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ABSTRACT

A pilot study and two formal studies were conducted with educable mentally handicapped (EMR) children to develop materials and procedures suitable for studying schema learning in EMRs and to demonstrate schema learning in EMRs in the absence of external guidance. The pilot and formal study I were conducted to develop suitable populations of stimuli conducive to minimal performance, allowing improvement room without arousing frustration. The Ss reproduced checkerboard patterns having 16, 20, 25, 30, and 36 cells, respectively. It was found that Ss performed above chance on matrices with 36 cells, cell number retained by Ss was not significantly affected by total number of cells within patterns, and visual channel capacity might be related to verbal components of intelligence. Formal study II was conducted to determine if EMRs were capable of schema concept learning using stimuli patterns from both pilot and first formal study. One group reproduced schema patterned checkerboards, while another group reproduced nonschematic patterns. Results indicated that EMRs were capable of schema concept learning without either prototype exposure or external feedback. (CB)

Final Report

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U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

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TABLE OF CONTENTS

INTRODUCTION

The conception of information as a measurable phenomenon has opened many avenues of research into man's mental functioning. Wiener's Cybernetics (1948) and subsequent articles by Shannon (1951), Miller (1953), and others all have in common the idea that we can learn much about human thinking and problem solving by viewing man as a producer, transmitter, and user of information.

Humans can be conceived as playing a variety of roles in a communication system. We learn something different about humans with each different role we analyze. Obviously, the analysis of some roles is more revealing than others. It is of especial importance to understand how a human functions as an information channel.

Consider a subject who views a visual pattern projected onto a screen and then reproduces it from memory on a piece of paper. In this case the subject serves as a channel through which information contained in the pattern passes from the screen to the paper (Evans, 1967b). In this sense, the subject is not only a channel, but also an encoder and decoder.

Channel capacity is perhaps the weakest link in the information processing chain. In contrast to other features of the information system, channel capacity probably cannot be directly increased. Human channel capacity is limited physiologically. Furthermore, the channel is usually overloaded due to the fact that humans receive far more information than they can possibly process. To add to the difficulties, humans tend to process a great deal of useless information. It can be seen, therefore, that a retardate, handicapped by a limited channel capacity, can profit from remedial training only to the extent that he can be taught to utilize his available channel capacity more economically. In turn, this can be accomplished only by improving his encoding and/or decoding habits.

Is there an encoding principle that will enable retardates to utilize their channel capacity more economically? An encoding principle that shows great promise was suggested by Woodworth (1938) and has been further developed by Oldfield (1954), Attneave (1957), and others. This principle has been called "schema plus correction" encoding. Basically, this principle holds that subjects can abstract the common, redundant features (the schema) of a class of stimuli. Once this has been done, specific stimuli can be encoded by identifying the class-schema and by then attending to those features that distinguish the specific stimulus from the class in general.

An often used example of how this encoding principle operates is as follows: If an American were to travel to the Orient, he would, at first, have great difficulty in distinguishing between individual Orientals. It would be especially difficult for him to recall what a specific Oriental looked like. One reason for this difficulty is that the American does not yet realize that cues that are useful in identifying

Americans (hair color, eye color, heights, etc.) are useless in identifying Orientals. Thus, he may erroneously attempt to remember a particular Oriental by noting that the Oriental has black hair, brown eyes, and is short. Soon, however, he discovers that nearly all Orientals have these characteristics. He then searches for features that are not shared by all Orientals and eventually discovers some. He can then efficiently encode for an Oriental's features by noting (1) that he is Oriental, and (2) that unlike most Orientals, he has a long nose, a scar on his right cheek, etc. He is then able to utilize efficiently his limited channel capacity by retaining the label of the class to which the person belongs (Oriental) and the few distinctive characteristics. If, at a later date, he were required to reproduce a likeness of the person, he could reproduce a great deal of the person's features merely by recalling that the person was an Oriental. He would, for example, be able to reproduce a short man with black hair, brown eyes, etc. In addition, the few distinctive features could then be added, allowing the person to be identified.

In order to use the "schema plus correction" principle, it is first necessary for the schema to be abstracted. The process of schema abstraction, in turn, leads to "Schematic Concept Formation" (SCF). SCF can best be understood by comparing it with traditional concept formation.

Traditional concept formation occurs when the subjects are trained to detect and respond to features that are invariant (unchanging) in each stimulus in a set of stimuli. The features the subject is to learn are nearly always arbitrarily selected by the trainer, and are usually features that the subject would not abstract in the absence of external reinforcement or feedback. As noted by Evans (1967a), traditional concept formation requires that the subject be guided by some form of external feedback provided by a trainer who already has knowledge of the concept.

In contrast, SCF involves the abstraction of probabilistic features of stimuli. No single stimulus necessarily follows the schema in all respects and no single feature of the schema will necessarily be represented in all stimuli (Evans, 1967a). Unlike traditional concept formation, SCF occurs merely on the basis of abstracting information contained in the stimuli themselves, without exposure to the schema prototype (Edmonds and Mueller, 1967a); Edmonds, Mueller, & Evans, 1966), and without knowledge of results or other external feedback (Edmonds & Evans, 1966a, 1966b; Edmonds & Mueller, 1967a, 1967b; Edmonds, Mueller, & Evans, 1966). In order for SCF to occur, the schema must not be purely arbitrary. The schema must be such a defining feature of the set of stimuli that the subject detects and responds to it in a more or less "spontaneous" fashion.

Unfortunately, even normal subjects do not always attend to the schema and nearly all subjects show considerable room for improvement in SCF. The question is, can subjects be taught to attend to schemata and having learned to abstract schemata, can they apply this encoding principle to new problems without further prompting from their teachers?

One possible approach is based on Harlow's learning set method (Harlow, 1949), by which subjects "learn how to learn." This method involves giving subjects a number of tasks, all of which involve the same general problem-solving principle. Using this approach, it has been found that subjects tend to abstract the general problem-solving principle and apply it when given new problems. "Learning how to learn" has been demonstrated with mental retardates (e.g., de Hann & Wischner, 1963, etc.), and even animals (e.g., Harlow, 1949, etc.). Unfortunately, none of these studies has used schematic tasks.

More recently, Edmonds, Evans, & Mueller, (1966) have developed evidence which indicates that at least college students can "learn how to learn" schemata. After the subjects had abstracted one schema, they were given a second schema to abstract, and so on until they had abstracted a total of four different schemata. It was found that they showed a striking improvement in the speed and accuracy of abstracting schemata as they learned the successive schemata. According to Edmonds, et al, the subjects were learning a general principle: that patterns can be best memorized by abstracting and using the schema that the patterns contain.

If mental retardates are also capable of "learning how to learn" schemata, then a powerful habilitation method will be feasible. Of all the general problem-solving principles that mental retardates could learn, the general schematic encoding principle would have far greater usefulness because it would allow the retardate to process a great deal of important information despite a very limited channel capacity. Furthermore, little or no linguistic ability is required for SCF to occur, as evidenced by the fact that most subjects are unable to verbalize what they have learned even when they have successfully abstracted a schema (Edmonds & Evans, 1966b). Of even more importance, once the retardate has become proficient in SCF, and has developed a habit of using schemata, there is the additional benefit that he can then engage in SCF in his everyday interaction with his environment, even in the absence of a teacher. The applicability of this method to normal children is obvious.

Although there has been considerable research dealing with traditional concept formation in retardates (e.g., House & Zeaman, 1960; Iscoe & Semler, 1964; de Hann & Wischner, 1963, etc.), there has been no study which demonstrates SCF in retardates. There is, however, indirect evidence that provides at least a hint at what might be expected.

In a study using chimpanzees, Kelleher (1958), found the subjects capable of detecting redundant features in a series of checkerboard patterns. Since chimpanzees are probably more limited in channel capacity than most mildly retarded subjects, this suggests that mildly retarded humans should be able to detect schemata in checkerboard patterns. However, this must be determined through experimentation with schema learning procedures, since Kelleher's chimpanzees received external reinforcement for correct responding.

Working with human retardates, Spitz (1964) found that his subjects could reproduce dot patterns in a 3 x 4 checkerboard form. Although the patterns differed in symmetry, no schema was used in constructing these patterns. Munsinger (1967) had children (and adults) reproduce 8 x 8

checkerboard patterns which were either random or redundant (schematic). He found that second and sixth-grade children were able to reproduce these patterns. Furthermore, these subjects were more proficient in reproducing the redundant patterns than the random patterns. This indicates that the subjects were learning and using the schema.

Since the intellectual capacity of mildly retarded subjects is roughly equivalent to that of normal second-grade children such as those in Munsinger's study (Robinson & Robinson, 1965), Munsinger's study suggests that mildly retarded subjects should also be capable of SCF if similar patterns were to be employed. However, it should be noted that "intellectual capacity" as commonly measured, may have little to do with visual channel capacity.

It is not difficult to envision an extensive research program concerning SCF in retardates. The present project, however, involved a cautious first step, beginning with mildly retarded subjects, and was designed merely to determine whether these subjects are capable of SCF with stimuli requiring very little channel capacity. If SCF is possible with these subjects, then future effort can be made to determine whether they can also develop the habit of using the schematic encoding principle when faced with new encoding problems.

Accomplishing the objectives of the proposal involved two steps. First, a suitable population of stimuli was developed, making certain that the subjects were capable of at least minimal performance. The information contained in the stimuli was tested until a level of difficulty was found which was not frustrating to the subjects, yet was difficult enough to leave room for improvement in their performance. The simple, straight-forward experimental stimulus that was used was a symmetrical checkerboard pattern, similar to those employed by Spitz (1964), and Munsinger (1967), described earlier.

The second step in the project was to determine whether mildly retarded subjects were capable of SCF when these patterns are employed. This step involved having one group of subjects reproduce checkerboard patterns that contain a schema, while another group reproduced nonschematic patterns. If the performance of the subjects that reproduce the schematic patterns is significantly superior to the performance of the other subjects, it would indicate that mildly retarded subjects are capable of SCF.

METHOD AND RESULTS

Pilot Study

Purpose. Before an investigation of SCF in mildly retarded subjects could be undertaken, a set of patterns must first be selected which mildly retarded subjects will be capable of reproducing from memory. Therefore, in the pilot study, retarded subjects attempted to reproduce checkerboard patterns that differed in the amount of information they contained. Patterns were selected which contained the greatest amount of information that the subjects were capable of reproducing from memory. Because only a limited number of retarded subjects were available for the formal study, the pilot study used subjects with IQ's below and above the mild retardate range.

Subjects. Fifteen experimentally naive patients at Hillcrest School, Hawley, Pennsylvania, served as subjects in the pilot study. Hillcrest School is a private residential facility for the interim care of mentally retarded male children. The school generally cares for approximately 100 children. Most of the children are classified by the Pennsylvania Department of Public Welfare as dependent and neglected children. The children's ages range from about 8 to 17 years. They are all ambulatory, toilet trained, and have no major physical handicaps. The racial composition of the school is roughly one half caucasion and one half negro. Habilitation programs are conducted at the school for the trainable and educable children. Nearly all of the children are at the second-grade achievement level.

The IQ's of the subjects in the pilot study ranged from 42 to 51 and from 68 to 79 as measured by an individual intelligence test administered no more than one year prior to the study. Children were excluded from the study if they had a physical or sensory handicap which would significantly interfere with their performance in the study. Those children who qualified to serve as subjects were then assigned individual numbers and a table of random numbers was used in selecting the children who served as subjects in the study.

Materials. Symmetrical checkerboard patterns of varying complexity (containing 4, 6, 9, 12, and 16 cells) were printed on cards. Five different cards of each level of complexity were prepared, making a total of 25 cards. Each square was 5/8" x 5/8". Approximately half of the cells in each matrix contained black circles and the other half were empty. Whether a specific cell was filled or empty was randomly determined, with a fixed probability of 1/2 of being filled and 1/2 of being empty. In information terms, each cell contained one bit of information, and the total information contained in a matrix was equal to the number of cells within the matrix. Thus the information on the cards ranged from 4 bits to 16 bits.

Task and Procedure. The subjects were trained individually. Each subject received the 25 cards in the same order of presentation, beginning with the simplest (2x2) matrices and continuing to the most complex (4x4). The following instructions were read to each subject:

"I'm going to show you some checkerboards, one at a time.

"I want you to look at the checkerboard and try to remember where each of the black circles is placed. When I take the checkerboard away, I want you to take your pen and put circles in the checkerboard on your paper wherever there are circles in the checkerboard that I show you. I'll give you plenty of time to make your checkerboard like mine, if you aren't sure, go ahead and guess. Do you have any questions?"

Each subject was then shown an example, consisting of a 2 x 2 matrix with the top two cells containing circles. If the subject correctly reproduced this example pattern he was then given the 25 patterns. If he made an error on the example pattern, or seemed unable to respond, he was told of his error and the instructions were read again. If he repeated his error, he was removed from the study.

The subject was shown each card for 15 seconds before it was removed and then he was allowed 30 seconds in which to reproduce the patterns by drawing circles in the appropriate squares on a separate sheet of paper on which the matrix was printed. Although encouragement was given, no knowledge of results was provided during the task.

Results. Four of the 15 subjects were unable to follow instructions. These subjects filled in every square of the example pattern. Even when told of their error, and when given an additional practice trial, these subjects were still unable to perform. All four of these subjects had IQ's below 46.

The 11 subjects that were able to follow instructions performed well above chance on all of the patterns. In fact, even on the most complex (4 x 4) patterns, they performed at 49.2% above chance.

It was concluded that 4 x 4 patterns are not sufficiently difficult for the purposes of the project. It was also concluded that subjects within the IQ range (52 to 67) that had been selected for the formal study should be capable of following instructions and completing the task.

Formal Study I

Purpose. The purpose of Formal Study I was the same as in the pilot study.

Subjects. Thirty experimentally naive patients at Hillcrest School served as subjects. Although these were not the same subjects as in the pilot study, they were selected in the same manner. Each subject was classified as mildly retarded (IQ between 52 and 67) on the basis of an individual intelligence test administered no more than one year prior to the study. The subjects' mean IQ was 58.7, with a standard deviation of 5.0.

Materials. Checkerboard patterns were constructed in the same manner as those used in the pilot study except that the complexities were 4 x 4, 4 x 5, 5 x 5, 5 x 6, and 6 x 6 (containing 16, 20, 25, 30, and

36 cells, respectively).

Task and Procedure. The subjects were trained in the same manner as in the pilot study, except that the 25 cards were randomly ordered for each subject such that no two subjects received the cards in the same order.

Results. The dependent variable was the percentage of cells correctly reproduced, employing the following formula that includes a correction for guessing:

$$100x \frac{\text{Cells Correct} - \text{Cells Incorrect}}{\text{Total Cells}}$$

As indicated in Figure 1, performance was quite good (50.09%) on the 4 x 4 matrices, but became progressively poorer on the more complex matrices. Nevertheless, the subjects as a group performed 22.1% above chance even on the 6 x 6 matrices (binomial approximation of the normal distribution, $z = 2.65$, $p < .005$). A repeated measures analysis of variance was performed. The effect of matrix complexity was highly significant ($F = 31.75$, $df = 4/116$, $p < .005$).

An analysis was also performed using as the dependent variable the number of cells correctly reproduced, correcting for guessing (subtracting the number of incorrectly reproduced cells from the number of correctly reproduced cells). Using this dependent variable, the effect of pattern complexity was not significant ($F < 1.00$). The results of this analysis indicated that the subjects retained a fairly constant number of cells from each pattern. Thus, although there was a decrease in the percentage of cells correctly reproduced as the matrix complexity increased, the number of cells correctly reproduced remained at about 8 squares per pattern regardless of the matrix complexity (See Figure 2).

It appears that the subjects were attempting to retain a given number of cells, regardless of the total number of cells in each matrix.

It was of interest to determine the degree of relationship between IQ and performance on the task. In order to increase the range of IQ's and to make use of data from both studies, only performance on the 4 x 4 matrices was used. These were the only patterns that were reproduced in both studies. The correlation between IQ and total number of cells correctly reproduced in the 4 x 4 patterns was significant ($r = .53$, $df = 39$, $p < .005$).

Twenty-four of the subjects had been administered the Wechsler Intelligence Scale for Children (WISC) which provides a Verbal score and Performance score as well as the Full Scale IQ. The correlation between Verbal score and total number of cells from the 4 x 4 matrices that were correctly reproduced was significant ($r = .43$, $df = 22$, $p < .025$). However, the correlation between Performance score and total number of cells correctly reproduced was not significant ($r = .17$, $df = 22$, $p > .05$).

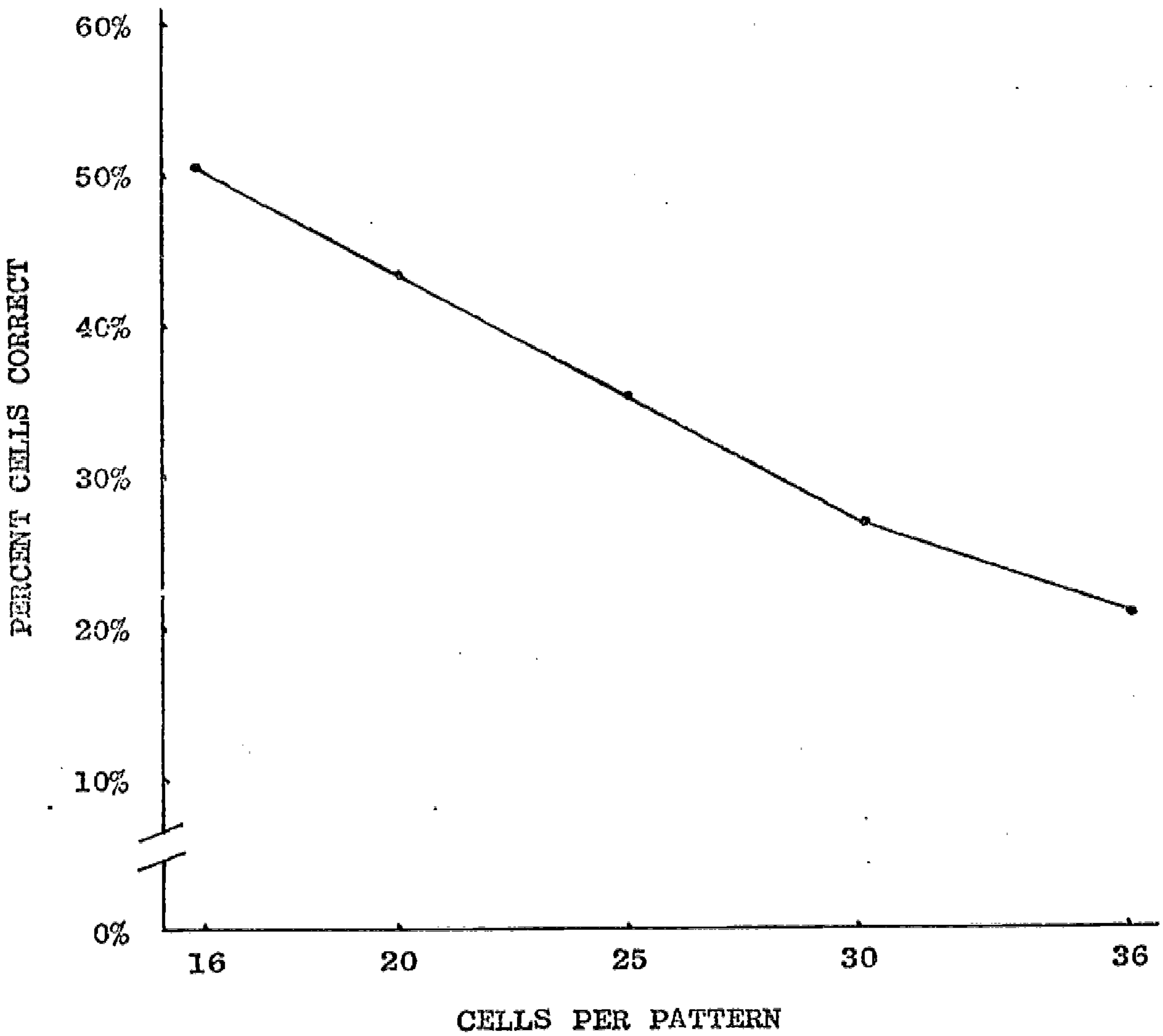

FIGURE #1. Percent of cells correctly reproduced as a function of the complexity of the patterns being reproduced. Each data point represents the average of thirty subjects.

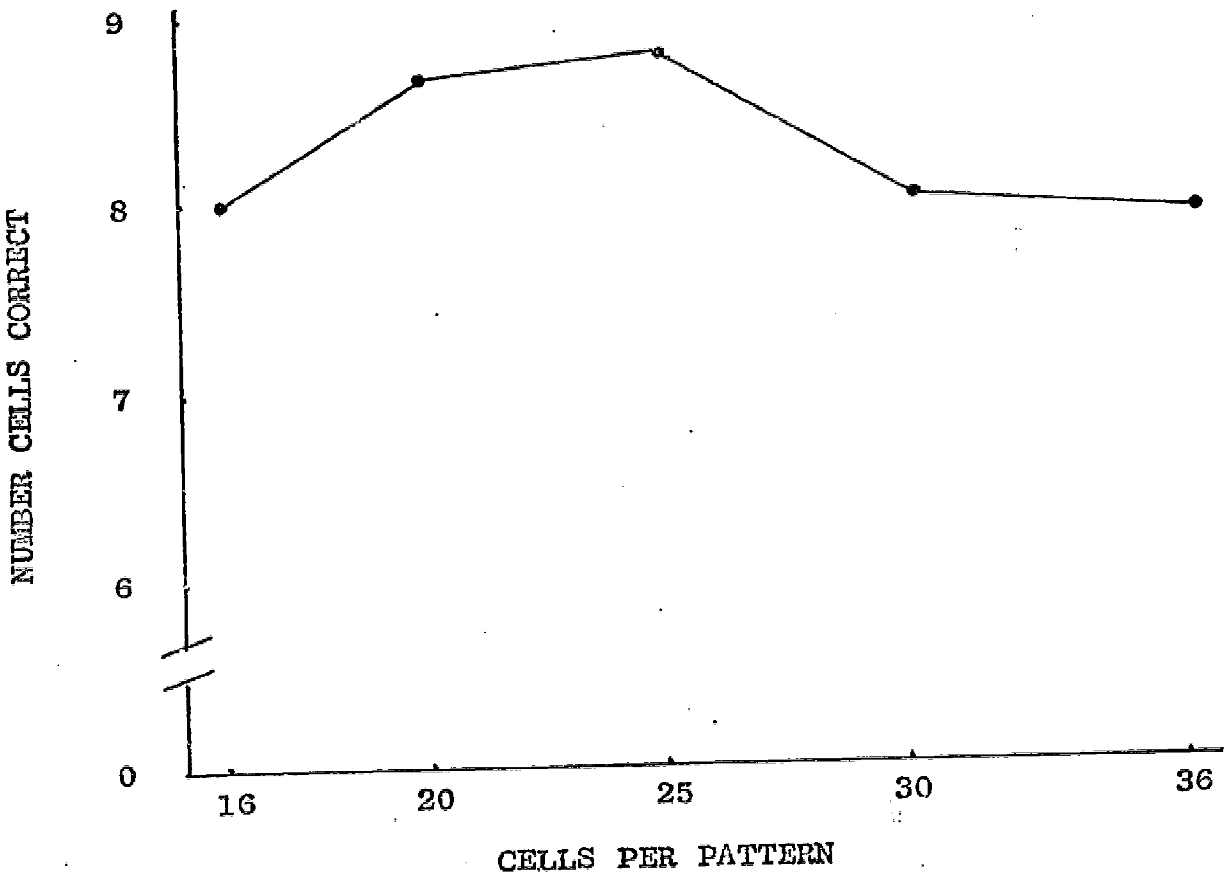

FIGURE #2. Number of cells correctly reproduced as a function of the complexity of the patterns being repro duced. Each data point represents the average of thirty subjects.

Formal Study II

Purpose. Formal Study II employed the patterns selected in Formal Study I in an attempt to determine if mildly retarded subjects are capable of abstracting and utilizing a schema contained in the patterns. If the subjects are capable of doing this without exposure to the schema prototype, and without external feedback, it will verify that they are capable of SCF. In turn, if they are capable of SCF, they should also be capable of "learning how to learn" schemata.

Subjects. 40 experimentally naive patients served as subjects. Although these were not the same subjects as those who served in the other studies, they were selected in the same manner. The subjects were randomly assigned to two groups of 20 subjects.

Materials. The materials were the same as in Formal Study I, except that all matrices were 6 x 6, and each subject received 20 patterns. The cards presented to the Experimental group were constructed as follows: one prototype checkerboard pattern was arbitrarily established with half of the cells filled with circles and half empty. All of the other patterns consisted of variants of the prototype. These variants were produced by establishing a probability of .97 that each cell in the matrix would have the same value (filled or empty) as the corresponding square in the prototype. The probability was .03 that it would have the opposite value. The redundancy level for this set of patterns was approximately 80%. The Control group received patterns in which the probability of each cell's being filled was .50 and being empty .50. The redundancy level for this set of patterns was 0%. The patterns given to the Control group were matched with the experimental patterns in terms of the number of filled and unfilled cells.

Task and Procedure. The subjects were trained individually, in the same manner as Formal Study I. The two groups were treated in an identical manner, except that subjects in the Experimental group reproduced patterns that were 80% redundant (schematic), whereas the patterns that the subjects in the Control group reproduced were 0% redundant (nonschematic).

Results. As indicated by Figure 3, the Experimental group's performance was slightly inferior to the Control group's performance on the first trial. However, the Experimental group's performance improved almost immediately, and on the final 10 trials the group correctly reproduced 80.54 of the cells (61.08% above chance). In contrast, the Control group's performance actually worsened, with the group correctly reproducing only 61.64% of the cells (23.28% above chance) on the last 10 trials. The difference between the groups on the last 10 trials was statistically significant ($t = 7.492$, $df = 38$, $p < .005$).

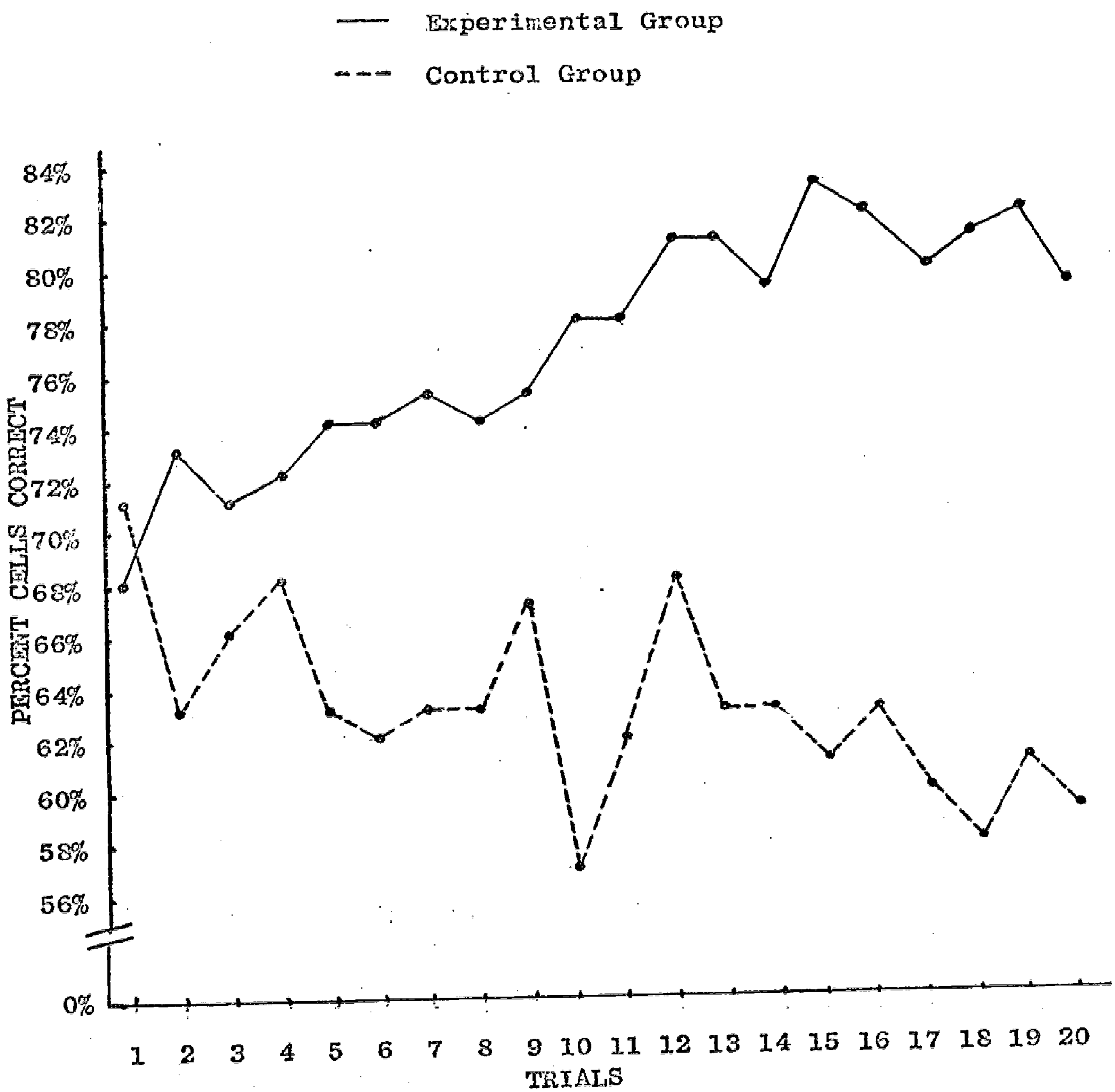

FIGURE #3. Percent cells correctly reproduced on each of twenty trials. Each data point is the average of twenty subjects.

CONCLUSIONS

The pilot study and Formal Study I indicate that subjects with IQ's above about 46 were capable of performing above chance on the pattern reproduction task. Further refinements of techniques may be necessary if subjects with IQ's below 46 are to perform the task. However, since the project was directed toward mildly retarded children, all of whom had IQ's of 52 or higher, it appeared that the task was appropriate and could be used in subsequent project activities.

Contrary to initial expectations, the subjects were capable of processing information from matrices of considerable complexity. On the basis of the results, it appeared that of the matrices tested, the 6 x 6 matrices were most suitable for further use. The subjects performed above chance on the 6 x 6 matrices, but their level of performance was sufficiently poor as to allow for considerable improvement.

An unexpected finding was that the number of cells retained by the subjects was not significantly affected by the total number of cells within the patterns. This indicates that when the subjects' information channels became overloaded there was not a decrease in the actual amount of information the subjects processed, only in the percent of information processed.

The pilot study and Formal Study I also indicate that visual channel capacity may be related to intelligence level, and particularly to the verbal components of intelligence. However, these correlations must be interpreted with caution since some subjects' IQ's were measured by the Stanford-Binet and others with the WISC, and these tests are not completely interchangeable. Moreover, since the range of IQ's was relatively restricted, correlations would tend to differ if subjects with more heterogeneous IQ's were sampled. In addition, it must be noted that all of the subjects were male. Nevertheless, the data suggest that the pattern reproduction task taps skills that are significantly related to those skills measured by IQ tests. Therefore, the task holds some promise as a diagnostic tool.

An important by product of the pilot study and Formal Study I was that materials were developed which can be used in subsequent SCF studies with retarded children.

Formal Study II demonstrated that mildly retarded subjects are capable of abstracting schemata without exposure to the prototype and without external feedback. Having the capacity to abstract schemata, using only the information contained in the patterns, it is almost certain that mildly retarded subjects are also capable of SCF and of "learning how to learn" schemata.

It is concluded that the project was successful in accomplishing its stated objectives: (1) to develop materials and procedures suitable for studying schema learning in mildly retarded children, and (2) demonstrating schema learning in mildly retarded children in the absence of external guidance. Generalizations from the studies are, of course, limited by the characteristics of the sample, the possible peculiarities of the patterns employed, and the relatively high redundancy levels of the patterns.

RECOMMENDATIONS

It is recommended that studies be undertaken to establish if mildly retarded subjects are capable of SCF, and if they are able to "learn how to learn" schemata. As noted earlier, if these subjects have these capacities, then they can benefit from their everyday interaction with the environment, even without a teacher to provide external guidance. Moreover, training these subjects to "learn how to learn" schemata may directly improve their learning of other skills. Therefore, it is also recommended that studies be conducted to determine which skills correlate with the ability to abstract and utilize schemata. When these skills are identified, it should then be determined if special training in schema abstraction results in an improvement in these other skills.

Additionally, studies should be undertaken to determine the extent to which the present findings can be generalized, employing different types of patterns, tasks other than reproduction, and lower degrees of redundancy. Eventually, cross-modal transfer should be studied (e.g. from visual to auditory). Ecological studies would also be called for in order to determine if subjects utilize this new encoding principle in unsupervised situations.

The present studies indicate that the patterns employed cannot be readily used with subjects who have IQ's less than about 46. However, additional studies will be necessary in order to determine at what IQ level (if any) that retarded children are incapable of schema learning when other patterns or tasks are involved.

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