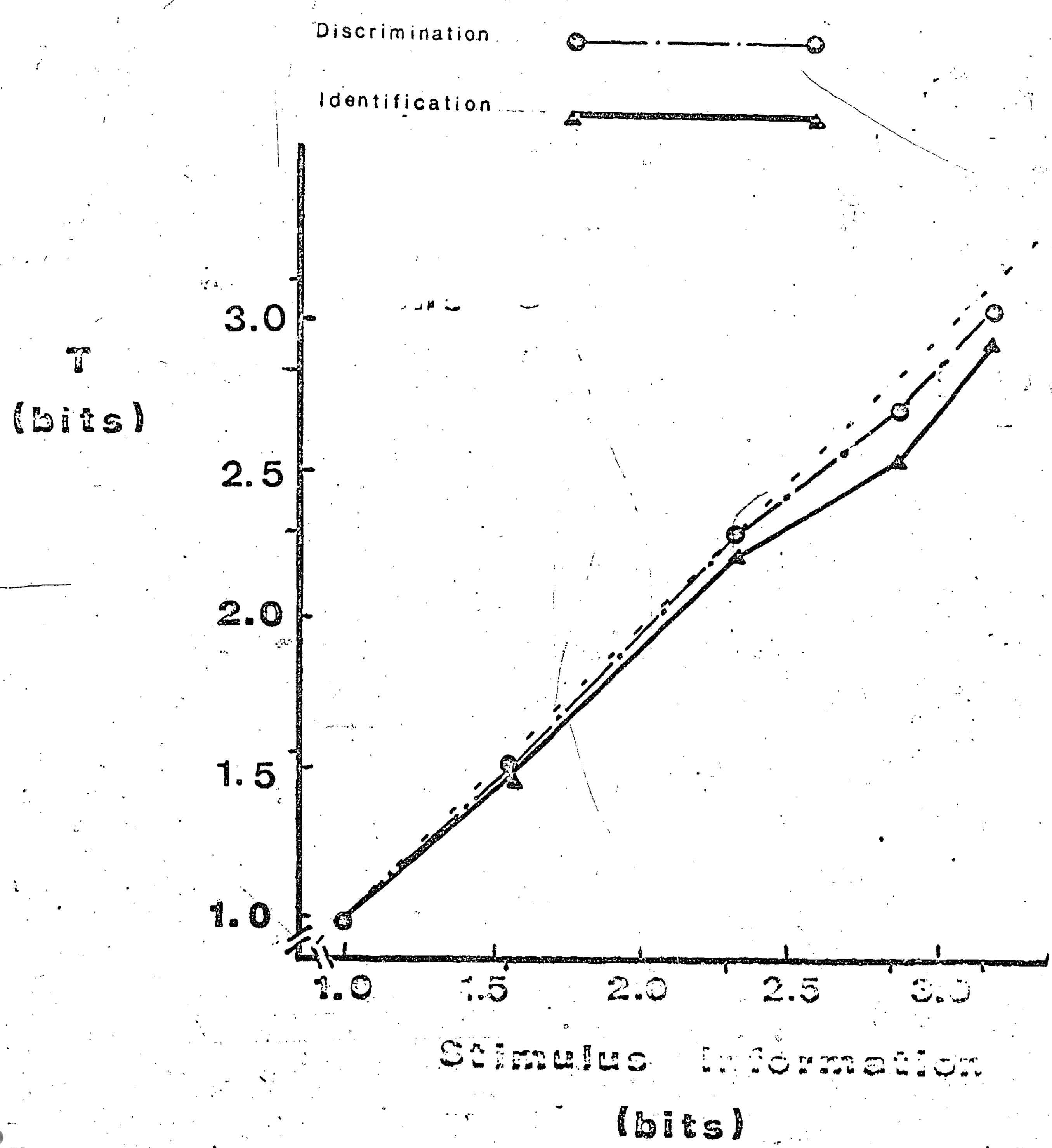


Figure 13

Discrimination and identification channel capacity functions for the sawtooth bidimensional combination.

2-Dimensions – Sawtooth



irreducable errors. The results were better than we had hoped or anticipated; performance was so generally good in some conditions that the information capacity was not approached. For this reason the results of the present experiment cannot be considered a completely adequate description of the transmission (identification and discrimination) capacities of these Ss with these stimulus sets, the errors being in the direction of underestimation with the more distinctive sets.

2. The procedure distinguishing identification from discrimination was, in spite of the general high level of performance, extremely effective. The differences were, in all dimension conditions but the 2-D orthogonal (which was close to perfect under both procedures) consistently if only slightly in favor of the discrimination. That the separation of the two functions is not greater may be attributed to at least two possibilities.

a) The identification function, which "should" be at asymptote at n = 9, assuming the dimensions to be simple (with the 1-D sets) or near the upper limit for these Ss with the 2-D set, appears in all cases to be still rising. Our Ss, in every condition, are operating at below their capacities (on the average). This is due to the unexpectedly powerful success of our training procedures, and the use of the dimensions of size and color which are not as simple as others.

b) Just as we are measuring a better than minimum identification capacity with our procedures, the discrimination function tends to be lower than maximum, because of the limitation on scan time (5 sec.) and the spatial separation of test and comparison stimulus cards. With "better" discrimination operations, the transmission curves would likely continue upward more sharply than in the present case. It is, however, a possibility and in important one, that the leveling of the discrimination functions represents a real difference in processing capacities between retardate and normal control populations. This must be explored in further comparative studies.

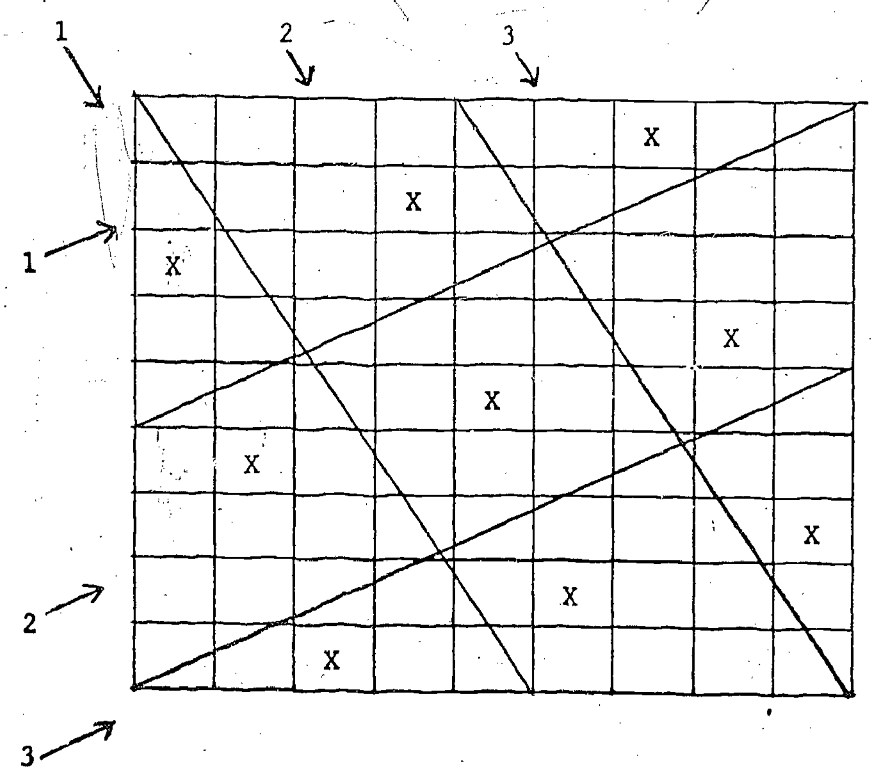
3. There is a very clear effect of increased dimensional variation in raising information capacity, even against the high levels of performance in the 1-D condition. This is a verification of all our previous findings.

4. The effects of dimensionality were analyzed in this experiment for the first time into redundant and non-redundant components. Although much of the speculation and theorizing about dimensional effects has been based on the assumption that redundancy is necessary, the present results are overwhelming in showing that non-redundant 2-D information is even more effective. Redundancy as such is perhaps of minimal importance. The most obvious interpretation suggested by these clear results is that the dimensional effect reflects both the number of alternatives to be resolved <u>and</u> the number of resolution categories on each of the component dimensions. (Another factor, logically, is the degree to which the component dimensions can be separated perceptually, i.e., dimensional independence.) In the orthogonal set, although no information is redundant, a correct identification can be made by resolving the test stimulus into one of only three classes on each dimension, whereas with the redundant sets all nine values on each appear. This result is certainly the one of most import in this experiment and demands much further experimental investigation.

5. The effects of different redundancy codes is also of some theoretical importance, both to the general perceptual problem and to the nature of the retardate condition. Again generalizations are limited by the fact that <u>S</u>s are not pushing at their processing limits, but there is no doubt that in the range of values studies the linear correlation set, the one most commonly used in studying redundancy, is poorer than the

ERIC

"sawtooth." An explanation of this is difficult to come by from the present data (and from previous studies), because there is no clear way to generate 2-D sets which do not confound a number of parameters. One possibility, suggested by Lockhead (1966), who found a clear superiority for the sawtooth over the diagonal set, is that the average distance of stimuli in a 2-dimensional psychological space is maximized in the sawtooth redundant and minimized in the linear redundant set. Another possibility is that the sawtooth set like the orthogonal set divides the stimuli into 3 levels of judgment for each dimension. Further clarification must come from additional research.



SECTION III

CODING IN SHORT TERM MEMORY

ERIC

Experiment 6

Coding effects in short-term memory

George Miller (1956) pointed out that the capacity of short term memory was limited and that this limitation was of the nature of about seven units. We use the vague term "units" because some doubt about the precise nature of the limitation still exists. Miller felt that the units in question were what he termed "chunks", organized clusters of material which could vary in information content. Later, others (Hyman & Kaufman, 1966) suggested that the short term memory limitation is in terms of information rather than chunks and that very short term memory may not involve explicit chunking at all, because chunking takes time (Lamb & Kaufman, 1966). In a more recent attempt to resolve the problem Kleinberg and Kaufman (1971) have suggested that while chunking takes time, given that necessary critical amount of time, memory <u>is</u> constant for chunks. If, however, there is not time enough for chunking then memory is constant for information. To support their contention Kleinberg and Kaufman demonstrated that at very short tachistiscopic exposure times subjects who had learned to code or chunk stimulus information did no better in recall than did subjects who had not learned to code. However, at longer exposure times the difference between coding and the non-coding groups was large.

While the hypothesis that coding takes time and is not very effective at short exposure times has received support from sources other than the Kleinberg and Kaufman study (see Ganzer & Fleischman, 1967) a problem exists. It is clear that some kinds of coding must occur at very short exposure times if we are to differentially perceive certain organized stimuli as opposed to less organized stimuli. For example, it has been demonstrated that whole words are as accurately recognized as isolated letters (Reicher, 1969; Wheeler, 1970), at short exposure times. Some kind of "word organization" must be responsible for this recognition ability. The question of whether this organization into words or chunking also works to increase the limits of short term memory is not answered by the recognition studies which characteristically use only one item. The three studies of this section all speak to the question of coding in short term memory and how it influences capacity at short and longer exposure times. The first experiment deals with stimulus materials which do not include words and for which a code must be learned in the experimental situation. The next two experiments do deal with "naturally" coded word-like items as well as non-words.

The questions asked in this experiment are the following:

(1) Does the relation of performance under explicit coding or chunking conditions to performance under non-code conditions remain the same at varying levels of short exposure time

(2) Can explicit chunking be effectively turned on and off by practiced subjects.

METHOD

Subjects

Four adult subjects, including the co-principal investigators, one graduate student and one undergraduate, serves as experimental subjects.

Apparatus and Stimulus Materials

Stimuli were presented on a two field Harvard tachistiscope, with a mechanical timer with a range from one second to 1/100 of a second.

The stimuli consisted of all possible combinations of the letter "S" and "Z" in nine unit horizontal arrays of three groups of three letters each. The letters were typed in large black block print on rectangular slips of white paper which was then centered on while 8-1/2" x 11" card. All possible combinations of S and Z in three trigram groups were constructed making for a total of 512 cards.

Procedure and Experimental Design

Each subject served in all experimental conditions. A sequence of three coding conditions, no code, code, and code off were run and within each condition, eight presentation times (800, 500, 300, 200, 100, 50, 25 and 10 milliseconds) were used. Ten daily sessions of approximately 30 minutes per session were required per subject, with the first four sessions being non code, the second four code and the last two code off sessions.

In the non code session S was seated in front of the tachistiscope, told how to use the machine to initiate each trial, given a few practice trials and told to start each trial at his convenience and immediately record what he had seen on a lined pad appropriately numbered for the trials within that daily session. Sixteen trials at each of the eight exposure times made up a daily session. Four such sessions were run and the 512 stimulus cards employed in a random fashion with the restriction that the number of trigrams consisting of only one letter was equal at each presentation time. This precautionary measure was taken to prevent any advantage due to implicit or perceptual grouping accruing to particular exposure times.

Following the non-code session, each S was given an octal code for the eight combinations of S and Z in trigram forms. He was permitted to practice this code in any way he saw fit until he had thoroughly learned it. After a few days he was then returned to the tachistiscope and once again run through four, self-paced, daily sessions identical to the non-code sessions except that his response was the code designation for each trigram rather than the letters themselves.

After the code conditions, two more daily sessions were run. Again these were identical to those run in the other two conditions, but S was instructed to ignore the code he had learned and record the trigram in letter as he had done in the earlier non code condition. Only two sessions were run and hence only half of the 512 cards were utilized, but as was the case in both earlier conditions the cards were completely randomized across sessions and presentation times with the restriction that some number of one letter trigrams appeared at each presentation time.

RESULTS AND DISCUSSION

One of the assumptions of this study was that because of the nature of the task and the number of sessions and memory trials within a session practice effects would be minimal. It was for this reason that the code and non code conditions were confounded with experimental sessions. However, inspection of figure 16 reveals that this assumption was unwarranted. It is clear that practice effects occurred over all ten sessions. It also appears to be the case that while coding may have depressed performance when it was first initiated, this depression was more than compensated for by increased practice. The confounding of practice effects and coding effects make interpretation of our data somewhat difficult. The problems are illustrated by Figure 17.

At the top of the figure we have presented hypothetical performance curves for our longest (800 msec) and our briefest (10 msec) presentation times. After a brief initial practice or warmup effect the non code performance might be expected to stabilize at both presentation times, with

Figure 16

Practice effects in all experimental conditions.

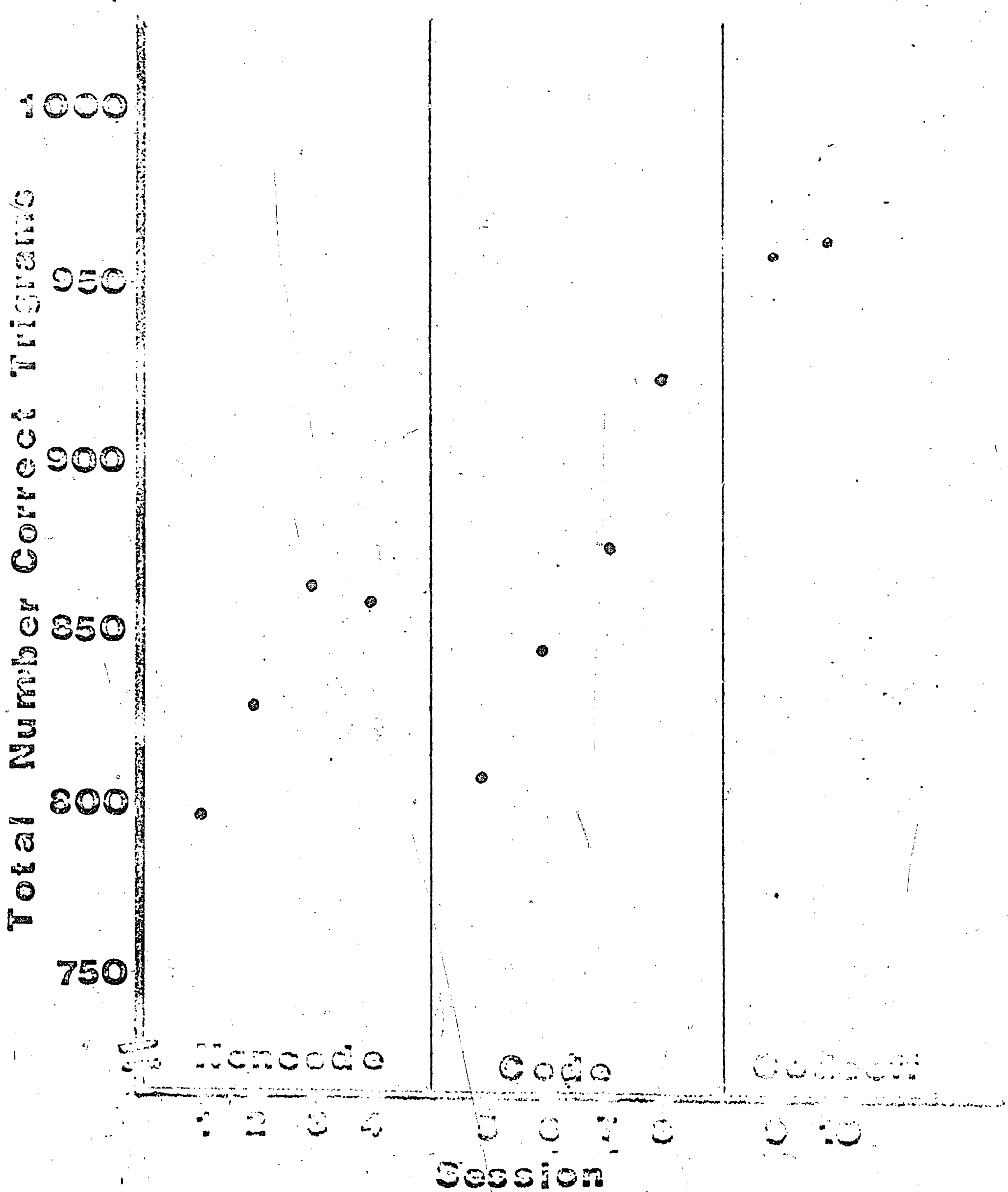
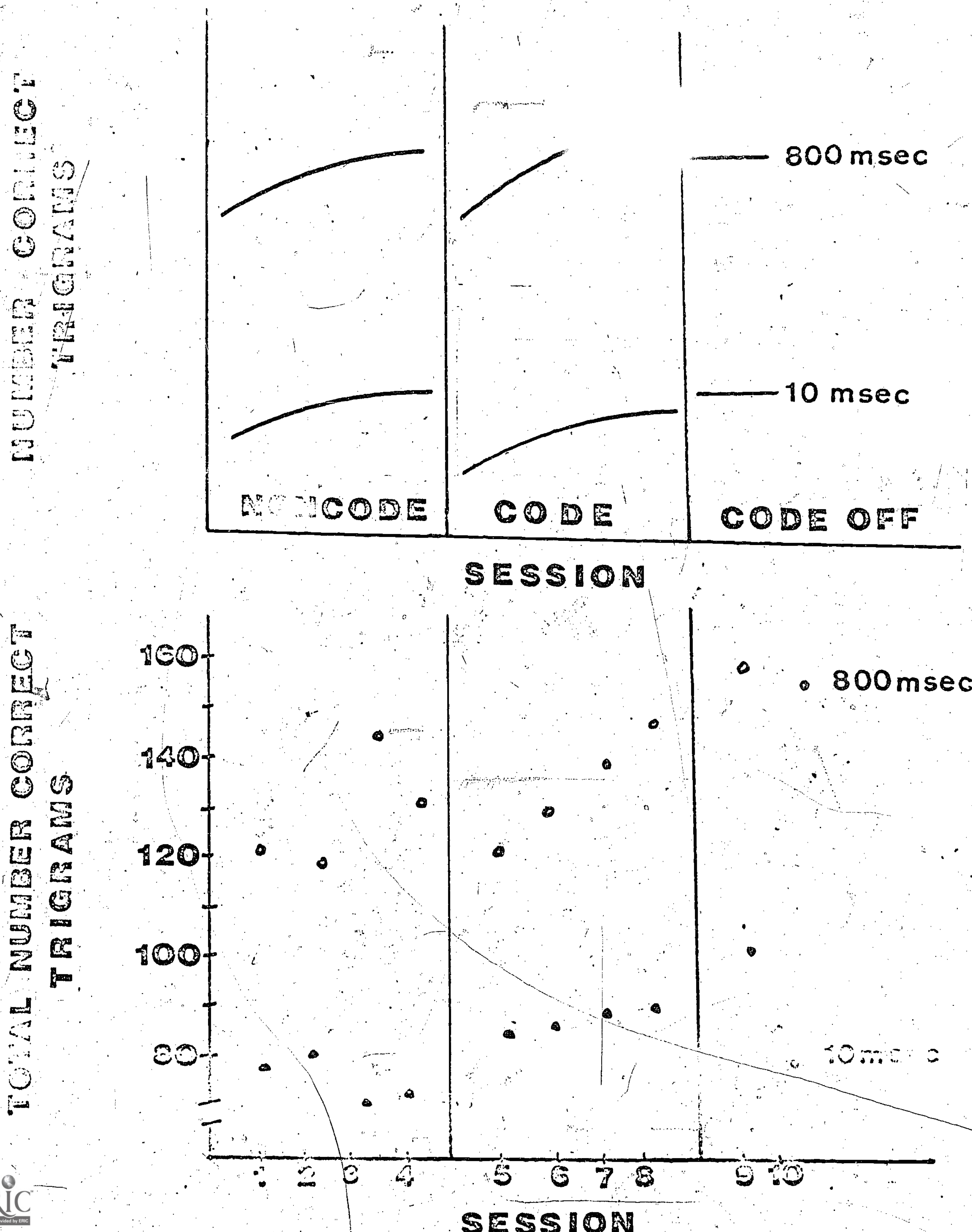

Total Number Correct Trigrams
1000
950
900
850
800
750
Code
Session

Figure 17

Theoretical and empirical effects of coding and non-coding at the shortest and longest exposure times.

ERIC



NUMBER CORRECT TRIGRAMS
800 msec
10 msec
NO CODE
CODE
CODE OFF
SESSION
TOTAL NUMBER CORRECT TRIGRAMS
160
140
120
100
80
800msec
1
2
3
4
5
6
7
8
9
10
SESSION

a lower performance level at 10 msec. of course. Code performance is what might be expected to interact with the two presentation times as the figure indicates. At the longer exposure time code performance should, after an initial warmup rise above the asymptotic level of non-code performance, because as we indicated earlier when there is time available for coding it should provide an advantage. At the short exposure time, however, there is no time for explicit coding and hence code performance remains at best at asymptotic level of non-code performance. In the hypothetical level we have even provided the coded performance at 10 msec. with a lower level than non-code performance, because Kleinberg and Kaufman (1971) found that not only was coding not effective at brief presentation times, but it actually depressed performance relative to a noncode group.

An inspection of our obtained data in the lower part of the figure illustrates the problem of confounded practice effects. With the exception of the 10th session in the 10 msec. group, the performance in the code off condition is better than the performance in the preceding code or non-code condition. There is also a general trend of improvement in all sessions for all presentation times as illustrated in Figure 16. Because of this we can not say that the superior performance under code condition at 10 msec. represents unexpected coding effects at short presentation times since practice may be as likely an alternative hypothesis. It is quite clear that code performance is not at all lowered with respect to the preceding non-code condition. The code performance at the 800 msec. presentation time does not show a marked improvement over the non code performance and is lower than performance under code off conditions because of the practice effect.

While the data of this experiment did not provide unequivocal answers

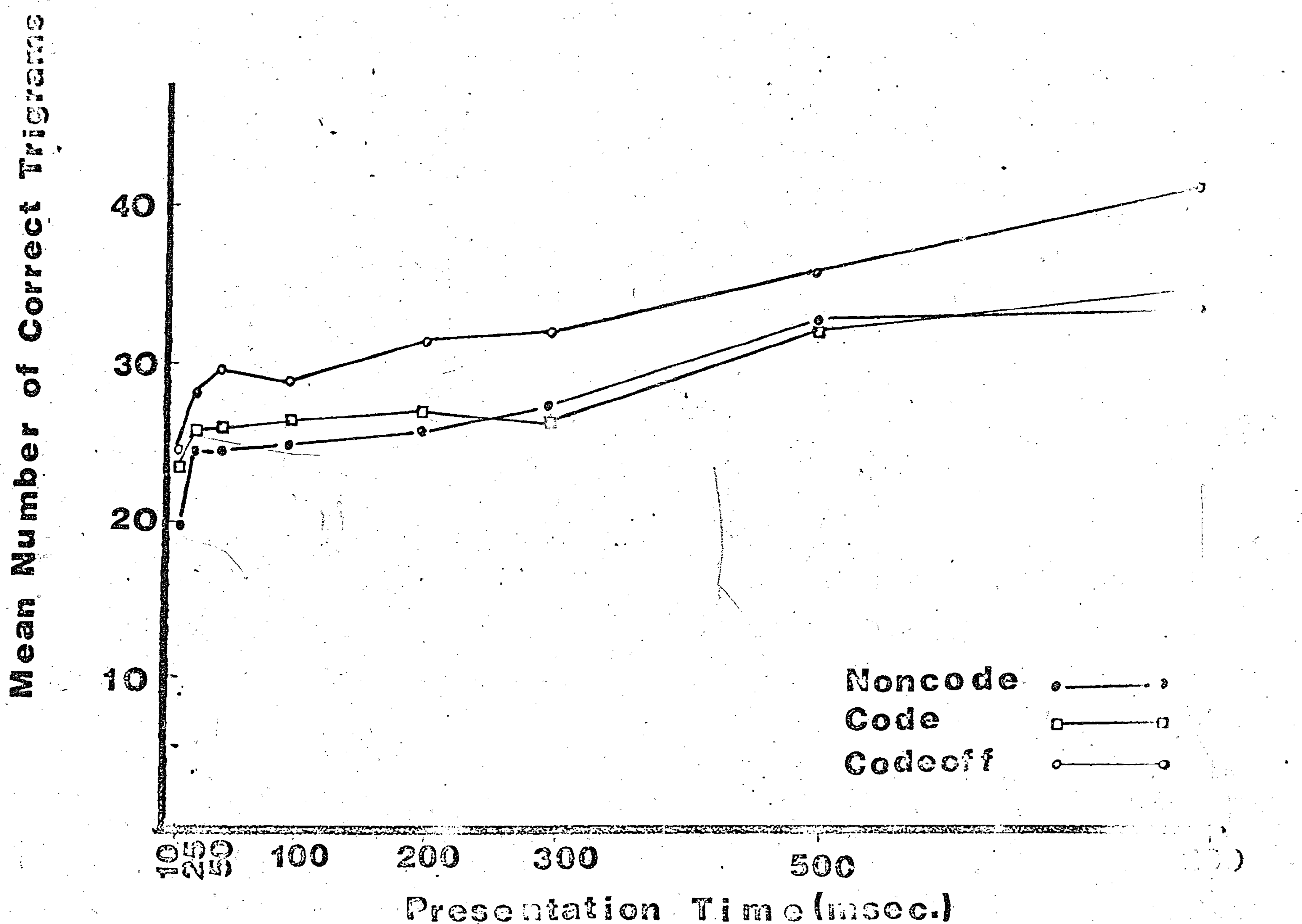
ERIC

to the question of coding at brief presentation times, they did provide some valuable information about presentation time effects per se. The very regular presentation time data illustrated in Figure 18 enabled us to choose a range of exposure times for the two following experiments which make the comparisons under [illegible]ation more meaningful.

With respect to the two ma[illegible]tions originally posed for this experiment, is there a difference in code and non-code performance at different exposure times, and can coding be turned on and off by the subject, the answers are unclear. The code-non-code differences found under different exposure times were not in the hypothesized direction and were clearly affected by practice. Practice contamination also obscured the question of manipulation of coding by instruction. However, both these questions are further investigated in the following two experiments.

Figure 18

Presentation time effects.



Mean Number of Correct Trigrams
40
30
20
10
10
25
50
100
200
300
500
Presentation Time (msec.)
Noncode
Code
Codeoff

Experiment 7

Short-term memory capacity for words and non-words

Although the outcome of experiment six was somewhat ambiguous, its data and those of other studies (Glanzer & Fle·schman, 1967; Hyman & Kaufman, 1966; Kleinberg & Kaufman, 1971) point to the fact that explicit coding does not increase memory capacity at short exposure times. However, as we have pointed out previously, it is very clear that some kinds of coding do affect perceptual processes like recognition. The fact that words are recognized as accurately as isolated letters (Reicher, 1969; Wheeler, 1970) attests to this fact. If a word is recognized more easily than an equivalent sized series of non-word letters it is because this word is coded into a single unit as opposed to the isolated units of the non-word. While this coding may be a function of many things, familiarity or practice, meaningfulness, pronounciability, phonemic quality, etc., the fact that it operates at short exposure times is what interests us. It seems to have been assumed that since recognition for words is clearly superior to non-word recognition, that memory capacity for words should exceed that for non-words when stimulus material is presented tachistiscopically. There is little empirical evidence to support that apparently reasonable conclusion, and if it is the case that coding takes time perhaps such short-term memory capacity difference may not exist. For a single word there may be enough time in a brief exposure to extract the code and hence recognize it, but is there enough time for coding when heavier demands are put upon the subject? This experiment explores the relation between presentation time and the word like characteristics of stimulus material in their effect upon memory capacity rather than recognition. Four levels of word quality are combined with four presentation times chosen as representative on the basis of the results of experiment six.

METHOD

Subjects

Five undergraduate students were paid at the rate of two dollars an hour to participate in the experiment.

Apparatus

Stimuli were presented on a two channel Scientific Prototype tachistiscope, with a pre and post field mask consisting of a solid black rectangle covering the area in which the stimulus letters appeared.

Stimuli

The stimuli consisted of three trigrams typed in black letters and centered on a 3" x 5" white card. Each trigram was constructed from a pool of letters consisting of the eight consonants N, B, J, T, D, G, P and V and the four vowels A, U, I, and O. All possible combinations of three types of trigrams, Consonant Vowel Consonant (CVC), Vowel Consonant Consonant (VCC) and Consonant Consonant Vowel (CCV) were generated by a computer program and the required trigrams randomly selected from these. Four types of trigram groupings were used. The most word like consisted of three CVCs and was labeled the 3-0 condition. The least word like consisted of some combination of CCVs and/or VCCs and was designated the 0-3 condition. The other conditions were 2-1 (two CVCs and one non-CVC) and 1-2 (one CVC and two non-CVCs). Sixty cards of each type were randomly selected with the restriction that an equal number of VCCs and CCVs were included in all non-CVC selections.

ERIC

Experimental Design

Each S was presented all four stimulus conditions at each of five presentation times (800, 400, 100, 50 and 10 msec.). Although the trigram groups within each of the four wordlike cond[illegible] selected, careful counterbalancing of stimulus cards by presentation time and subjects was carried out to avoid problems with particular letter combinations. The counterbalancing consisted of dividing the total number of stimuli (240) into five groups of 48 each, with each group containing 12 of each stimulus type (condition). The five groups were then balanced in a Latin Square design with the five subjects and five presentation times.

Procedure

Each S was run for two daily sessions. At each session all presentations times were given in descending order from 800 to 10 msec. with six cards of each condition at each presentation time. After each daily session all the stimulus cards were shuffled normally and regrouped for the next daily session. During this regrouping some imbalance occurred in the number of stimuli of each type per each presentation time. The imbalance was minor, however, and the regularity of the data indicated that it had little effect on the operation of the independent variables.

A trial began with S fixated upon the black rectangular pre-field mask. Upon the word "ready" from E, S could activate the stimulus field by pressing a button when he felt prepared to do so. The mask returned after the designated exposure time had elapsed and S were instructed to write what he has seen on his response sheet. Instructions were given to write all the letters he had seen in their appropriate order. If S could remember a letter in a trigram but not the one preceding or following it he was instructed to indicate the omitted ones with dashes. At the beginning of his first experimental sessi S was told which consonants and vowels made up the pool from which the trigrams were drawn, and was also instructed that a single letter could appear more than once in a particular stimulus card.

Eight warm up trials at 800 msec. were given at each experimental session.

RESULTS AND DISCUSSION

The response measured was number correct letters reported. To be designated as correct each letter had to match the stimulus letter in position as well as form. Therefore, even if all nine letters of a particular stimulus card were reported, only those which occupied the identical position they had on the stimulus card would be counted as correct.

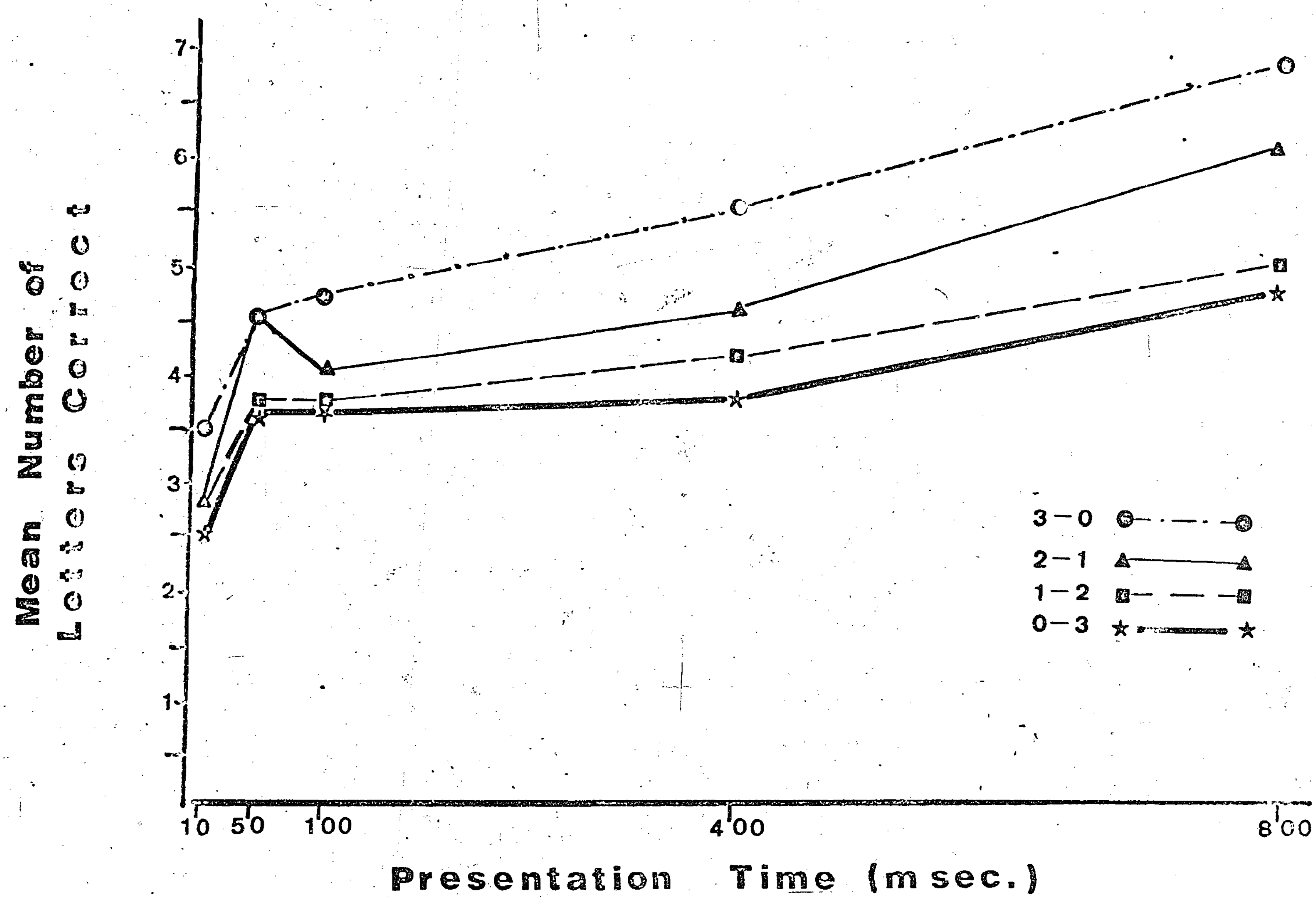
Because of the imbalance in type of stimulus card produced by the manual randomization, analysis of the data was run on mean number correct letters rather than total number correct. That this measure is a useful one is attested to by the very regular data revealed in Figure 19.

An inspection of Figure 19 reveals consistant differences among the levels of both independent variables. The more word like (and hence codeable) the stimuli the better the memory. This effect was regular at all presentation times with the 3-0 group providing the highest recall level and the 0-3 the worst. The other two groups (2-1 and 1-2) ordered themselves appropriately with respect to number of word like units. An overall test for the word conditions produced a significant F of 11.49 (df = 3,76; $p < .001$). The effects of presentation found in experiment six were found here as well, with the presentation time F = 26.30; df = 4,76; $p < .001$).

Figure 19

Recall with varying presentation time

for all trigram conditions.



Mean Number of Letters Correct
7
6
5
4
3
2
1
10
50
100
400
800
Presentation Time (msec.)
3—0
2—1
1—2
0—3

In experiment five it appeared that explicit coding was not helpful over the range of presentation times studied. It is even more clear in the present study that the kind of coding which is responsible for word perception is very effective over the same range of presentation times. If it is true that the time of coding represented by learning the explicit octal code requires time to operated effectively in short term memory, it is equally true that the kind of coding involved in word perception does not require that much time to operate effectively. The question of coding and memory for words as opposed to non-words is further explored in the final experiment.

Experiment 8

The effects of coding and response mode upon short term memory for words and non-words

In experiment six we discussed the possible effects of coding upon performance in short term memory tasks. We cited the hypothesis of Kleinberg and Kaufman (1971) which stated that since coding was a time consuming process it would prove ineffective at very brief presentation times but quite effective at longer presentation times. The absence of any difference between our code and non-code groups in experiment six spoke toward the accuracy of that hypothesis, despite problems of interpretation produced by a large practice effect. However, experiment seven demonstrated quite convincingly that some kind of coding was effective at brief presentation times. Consonant vowel consonant trigrams were remembered much better than were CCVs or VCCs even at the very shortest presentation time. Clearly the difference between the word code and the octal code of experiment six must be a crucial one. As we suggested many dimensions of difference may be considered. The familiarity or amount of practice associated with each type of coding is one such factor. Although we attempted in experiment six to give extended practice with the octal code, the total amount falls far short of the number of times the normal adult has said "cat" upon seeing "CAT." Another possible difference lies in the meaningfulness of the symbols. The number of associations to "CAT" is probably far more extensive and those associations more organized than those we get when we code "SSS" as "zero." In addition to these differences, the pronouncibility of words as opposed to non-words is a possible factor affecting coding effectiveness. While these factors are in and of themselves interesting there is another tack which may be taken in an attempt to understand the effects of coding in short term memory. If we accept the superiority of the word code to the explicit octal code, we might ask how the word code operates? Does it make the input of information into the memory system easier? Does it facilitate output or retrieval from the memory system? Is it at all manipuable via experimental instruction? It is to these questions that the present experiment is addressed. We also have attempted to replicate the superiority of words to non-words found over the presentation times of experiment seven and have further extended the presentation time range to six seconds. The rationale for this rather long presentation time lay in the evidence provided by Kleinberg and Kaufman that explicit coding of the sort we used in experiment six is effective at this presentation time. We know that word coding is effective at short times, if it has relatively greater effectiveness at this longer time its similarity to the explicit code in at least one empirical sense is demonstrated.

In order to discover whether word coding operates at the input or output level we instructed subjects to remember and/or report stimulus material in either syllable or letter form. Stimulus material consisted of word like CVCs or non-word like VCVs and CCVs. All reasonable combinations of syllable or letter coding (remembering) and syllable or letter reporting were investigated. In addition another aspect of response mode was investigated, whether or not the report was made orally or in a written manner. The possibility that the necessity for producing a letter by letter response when writing may attenuate word versus non-word differences led us to include this manipulation.

METHOD

Subjects

Thirty subjects enrolled in a freshman psychology course participated in this experiment in partial fulfillment of the course requirement.

Materials

The stimuli were generated by a computer program which selected letters from a pool of eight consonants; B, D, G, J, N, P, T and V; and four vowels; A, E, I, and O. All trigrams, CVC and non-CVC were generated three to a row such that in any given row no two letters were repeated. In generating rows of trigrams for the non-CVC condition six types of non-CVCs were formulated: (1) CCV, CCV, CCV; (2) VCC, VCC, VCC; (3) CCV, VCC, CCV; (4) CCV, CCV, VCC; (5) VCC, VCC, CCV; (6) VCC, CCV, VCC. Forty cards each composed of nine CVCs and forty cards composed of nine non-CVCs were then constructed for use as stimuli.

All stimulus cards were constructed such that no letters were repeated in any given row and no given letter was placed adjacent to itself in any given column. Of those forty cards constructed for the non-CVC condition, 20 were selected to have a row of type 1 and 20 a row of type 2. Of the 20 cards having a row of type 1, 10 had a row of type 3 and 10 a row from type 4. The final row was selected randomly without replacement from either type 5 or type 6. This selection procedure was repeated for those 20 stimulus cards which contained a row from type 2. That is, 10 having a row from type 5 and 10 from type 6. The final row for this group of stimuli being selected from either type 3 or 4. Each card was then constructed to allow each type to appear in each row position.

ERIC

Procedure

Each of the thirty $\underline{S}$s was assigned to one of five experimental conditions differing with respect to a combination of coding and response instructions. The five conditions were: (1) Code Syllable, Oral Syllable (CS, OS); (2) Code Letter, Oral Syllable (CL, OS); (3) Code Letter, Oral Letter (CL, OL); (4) Code Syllable, Written Letter (CS, WL) and (5) Code Letter, Written Letter (CL, WL). Each subject assigned to a condition received the appropriate instructional set and was run through a series of 80 trials.

Coding instructions requested that each subject "try to remember" each trigram as either a syllable (code syllable) or as a group of three individual letters (code letter). The reporting instructions simply requested that $\underline{S}$ orally report by syllable (oral syllable) or letter by letter (oral letter) or write what he had seen, necessarily a letter (written letter) rather than a syllable condition.

The presentation of stimuli was arranged such that 10 randomly selected CVCs and 10 randomly selected non-CVCs were presented tachistoscopically at 6 sec, 800 msec, 100 msec and 10 msec in that order, accounting for all 80 stimulus cards. The sets of ten stimulus cards were also counterbalanced (e.g., AB, BA, BA, AB) the order being reversed for each subject. Following completion of the eighty trials the cards were shuffled and reorganized according to the scheme described. All oral responses were recorded on tape as well as on response sheets from which they were scored.

Experimental Design

The design of the experiment was essentially an incomplete factorial with two levels of coding and three levels of response mode. The two levels

ERIC

of coding, by syllable or by letter, were combined with the three levels of response mode, oral syllable, oral letter and written letter (the response mode possibility of written syllables made no sense). One of the six possible combinations of this 2 x 3 design, code letter, oral syllable, was omitted. We felt that while it might be reasonable to ask a subject to remember a syllable and then essentially spell it out, it would be much less reasonable to ask him to try to remember letters, not syllables, and then ask for syllables.

RESULTS

The effects of word coding on short term memory are seen in Figure 20. Here the mean number of letters recalled per stimulus card, of a word or non-word type, are shown as a function of presentation time variation. The data are very similar to those of experiment seven, revealing superiority of word like stimuli (CVCs) to non-word like stimuli (non-CVCs) at all (even the very shortest) presentation times. This effect was highly reliable ($F = 198.8$, $df = 1,175$; $p < .001$). The increasing superiority of the CVC condition as a function of increasing presentation time which appeared in experiment six but did not reach statistical significance, also appears in this experiment as shown by the strong interaction of time by word condition ($F = 73$; $df = 3,175$; $p < .001$).

The group effects which represent the effectiveness of instruction to code and/or report differently are illustrated in the bar graph of Figure 21 and are shown as a function of presentation time in Figure 22. The significance of the differences seen in these figures was tested by means of a set of orthogonal comparisons based upon the following logic:

1. If the reporting mode (output) was of import then oral conditions should differ from written conditions and so one of the comparisons was

Figure 20

Performance under CVC and non-CVC conditions at varying presentation times.

ERIC

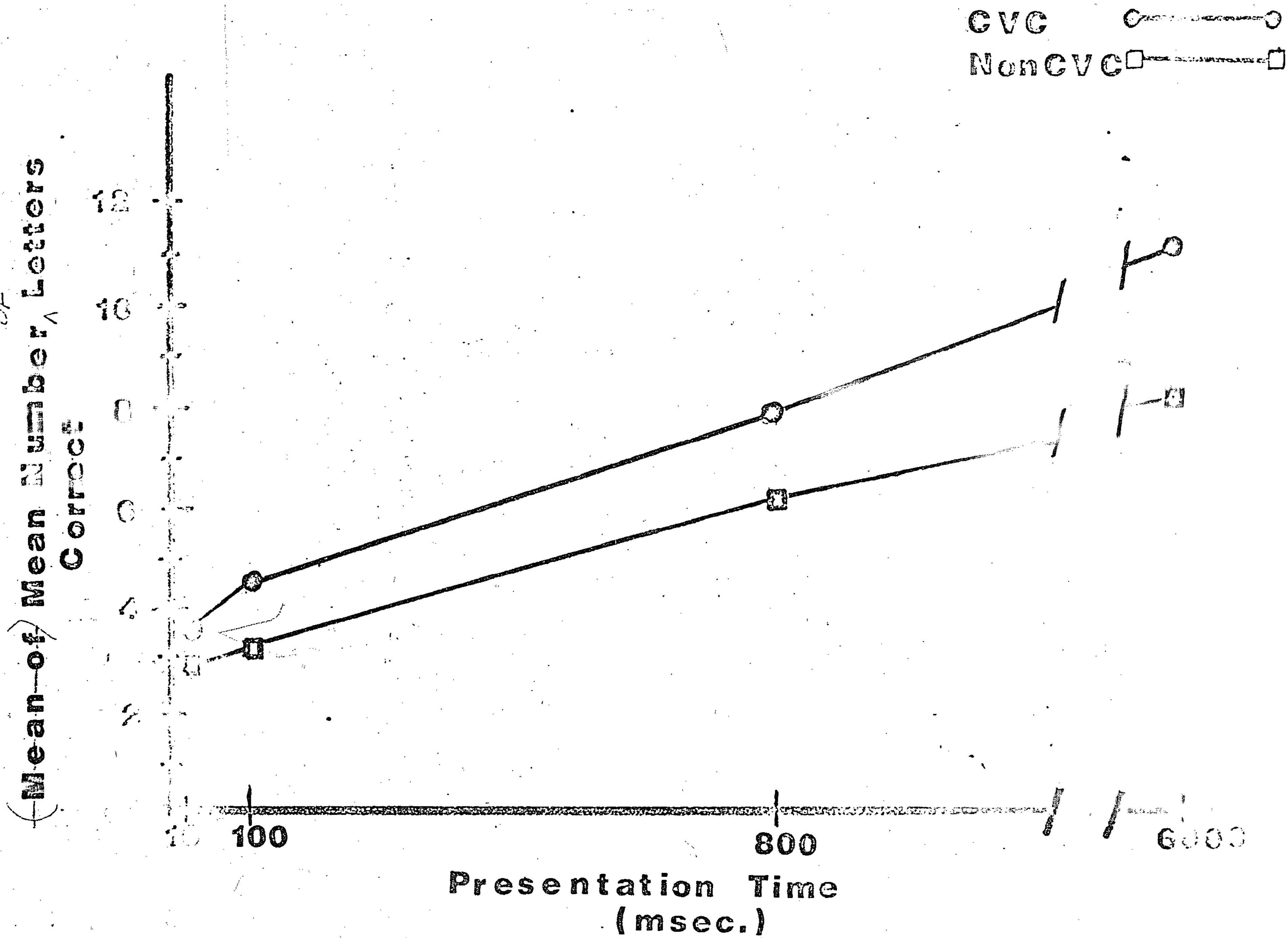

CVC
NonCVC
Mean Number Letters Correct
12
10
8
6
4
2
100
800
Presentation Time (msec.)

Figure 21

Performance under combinations of coding and report conditions.

ERIC

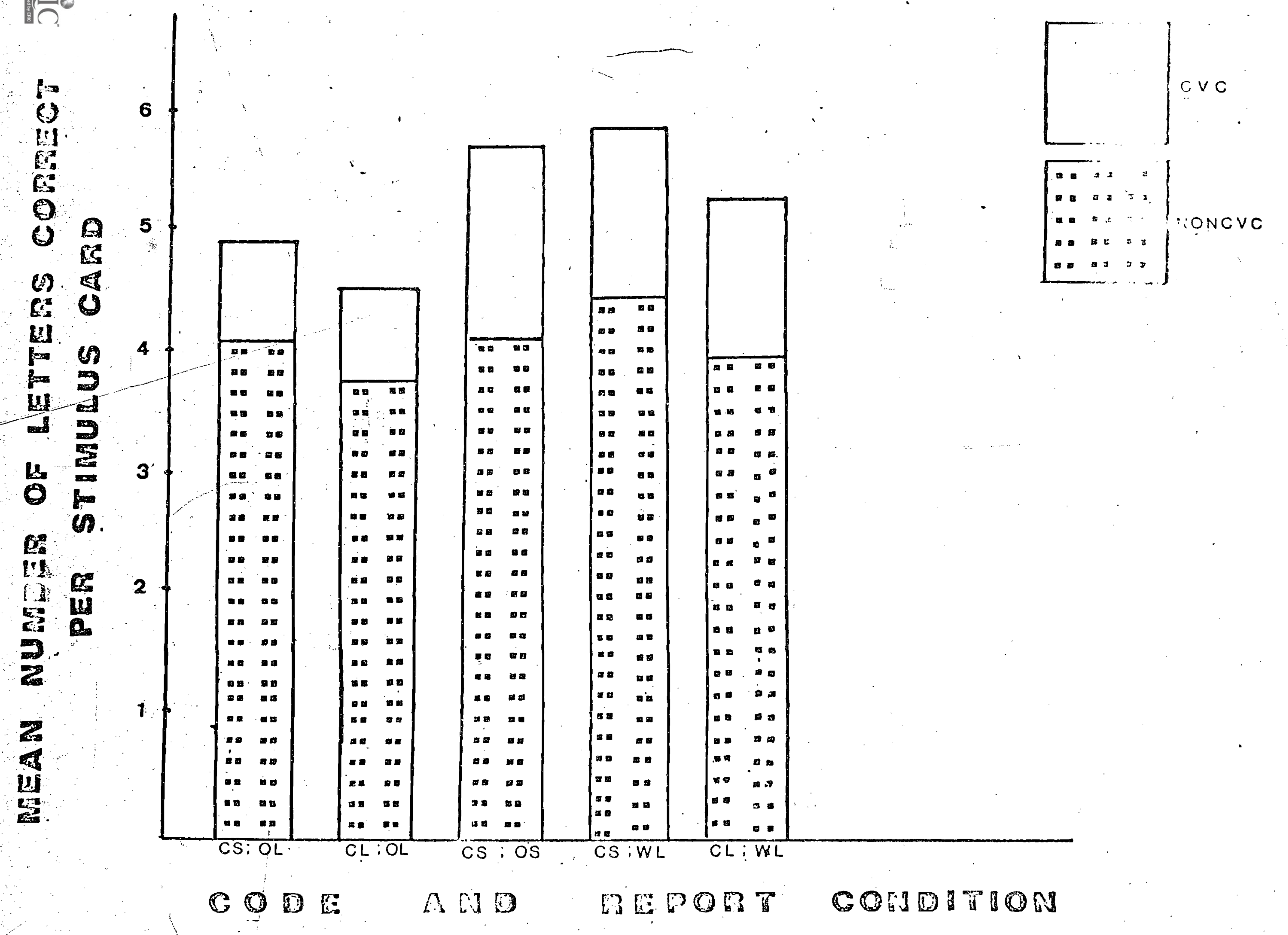

MEAN NUMBER OF LETTERS CORRECT PER STIMULUS CARD
6
5
4
3
2
1
CS; OL
CL ; OL
CS ; OS
CS ; WL
CL ; WL
CODE AND REPORT CONDITION
CVC
NONCVC

Figure 22

Performance under combinations of coding and report conditions at varying presentation times

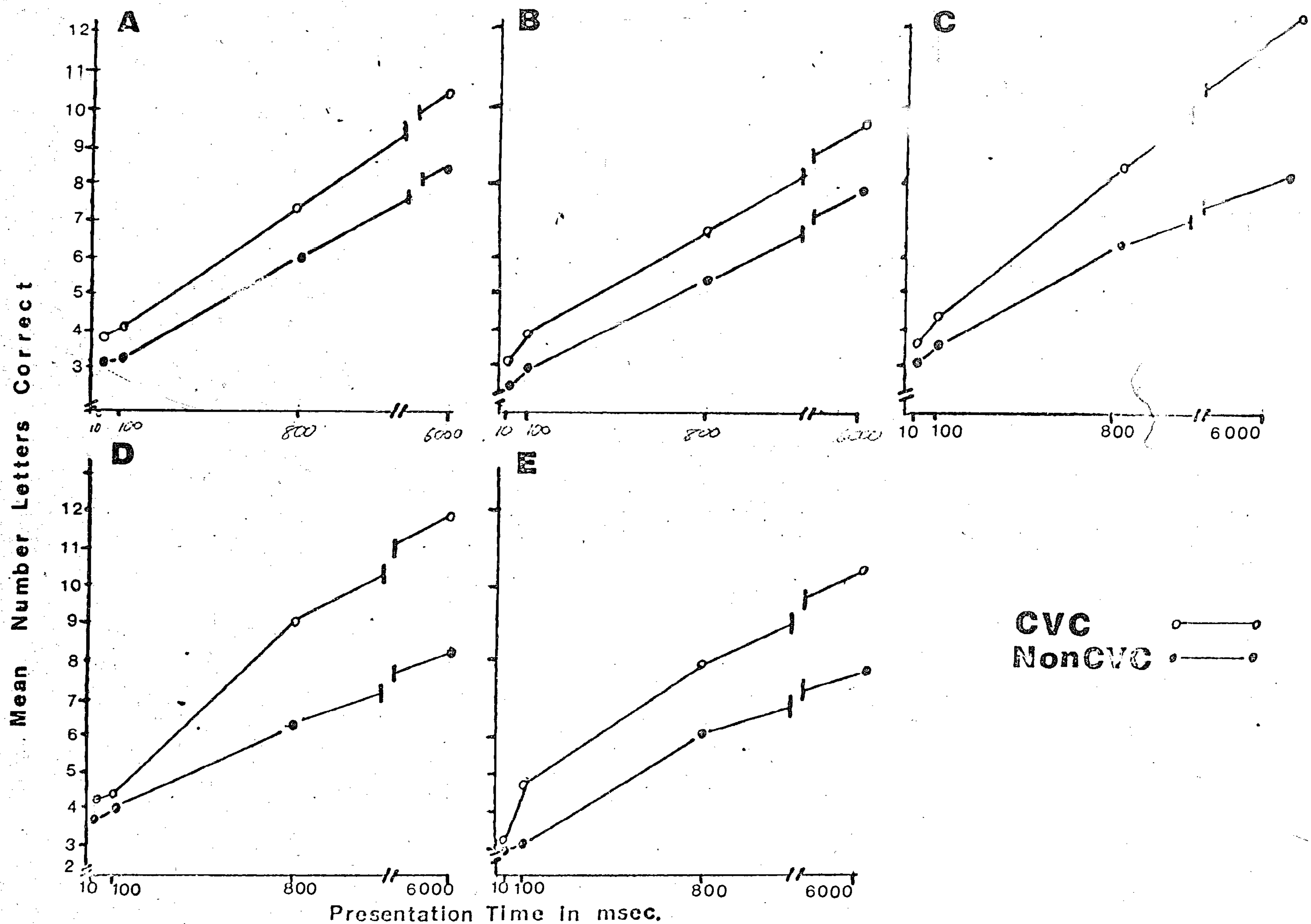
A: code syllable, oral letter

B: code letter, oral letter

C: code syllable, oral syllable

D: code syllable, written letter

E: code letter, written letter


A
B
C
D
E
Mean Number Letters Correct
Presentation Time in msec.
10
100
800
6000
2
3
4
5
6
7
8
9
10
11
12
CVC
NonCVC

between groups CS, OL + CS, OS + CL, OL versus CS, WL + CL, WL.

2. If reporting letters differed from reporting syllables then group CS, OL should differ from group CS, OS and this was the second comparison.

3. The third comparison dealt with the effectiveness of instruction on input. If coding was effective then the syllable coding CS, OL + CS, OS should be better than CL, OL. This comparison involved coding versus non-coding of input within oral report conditions.

4. The fourth comparison was of coding versus non-coding of input under written report conditions and involved the groups CS, WL versus CL, WL.

Of the above comparisons only the one comparing coding of input under oral report conditions reached statistical significance ($F + 4.53$; $df = 1,25$; $p < .05$). The coding instructions under written report conditions comparison fell between the .05 and .10 levels ($F = 3.46$; $df = 1,25$; $p < .10$). The report conditions overall did not seem to make much difference and produced small Fs. However whether one reported orally by syllable or orally by letter did seem to make a difference depending upon the type of material. The difference was large when dealing with CVCs but minimal with non CVCs. This difference was substantiated by an interaction F of 4.81 ($df = 1,175$; $p < .05$). Again since the difference between CVCs and non CVCs increased with time this reporting material-interaction also increased with time and a significant three way interaction was found ($F = 8.98$; $df = 1,175$; $p < .001$) as well as a two way interaction between time and CS, OS versus CS, OL ($F = 2,87$; $df = 3,175$; $p < .05$).

Although an overall effect of coding instruction was found, this effect did interact with type of material. The difference between syllable coding and letter coding for oral reporting was greater for CVCs than non-CVCs ($F = 4.39$; $df = 1,125$; $p < .05$).

DISCUSSION

The large difference between performance with non-CVC material represents a strong reaffirmation of the operation of coding in short term memory demonstrated in experiment seven. The fact that the coding involved in remembering word like material may have some similarity to the type of code used in experiment six and other studies (Kleinberg & Kaufman, 1971; Lamb and Kaufman, 1966) is demonstrated by the interaction of presentation time and relative ease of remembering words and non-words. The longer the presentation time the greater the superiority with CVC material. This difference makes a great deal of sense when considered in light of the hypothesis that coding takes time. However, the fact that word coding differs from the type of explicit coding previously discussed is evidenced by the fact that word-non word differences are found at presentation times as fast as ten milliseconds. The explicit octal code used in experiment six was not effective at such brief exposures.

In addition to pointing to the effectiveness of word coding in short term memory, this study has demonstrated what we were unable to determine in experiment six, that is that coding in short term memory is to some extent under the subject's control and may be manipulated by instruction. Instructions to code by syllable provided more effective performance than did instructions to code by letter. While this difference was somewhat affected by type of material used (word or non-word) it did favor syllable coding in both bases. The partial control of this coding process also speaks to the explicit nature of the word code. It is not just a Gestalt like perceptual code which is immune to control, but can in part at least be turned on and off by the subject.

The response mode effects also shed some light upon the nature of the word code. Oral syllable reporting is more effective than is letter reporting when word like material is recalled. This finding speaks to a pronounciability effect in coding. When material is prounounceable in unit form, producing the response in that fashion is superior to producing it letter by letter. That this is a syllable effect and not an effect of coding-response mode compatibility is evidenced by the fact that the code letter-oral letter group is not better than the code syllable-oral letter group, but the code syllable-oral syllable is better than the code syllable-oral letter.

CONCLUSIONS

The experiments described in this report have provided information about many facets of the perceptual responding of retarded children, normal children and normal adults. Although a reading of the discussion section of each individual experiment provides a more comprehensive picture, this section summarizes our conclusions under four major categories: identification capacity, effects of dimensionality, paradigm comparisons, and memory effects.

Identification capacity

It is clear from our data that retarded children do not identify simple stimuli as well as do normals. This deficit is found with stimuli which vary unidimensionally and multidimensionally.

However, the deficit seems to occur at all levels of stimulus information and does not necessarily reflect channel capacity differences. That is, information is not transmitted equally well by retardates and normals at low levels of input with retardates reaching asymptote at a lower level than normals. Performance of our retarded children was inferior to normal performance at all points. Interestingly, this deficit was found to hold for both CA anc MA controls. The finding of both an MA and an IQ correlate of the identification deficit was somewhat surprising. In addition a developmental correlate of identification ability was found, with sixth graders outperforming first graders and college students providing the highest levels of information transmission.

The mechanisms underlying the retardate identification deficit are still unknown to us. Memory differences seem to play a role as the delay effects to be presently discussed indicate. In addition, retardates seem to be more susceptible to context effects, that is the effect of preceding trials upon the present response. These context effects appear more strongly as task demands increase. Whether the context effects stem from a generalized strategy of our retarded subjects (the kind of "distractability" customarily attributed to retardates) or a specific strategy associated with our particular identification procedure is as yet undetermined. What we do know is that identification performance can be dramatically improved by gradual training techniques. By shifting from a less perceptually demanding discrimination task to our identification task we were able to get perfect information transmission from our retarded subjects at stimulus information levels much higher than those for which we got relatively poor transmission when we used an identification procedure alone.

Dimensionality effects.

The effects of redundancy or additional dimensions of variation upon identification were consistent and expected. In general, the greater the number of dimensions along which the stimulus to be identified varied the better the performance by retardates, normal children and college students. While there were interactions of dimensionality with intellectual and developmental factors, they were not entirely consistent. It did seem to be the case that retardates benefited more from the addition of redundant information than did normals. Their performance with bidimensional stimuli in experiment one was better than their performance with unidimensionally varying stimuli, a relative difference which exceeded the comparable normal control difference. Again in experiment two the retardates performance on tridimensional stimuli was superior to either uni- or bidimensional stimuli, although the normal control bidimensional and tridimensional performance did not significantly differ. The college students in experiment four however, did perform better on the tridimensional as opposed to the bidimensional condition.

The information transmitted for unidimensional stimuli was fairly consistant across a wide variety of stimulus dimensions if we assume that our upper levels of stimulus information were close to channel capacity, and in light of previous findings and our own data this assumption seems reasonable. While this regularity across type of dimensions was found, the developmental and intellectual differences mentioned earlier were also to be found. That is, identification capacity did not vary too much as a function of the particular type of single stimulus dimension, but did vary with respect to CA, MA and IQ.

Interesting effects of type of dimensional combination were discovered. In a situation involving three dimensions, two of which were part of the figure and one the ground, bidimensional combinations of the figure dimensions proved easier to identify than did bidimensional figure-ground combinations. This effect is somewhat intuitive and fits nicely with ideas about the integrality of certain stimulus combinations (Lockhead, 1966). What we found surprising were the effects of the different bidimensional combinations looked at in experiment five. In our bidimensional combination condition in other experiments (experiment 1, 2, 3 and 4) we had used the perfectly correlated redundant combination in which the first value on one dimension was paired with the first value on the second dimension, the second with the second, the third with the third and so on. We felt that this type of combination (the diagonal) provided one of the best conditions for distinctiveness. We were greatly surprised to find that the totally orthogonal combination of experiment five proved to be even more distinctive. The saw-tooth combination which had been investigated in other experiments and had been found to be equal to or better than the diagonal, was found to be so in our study but it too failed to equal the independent uncorrelated condition.

Paradigm comparisons.

The conventional identification paradigm is often called the absolute judgment task, one in which the subject is asked to supply a particular label for a particular stimulus. In order to circumvent the problems of verbal deficiencies in our retarded children we used a recognition or delayed match-to-sample paradigm for our identification studies. We found that not only did this technique overcome verbal communication problems, but it probably acted as an aid to memory for the pool of stimuli which must be considered. Of the types of identification paradigms investigated with college student subjects, the absolute judgment task which provided no memory aid and put great demands upon memory was the most difficult while the discrimination task, a situation which put no demands upon memory, was by far the easiest. The other paradigms (matrix after and matrix before) fell between these two, depending again upon the demands placed upon the subjects' memory. The importance of the particular paradigm employed was emphasized by the outcome of experiment five, in which retarded children were gradually shifted from the easier discrimination task to the more difficult match-to-sample. In our first experiment retardate information transmission was so poor, even at levels of stimulus information as low as one bit that no statement about channel capacity or asymptotic level could clearly be made. However,

ERIC

by first providing discrimination training and then shifting to the match-to-sample technique, performance was perfect at better than two bits of stimulus information and problems with estimating channel capacity arose from the very high rather than the very low performance levels!

Memory Effects

The importance of memory in identification illustrated by our paradigm comparisons is further emphasized by the effects of delay upon match-to-sample performance. Both retarded and normal children suffer degraded performance as delay between the stimulus and the response matrix is increased. This detremental effect of increased memory demand seemed to occur more seriously with retardates in our first experiment, but affected retardates and normals equally in experiment two.

A slightly different approach to memory was taken in experiments six, seven and eight. The effects of coding upon short term memory were investigated and the following general conclusions may be drawn:

1. Explicit coding in the form of an octal code was not demonstrated to be effective at very short stimulus presentation times, a finding consistant with the hypothesis that coding takes time.

2. The coding involved in distinguishing a word from a non-word of equal number of characters is effective at very short presentation times, a finding inconsistant with the hypothesis that coding takes time.

3. Word coding is to some extent under the control of the subject since its effectiveness is manipulable by instruction, but it is clearly different in other respects from explicit codes like the octal code since it does dramatically improve short term memory at even the smallest exposure time.

ERIC

4. The mode of response (written or oral) makes little difference in performance of a short term memory task for trigrams but whether the trigrams must be reported by letter or syllable is important for more word-like trigrams.

ERIC

REFERENCES

Belmont, J. M. Long term memory in mental retardation. In Ellis, N.R. (Ed.) International review of research in mental retardation. Volume 1, New York: Academic Press, 1966.

Belmont, J. M. & Butterfield, E. C. The relations of short-term memory to development and intelligence. In Lipsitt, L. P. and Reese, H. W. (Eds.) Advances in child development and behavior. Volume 4. New York: Academic Press, 1969.

Erikson, L. W. & Hake, H. W. Multi-dimensional stimulus differences and accuracy of discrimination. Journal of Experimental Psychology, 1955, 50, 153-160.

Fitts, P. M. & Posner, M. I. Human performance. Belmont, California: Brooks/Cole, 1967.

Glanzer, M. & Fleishman, J. The effect of encoding training on perceptual recall. Perception & Psychophysics, 1967, 2, 261-264.

Hyman, L. M. & Kaufman, H. Information and the memory span. Perception & Psychophysics, 1966, 1, 235-237.

Kaufman, H. & Wilson, M. Information processing in the monkey. Psychonomic Society, San Antonio, October, 1970.

Kaufman, H. & Levy, R. M. Analysis of the combination of perceptual dimensions. Psychological Bulletin, 1971, Vol. 75, No. 6, 369-378.

Kodman, F., Jr. Sensory processes and mental deficiency. In Ellis, N. R. (Ed.) Handbook of mental deficiency. New York: McGraw-Hill, 1963.

Lamb, J. C. & Kaufman, H. The effects of coding procedure on human information transmission. Perception & Psychophysics, 1967, 2, 256-262.

Lockhead, G. R. Effects of dimensional redundancy on visual discrimination. *Journal of Experimental Psychology*, 1966, *72*, 95-104.

Miller, G. The magical number seven, plus or minus two. *Psychology Review*, 1956, *63*, 81-97.

Olson, D. R. Information-processing limitations of mentally retarded children. *American Journal Mental Deficiency*, 1971, *75*, 478-486.

Reicher, G. M. Perceptual recognition as a function of meaningfulness of stimulus material. *Journal of Experimental Psychology*, 1969, *81*, 275-280.

Scott, K. G. & Scott, M. S. Research and theory in short-term memory. In Ellis, N. R. (Ed.) *International review of research in mental retardation.* Volume 3. New York: Academic Press, 1968.

Spitz, H. H. The role of input organization in the learning and memory of mental retardates. In N. R. Ellis (Ed.) *International Review of Research in Mental Retardation*, Vol. 2, Academic Press: New York, 1966.

Spitz, H. H. & Borland, M. V. Effects of stimulus complexity on visual search performance of normals and educable retardates. *American Journal of Mental Deficiency*, 1971, *75*, 724-728.

Wheeler, D. D. Processes in word recognition. *Cognitive Psychology*, 1970, *1*, 59-85.

Zeaman, D. & House, B. J. The role of attention in retardate discrimination learning. In Ellis, N. R. (Ed.) *Handbook of mental deficiency.* New York: McGraw Hill, 1963.