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LOGICAL PRETRAINING AND MEMORY AID IN A DEVELOPMENTAL STUDY OF CONCEPTUAL RULE LEARNING

by

© PETER FURSTENAU

A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance a thesis entitled "Logical Pretraining and Memory Aid in a Developmental Study of Conceptual Rule Learning", submitted by Peter Furstenau in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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Abstract

An experiment was performed investigating the effect of two factorially designed manipulations on the developmental course (cross-sectionally) of conceptual behavior. The task examined at three grade levels (grade two, seven and twelve) was the solution of an exclusive disjunctive rule problem. The two experimental manipulations designed to facilitate the solution of this task was a type of logical pretraining, truth-table classification pretraining, and an artificial memory aid which provided to the subject previously presented task information.

The results showed that both experimental manipulations improved performance for all grade levels, with the larger effects occurring at the lower grade levels. The combination of the two conditions improved the performance of the grade two subjects to that of the grade twelve subjects in terms of an overall measure of performance, trials to criterion. However, in spite of such overt improvements for the lower grades due to the experimental manipulations, there were qualitative differences in the way the three grade levels solved the task regardless of experimental condition.

The results were interpreted as supporting approaches that consider conceptual development to be primarily influenced by learning, although some limitations to such an interpretation were considered in view of the observed qualitative grade differences in the solution of the task. An additional conclusion concerned the developmental progression in the manipulation of symbols, where a finding contrary to expectations from Piagetian theory was obtained.

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Introduction

The present experiment is an attempt to extend the understanding of the normal development of conceptual behavior and to suggest some ways in which this normal development can be manipulated. Specifically, the study is concerned with the development of one efficient strategy of solving conceptual problems and the increase with age in memory for relevant information in concept learning.

Conceptual behavior can be defined (Kendler, 1964) as the classification of objects or events into categories that have some set of properties or characteristics in common, which makes the objects 'similar' to the subject. The similarity of these objects can best be characterized as 'psychological' similarity that 'binds the members of one class to another' (Elkind, 1969). This view of concepts is based on the idea of common features or the intersection of common properties among the exemplars of a concept. When a subject learns a concept he is, according to this view, seeking for invariant properties among the various exemplars.

One alternative view of concepts is that they are not based on the reductive process of seeking common properties among the exemplars, but that it involves the abstraction from the exemplars of a set of rules that specify the concept (Bransford, 1970). A concept in this alternate view is conceived to be composed of a set of symbols, and a set of rules for the specific combination of the symbols. This is a generative view of concepts in the sense that given the symbols and the rules (intension of the concept) all instances of a particular concept (extension of the concept) can be generated. This latter generative view of concepts derives from Cassirer (1923) and has been recently utilized by Langer (1970) and Furth et al. (1970). The essence of a concept in this view is not the common features of the various exemplars of the concept but the rule system that can generate these exemplars. The rule system can be viewed analogously to the rule system used to generate a grammatical sentence as proposed by Chomsky (1957).

The present study approaches conceptual behavior from the 'intersection' approach to concepts as proposed by Bourne (1969b). This approach has been criticized for lacking in the specification of 'enabling' structures (Newell, 1969), and for neglecting the intentional properties of concepts (Elkind, 1969; Furth et al., 1970). Bourne has stated his preference for an analysis of conceptual behavior that relies on descriptive rules or regularities of behavior. Newell criticized this approach because he felt that it is also important to consider the psychological structures that enable the observed behavior to be produced. According to Newell, the specification of such enabling structures adds insight to the understanding of the observed behavior. Bourne (1969b) has however pointed out that the 'intersection' approach can provide a theoretical model of conceptual behavior which is based on observed regularities or rules of behavior, but which does not necessarily imply intervening hypothetical processes which control such behavior.

The study of the development of conceptual skills has to a large extent been initiated through structural approaches to cognitive development by Piaget and Werner (Langer, 1970), who have tended to minimize the role of learning in conceptual behavior. The proponents of the intersection approach on the other hand consider learning to be a major process in the development of conceptual skills (Bourne et al., 1971, p. 244), and the experimental paradigm of this approach to concept learning lends itself to a learning analysis of such development.

The development of concept learning ability normally proceeds over several years. Large increases in performance have been found for the age interval of five to twelve years, with smaller increases for older subjects (e.g., King, 1969; Snow and Rabinovitch, 1969; Eimas, 1969; Bourne and O'Banion, 1971). Two factors that have been thought to underlie these performance increments are: (1) age-related changes in strategies of dealing with information and (2) changes in memory processes. Since the theoretical ideas of the role of these two factors in concept learning have come from studies using adult subjects, these studies will be reviewed before considering developmental aspects of concept learning.

The type of task used in studying concept learning can best be understood through a description of the experimental procedure involved. In the typical concept learning experiment by Bourne the subject is confronted with a set of stimuli which are divided arbitrarily by the experimenter into two classes: instances and noninstances of the concept. The classification rule for dividing stimuli into instances and noninstances may involve the dimensions of the stimulus set and rules of relating the attributes of these dimensions. The subject's task is to discover the basis of the scheme for classifying stimuli into instances and noninstances and to place each stimulus into one of these two categories. This kind of conceptual behavior is economical and efficient, since it allows one to code many diverse things into fewer categories and thereby simplify the understanding of the environment to some degree.

Concept learning can be divided into attribute and rule learning, or the combined learning of both of these. Attributes are the points on the dimensions of the concept, while the rules are the logical connections between various attributes. In attribute learning the subject's task is to identify the relevant attributes, while in rule learning he has to determine which particular rule is involved. Representative conceptual rules are described in Table 1, and assignment of stimulus patterns to response categories (positive or negative) for some of these rules are presented in Table 2.

Bourne (1967), in studying the rule learning aspect of concept learning, has found that adult subjects that solve such problems efficiently, or practiced subjects, use what could be described analytically as a truth-table strategy. This is a strategy of coding the entire stimulus population into four classes depending on the presence (or truth-value) or absence (or false-value) of the relevant attributes. So for example, the truth-table classification of a set of stimuli involving the two relevant attributes "red" and "square" would involve the following classifications: items that are both "red" and "square", or "True and True", items that are "red", but not "square", or "True and False", items that are not "red", but "square", or "False and True", and items that are neither "red" nor "square", or "False and False". For a subject to use this scheme properly would mean that he is correctly attending to the two relevant attributes, and that he is able to collapse over irrelevant variations of the stimuli. Irrelevant variations of the stimuli have no effect on the truth value of a stimulus or on the classification of a stimulus into instances or non-instances.

Once the subject has conceptually reduced the stimulus population to these four classes, it is then only a matter of associating a particular

Table 1

Conceptual rules describing partitions of stimulus populations with two relevant attributes (after Haygood and Bourne, 1965)

Basic Rule			Complementary Rule		
Name	Symbolic Description	Verbal Description	Name	Symbolic Description	Verbal Description
Affirmation	R	All red items are examples	Negation	$\bar{R}$	All not red items are examples
Conjunction	$R \cap S$	All red and square items	Alternative Denial	$\bar{R} \cup \bar{S}$	All items either not red or not square
Inclusive Disjunction	$R \cup S$	All items red or square or both	Joint Denial	$\bar{R} \cap \bar{S}$	All items neither red nor square
Conditional	$R \rightarrow S$	If the item is red then it must be square	Exclusion	$R \cap \bar{S}$	All items red and not square
Biconditional	$R \leftrightarrow S$	Red items if and only if they are square	Exclusive Disjunctive	$R \bar{\cup} S$	All items which are red or square but not both

Table 2

Assignment of stimulus patterns to positive (+) and negative (-) response categories for six of the rules described in Table 1 (relevant attributes are Red and Square).

Stimulus Class	Truth-table Notation	Example	Affir-mation	Conjunction	Inclusive Disjunction	Exclusive Disjunction	Con-ditional	Bicon-ditional
R S	T T	Red Square	+	+	+	-	+	+
R S	T F	Red Triangle	+	-	+	+	-	-
R S	F T	Blue Square	-	-	+	+	+	-
R S	F F	Blue Triangle	-	-	-	-	+	+

class of stimuli with either a positive or a negative label to respond correctly on the conceptual task.

The evidence for the existence and effectiveness of the truth-table strategy has come from inter-rule transfer experiments (Bourne, 1967), and from experiments in which the subjects were actually instructed in truth-table classifications (Dodd, et al., 1971), The kind of rules that are typically employed are disjunctive, conjunctive, conditional, and biconditional rules. These rules determine the various ways in which the four categories of the truth-table are assigned either as positive or negative instances of the concept. Theoretically, if the subject is given the relevant attributes, and if he understands these rules, he should require at the most one error for the placement of each truth-table category, since for any one rule the combination of positive and negative categories is unique. Bourne has found that in the first few problems of the inter-rule transfer experiments subjects often make more than one error for each of these stimulus categories, but that after several such problems the subject is able to solve the conceptual task with one or less errors per category. In experiments where the subject receives instructions in the truth-table strategy, subjects will often solve the task with a minimum number of errors.

Assuming a truth-table strategy, one variable that would be expected to affect the performance on rule learning tasks would be memory for relevant information. At the very least, the subject would be required to remember the outcome of two to four classes of stimulus configurations before he is able to solve the problem. While with practice the subject can usually perform adequately in this situation, at earlier stages the memory for previous instances seems to be poor. For this reason any condition that aids the subject's memory should facilitate performance, especially in the early stages of learning. Some experiments have shown that providing the subject with past instances as well as their outcomes by a memory aid significantly raises their performance on concept learning problems (Bourne, et al., 1969; Denny, 1969 and Pishkin, 1967).

An additional finding in these experiments was that the memory aid decreased the differences in difficulty between easy and difficult rules, which suggests that one reason why some rules are initially more difficult than others is that some stimuli and their outcomes for the harder rules are more difficult to remember than in the easy rule situation. In other words, certain stimulus-outcome configurations are more difficult to retain than others.

These kinds of data seem to indicate that the efficient solution of concept learning tasks requires the subject to code the stimulus population into the four categories of the truth-table. With such a reduction, solving the task can be considered a 4 - 2 item paired-associate task. Chumbley (1972) has presented a theory of concept learning which similarly divides concept learning into two component processes. In this theory the learner is seen as initially determining the relevant attributes which is followed by a paired-associate stage. According to the theory the subject first attempts to determine which dimensions and attributes are relevant, and then pairs the various stimulus classes (which may be the categories of the truth-table) with the appropriate response categories.

Prior to the efficient operation of the truth-table strategy there are reliable differences in difficulty among conceptual problems based on the various rules. Typically the order of difficulty goes from conjunctive, to disjunctive, to conditional, and to biconditional. The biconditional rule is the hardest to master and usually requires about twice as many trials to criterions as any other rule. A typical score in a biconditional rule learning task involving four trinary dimensions might be about 60 trials to solution (Bourne, 1967). For a disjunctive task it could be less than half of that. However, once the truth-table strategy has been mastered, either by direct tutoring or through inter-rule transfer, these initial differences among the rules are essentially eliminated. The behavior on conceptual problems at this stage appears to be directed by a set of rules that lead to the minimum number of instances to solve a particular problem.

Bourne has shown that the truth-table strategy that adults often exhibit in the inter-rule transfer experiments and in the truth-table pretraining experiments is less likely to be displayed by children. In a study illustrating this trend Bourne (1969a) gave adults and children of varying ages first several conceptual problems based on four basic rules, and then a sorting task based on the four categories of the truth-table. The results of the rule learning task showed the expected superiority of the older subjects. The adults solved the conjunctive rule learning task in fewer trials to criterion than the younger subjects. In the later sorting task the subject was given the two relevant attributes, and asked to sort the stimuli into four categories which were not specified. A correction procedure was used allowing the subject to observe the correct placements of stimuli. For the adults the previous rule learning experience greatly affected the performance on the truth-table sorting task, which can be taken as evidence that adult subjects evolved a truth-table approach through the multiple rule learning. For the children, however, especially the younger ones, there were some transfer effects from the prior rule learning, but the effect was not very strong. Unlike the adults, the children made repeated errors in the placements of stimuli in each of the four categories. This seems to indicate that the younger subjects did not generally acquire the truth-table strategy in the prior rule learning situation. The reason for this lack of transfer effects could be that the rule learning task was not too well suited for the acquisition of the truth-table strategy for these young children. The younger subjects probably were deficient, at the end of rule learning, in some of the basic skills necessary for the truth-table strategy; in addition to this deficit, there were high memory requirements in this task which were probably too great for the younger children to function well.

These two ways which could have led to the poorer performance of the younger subjects are inter-related in the sense that poor memory in this case may be partially a function of the lack of the truth-table strategy. Not only does a well-learned truth-table strategy facilitate in the logical elimination of various alternate rules in the rule learning task, but it should also facilitate the remembering of previous instances and their outcomes.

The impositions of the truth-table strategy on the stimulus set should facilitate the remembering of previous instances and their outcomes because it allows the subject to partition the stimulus set into the four categories of the truth table and to recall items by categories. This means that while overall recall should be improved, the greatest value, in terms of memory, of this strategy is that it focuses the subject's attention to the relevant aspects of the categories. In effect, recall for relevant information should be improved.

This kind of selective memory has actually been reported by Trabasso and Bower (1964) who found that when adult subjects were asked to recall previous items in a conceptual task, they typically recalled partial stimulus specifications. The important thing, however, in this study was that the partial information that was recalled was relevant to the concept being used.

In general, categorized items are more easily remembered than discrete and unrelated items. This effect holds for adults and to some extent as well for children, and the increase in amount of recall for related items is often several times larger than for unrelated items (Bousfield, 1953; Mandler, 1967). Subjects usually free-recall and produce related items by the categories they have perceived during the learning (or also the production) of the list. The recited list in such a task contains clusters of related items.

The performance of children in free-recall tasks has been shown to differ from that of adult subjects in terms of the degree of clustering. Children produce less clustering than adults, and for very young children (below the age of five to six years) there is sometimes no clustering at all (Neimark, et al., 1971; Rossi and Wittrock, 1971). Since the degree of clustering is strongly related to amount recalled, it is on the basis of this factor alone that a large proportion of the differences in recall associated with developmental level can be accounted for.

Related to this developmental trend in clustering is the finding that if the memory process is separated into acquisitions, storage, and retrieval, differences in memory performance between adults and children are located primarily in the acquisition stage. Belmont and Butterfield (1968) separated forgetting from acquisition and retrieval processes by providing retention tests at several time intervals after the presentation of the stimulus material. Their rationale for this separation was that a retention test immediately after the presentation of the stimulus material provides measures for acquisition and retrieval processes, and that later tests provide information about forgetting. Several studies (Belmont, 1967; Belmont and Butterfield, 1968) have presented evidence that for subjects aged 8 - 20 years, and for both verbal and perceptual material, there are no differences in the slope of the forgetting curves for the different age groups. If the level of acquisition of material is controlled, then the different age groups forget the material at the same rate over time. In further studies, Belmont and Butterfield (1968) have shown that obtained age differences in memory may be primarily due to differences in acquisition strategies. In one of their experiments the subject's task was to memorize the serial position of items in a nine item list. Following the self-paced learning of the list the subject had to indicate the serial position of a test item. The apparatus was set up to record several responses of the subject, including temporal variables such as the self-pacing during learning, and the latency to respond to items. On the basis of hesitation patterns (in the learning stage) and corroboration by verbal reports it was found that college students learned the lists usually in chunks of three items. Students younger than thirteen years however appeared to learn the items individually.

These data by Belmont suggest that a major cause for observed memory differences between children and adults is that the adults apply various organizations, in the acquisition stage, on the material to be recalled. Children, however, are more likely to remember such material in terms of discrete entities. Similar data has been reported by Flavell, Fredricks, and Hoyt (1970) in a study characterizing developmental changes in memorization processes in young subjects ranging in age from the nursery school to grade four level. In a serial recall task this study found that the younger subjects differed from the older ones primarily in terms of the level and kind of activities accompanying memorization: the younger subjects made fewer naming and anticipation responses, and also showed less active rehearsal. These studies show that a major difference in memory processes between adults and children occurs during acquisition, where adults (and older children) have learned to utilize strategies and techniques to organize and simplify diverse information and to actively rehearse the material. Such a view of adult remembering is consonant with current studies of recalling verbal material over short term intervals. For example, Waugh (1972) has identified selective rehearsal and reorganization of stimuli as some of the active processes of organizations occurring in the remembering of a list of words.

Of course, there are developmental differences in memory due to other developmental factors, as can be seen by the fact that digit recall on the Wechsler Intelligence Scale (Wechsler, 1949) is a reliable item for the determination of mental age indices. But for the age range of 6 - 16 years, these differences are smaller than the kind of differences associated with the factors discussed above.

If there are demonstrable developmental differences in memory processes in verbal learning tasks, there may also be such differences in concept learning tasks, which involve memory processes. When a subject solves a concept learning problem he typically utilizes information from previous stimuli. The solution of attribute and rule learning conceptual problems could conceivably occur without memory for specific stimulus outcome information. Early theories of concept learning (Bower and Trabasso, 1964a; Restle, 1962) assumed such a situation. These theories were characterized as "no memory" theories of concept learning since they assumed that a subject could solve a conceptual problem without remembering any previous instance and its outcome. These theories stated that a subject would randomly guess (on the basis of the perceived dimensions of the stimulus population) at a hypothesis and respond to stimuli according to this hypothesis until he encountered an error. Following an error trial the subject would again randomly select another possible hypothesis. This process of hypothesis testing would continue until the subject selected the correct hypothesis and thus would make no further errors.

Subsequent studies (e.g., Trabasso and Bower, 1964) however have shown that subjects do remember and utilize previous stimulus-outcome information when solving attribute learning tasks. Other studies testing the "no memory" assumption have shown that misinformation feedback decreases performance (e.g., Erickson, 1968), and that subjects perform poorer when they have to solve several conceptual tasks simultaneously (e.g., Restle and Emmerick, 1966). These kind of studies can be interpreted as indicating that typically subjects use some limited information about previous events in conceptual tasks, and that any manipulation to interfere (via misinformation or multiple tasks) with the remembering of this information hampers concept learning. One reaction to these kind of data was a model of concept learning by Trabasso and Bower (1968) in which the subject is seen as remembering nothing but the most recent stimulus. Such a 'local consistency' model still however does not account for data which show that subjects remember more about previous events than just the preceding stimulus (e.g., Cahill and Hovland, 1960).

Most current theories of concept learning view the subject as solving a conceptual task through a hypothesis testing procedure, as proposed by Bruner, Goodnow, and Austin (1956). According to such hypothesis testing theories (e.g., Restle, 1962; Hunt, 1962), the subject solves a conceptual problem by evaluating various alternative guesses of the correct categorization rule. Such guesses are guided by information contained in previous stimulus and outcome events.

Hypothesis testing models of concept learning that assume some limited memory for preceding events appear more plausible than the "no memory" models in view of studies that show the subject retaining and utilizing prior instance information. These models differ in terms of how much remembered information they ascribe to the subject. However, the efficient adult subject remembers and utilizes more than simply the outcome of a trial according to current theories of concept learning (e.g., Williams, 1971). In order to attain the solution of a conceptual task the subject is assumed to make inferences about the solution from previously presented instances. Such inferences are not likely to be random guesses, but are based on the information contained in the preceding events. Of course, memory for previous stimulus-outcome information is not considered to be perfect, but even partially retained information can narrow down the number of likely solutions. Support for such a view of the role of memory in concept learning derives from studies using artificial memories, where preceding stimuli and their outcomes are kept within view of the subject (e.g., Bourne, et al., 1969; Pishkin, 1967). In these studies the visual availability of previously presented information (which obviated remembering such information) improves performance on conceptual tasks.

Since the efficient solution of conceptual problems requires some memory for preceding events, how do adults and younger subjects retain such information? At present studies on the role of memory in concept learning have not specifically examined how subjects remember such information. One model with assumptions about memory processes in concept learning has been proposed by Williams (1971). The model specifies that selected stimulus information is retained in a buffer store of short duration, and that information about tested hypothesis is retained in a separate store of longer duration. This model however fails to consider and specify how stimulus and outcome information is retained and utilized beyond the short interval of a buffer storage. Bourne has suggested that further studies in this area are necessary: "We suspect that in the future, investigators of concept learning will begin to turn their attention to the strategies and techniques that subjects possess or acquire for retaining solution-relevant information over time" (Bourne, Ekstrand, and Dominowski, 1971, p. 237).

One major purpose of the present study is to evaluate the utility of one such strategy that subjects acquire developmentally that may be an aid for retaining solution-relevant information in concept learning. Studies on developmental changes in memory (e.g., Belmont and Butterfield, 1968; Flavell, Fredricks, and Hoyt, 1970; Neimark, Slotnick, and Ulrick, 1971; Rossi and Wittrock, 1971) have pointed to organizational and rehearsal factors as major determiners of developmental differences in memory. These studies have shown that older children and adults have ready strategies for actively organizing material to be recalled, while young children often lack such strategies. One kind of strategy that can conceivably provide an organizing structure for the remembering of solution-relevant information in concept learning tasks is the truth-table strategy. In the typical concept learning experiments the total stimulus set often consists of up to 100 stimuli - the various combinations of several binary or trinary stimulus dimensions. By partitioning these various stimuli into four or fewer truth-table categories, subjects who use this strategy should benefit in terms of facilitated recall of information about previously presented stimuli and outcomes necessary to solve the conceptual problem.

Studies on developmental changes in memory have shown that young children's recall is considerably poorer than older subjects primarily because of a deficit in organizational strategies. Such developmental recall differences, while they have not specifically been shown there, can reasonably be expected for the memory requirements involved in solving conceptual tasks. Also, developmental studies by Bourne (1969a) have indicated that young subjects generally lack the truth-table strategy when solving conceptual rule learning problems, while older subjects often exhibit the utilization of this strategy. Since these two component activities, recall of solution-relevant information about previously presented items, and the truth-table strategy, have been shown to characterize the efficient solution by adults of complex conceptual tasks, it is proposed that the demonstrated deficit of these two component activities in young children accounts for a large proportion of the observed performance differences in complex conceptual behavior that are associated with age.

The present study was designed to evaluate the proposed developmental relationship between two component activities, truth-table classification and recall of solution-relevant information, and performance on conceptual rule learning tasks. The main purposes of the study were to determine: (1) the developmental changes that occur in the role of these component activities in concept learning, and (2) the extent to which the conceptual performance of the younger subjects could be improved to the level of that of the adult subjects through manipulation of the component activities.

The study was carried out with subjects at three developmental levels; grade two, seven and twelve. Truth-table classification ability was manipulated in this study by a short training program designed for the acquisition of this strategy. All subjects either received this pretraining or 'dimensional' pretraining which familiarized the subjects with the dimensions of the stimulus set in order to provide perceptual experience with the stimuli equivalent to the truth-table pretraining. Memory for previous events was manipulated by an artificial memory aid which displayed the information of previous trials. With such an aid (in the 'memory aid' condition) the subject has visual access to all previously presented stimuli and their categorizations, and without this aid (in the 'no memory aid' condition) the subject had to rely on his own memory for such information. The conceptual task in the present experiment was a rule learning task based on the exclusive-disjunctive rule. From this design several general expectations about the outcome of the study were derived on the basis of the results of prior experiments, Bourne et al.'s (1971) model of concept learning, and the proposed developmental relationship of two component activities of concept learning and performance on conceptual tasks.

An exclusive-disjunctive rule learning task is of intermediate difficulty (Denny, 1969), and consequently was expected to be of considerable difficulty for the youngest (grade two) subjects in the present study. It was therefore expected that there would be an increase in performance (as measured by trials to criterion) as the grade level of the subjects increases. Such a developmental increase in performance is an obvious expectation and has been reported for a variety of conceptual rule learning tasks and ages (e.g., Bourne and O'Banion, 1971).

Previous studies on the effect of truth-table pretraining have indicated facilitory effects on conceptual performance for adults (Dodd et al., 1971) as well as for children (Bourne, 1969a). For young children (mean age of 5.5 years) this effect is small or non-existent, but children aged about 7.5 years benefit from such pretraining. On the basis of these studies it was expected that the truth-table pretraining would increase the performance of all subjects, including the lowest grade level group, whose mean age was 7.8 years.

The effect of the artificial memory aid was expected to depend on an interaction with grade level and type of pretraining. While for the grade twelve subjects the memory aid was expected to faciliate performance, as has been indicated in previous studies (e.g., Bourne, Ekstrand, and Montgomery, 1969), for the grade two students the memory aid alone was not expected to significantly increase performance on the conceptual task. The reason for this expected lack of facilitation of the memory aid is that the grade two subjects are thought (on the basis of the present analysis) to lack the kind of organizational skills necessary for the evaluation and use of the displayed stimulus set. In other words, the various colors, sizes, and shapes of the stimuli are likely to overwhelm and confuse, at least initially, rather than aid in the solution of the problem. However, the prior truth-table training should provide the child with the necessary skills to impose some order on this multidimensional stimulus array and enable him to utilize the memory aid efficiently.

Finally, it was expected that the joint effect of the truth-table pretraining and the memory aid will increase the conceptual performance of the younger children to that of the grade twelve subjects. If the conceptual performance of the younger subjects who have had both the truth-table pretraining and the memory aid approaches the level of performance of the adult subjects in this condition, then it may be concluded that these two variables are the ones primarily involved in the age-related performance differences in conceptual rule learning.

These general expectations of the outcomes of the study make certain assumptions about the nature of cognitive development, particularly in the area of conceptual development. They imply that (1) this kind of behavior can be conceptually separated into broad component activities, (2) these component activities follow a determinable developmental course, and (3) the developmental course of the component activities can be altered by experimental manipulations. Piaget (1953) has to a large extent initiated the current interest in cognitive development, especially in the area of conceptual development. His view on cognitive development however is that the development of cognitive skills cannot be significantly altered by special training procedures. According to Piaget, while such training may lead to local improvements in the performance of a particular skill, gains are only short-term and do not generalize to other related skills. Because of these different expectations about the effect of special training on conceptual development, the outcome of the present study may have implications on the issue of the role of learning and experience in conceptual development.

Method

Subjects

The subjects were 120 students from the Edmonton Public School system. There were 40 grade two students ranging in age from 7.4 to 8.3 years (mean age: 7.8 years; SD = 0.3), 40 grade seven students ranging in age from 12.0 to 13.9 years (mean age: 12.9 years; SD = 0.6), and 40 grade twelve students ranging in age from 16.6 to 20.3 years (mean age: 17.9 years; SD = 0.8). The subjects were selected from three schools located in lower middle class and middle class residential districts. The schools were Avonmore and Parkview Elementary and Junior High Schools and Harry Ainlay High School. Since no attempt was made to equate the three schools in terms of the socio-economic level of its students other than the approximate designation 'lower middle to middle class', it is possible that there may be some bias inherent in the results of the study. It may be that the grade twelve students came from a higher socio-economic background than the grade two and seven subjects, who came from two schools in different parts of the city. The most likely source of the differences would be differences in general intelligence, since high IQ subjects have been shown to perform better on conceptual tasks than low IQ subjects (Denny, 1966). However, if differences in IQ as a result of differences in socio-economic levels were present in the three schools, they are believed to be slight, since the differences in socio-economic levels between the schools were not very great.

Within each grade, assignment to the four experimental conditions was by random selection procedures with one restriction being that an equal number of boys and girls were chosen for each experimental condition. All the students in each grade level were numbered (the first person on the class lists were assigned the number 1, the second person on the class list the number 2, etc.), and then with a table of random numbers 40 subjects in each grade level were selected with the restriction that there were 20 boys and 20 girls. These randomly selected students were then divided into the four experimental groups within each grade level by assigning the first selected student to the first experimental group, the second student to the second group, etc., according to the pattern a - b - c - d - d - c - b - a, etc. Again the restrictions in this assignment was that there were an equal number of boys and girls in each of the four experimental conditions. One grade two subject was excluded because she was unable to complete the training condition.

<u>Design and Procedure</u>

The design of the study was a three-way factorial in which the independent (and organismic) variables were memory load conditions (two levels: memory-aid [M] and 'no memory-aid' [N], pretraining (two levels: truth-table pretraining [T] and dimensional pretraining (D], and grade level (three levels: grade two [2], seven [7], and twelve [12]). This factorial design created twelve independent groups each with ten randomly assigned subjects.

The twelve experimental groups can be mnemonically identified by the letters and numbers presented above in brackets after each attribute name. For example, the grade two subjects that were in the memory aid and dimensional pretraining conditions are identified by the abbreviation 2MD, with grade level being the first index, memory conditions being the second index, and pretraining condition being the third index. Thus, the twelve groups can be identified in the following manner: 2MT, 2MD, 2NT, 2ND; 7MT, 7MD, 7NT, 7ND: 12MT, 12MD, 12NT, and 12ND.

The experiment contained three consecutive tasks: a pretraining task (i.e., truth-table or dimensional pretraining), the practice rule learning task of a conceptual problem based on the conjunctive rule, and the rule learning task of a conceptual problem based on the exclusive disjunctive rule. Each of these tasks will be described separately and consecutively.

Each subject performed individually in the experiment. The time required for administration of the complete experimental procedure ranged between 15 - 50 minutes. The experiment was carried out at the three schools. Every subject received general instructions about the task indicating that it was a card sorting task, and describing the three values on each of the four geometric dimensions. Subjects receiving dimensional pretraining were given 60 cards and were asked to sort them into three categories corresponding to the three attributes of the four stimulus dimensions. Subjects sorted the stimulus cards according to only one dimension at a time. Each subject sorted 15 cards for each dimension. Instructions for all tasks are presented in the Appendix.

The remainder of the subjects received truth-table instructions. Each subject in this condition solved two truth-table sorting problems. In the first problem the two relevant attributes were "red" and "triangle", in the second problem the two relevant attributes were "yellow" and "square". The subjects were asked to sort a total of 60 cards for the two problems into four boxes depending on the presence or absence of the two relevant attributes. One box was designated by the joint presence of both relevant attributes or joint truth value (T-T); two boxes were designated by the presence of only one or the other relevant attributes (T-F and F-T); and the fourth box was designated by the absence of both relevant attributes (F-F). In the first truth-table task the four boxes were described verbally and were also labeled pictorially; for the second problem the four boxes were identified only verbally. To ensure that the subjects understood the task they were asked, prior to sorting, to name the four categories and to describe the cards in these categories.

To provide the subjects, particularly the younger subjects, with some familiarity with solving concept learning problems, following pretraining all subjects were given the practice rule learning problem. In this problem the subjects were given two relevant attributes "red" and "square", and were asked to solve the problem which was based on the conjunctive rule. Instances of the concept were called "winners: and noninstances were called "losers". Subjects were asked to predict the outcomes of one trial at a time. Stimuli were presented one at a time to the subjects until they had reached a criterion of 16 consecutive correct predictions. The stimuli were presented to the subject manually by the experimenter on a table between E and S. Feedback in terms of the proper categorization of a stimulus and the correctness of the subject's prediction was given verbally by the experimenter. After every nine trials the subjects were asked to describe the winners.

The practice problem was given to provide all subjects with some familiarity in the solutions of a conceptual rule learning task. Such familiarity is necessary to ensure that the task is approached as a rule learning task rather than as a less specific problem solving task, in which the subject may know neither the required rule nor other components of the task, such as the type of problem and the type of solution required. The inclusion of the practice task was intended to ensure that the test task involved primarily rule learning for all subjects.

Following the conjunctive rule learning task subjects in the truth-table pretraining condition were instructed in the relevance of the truth-table strategy in the solution of rule learning tasks. This was done by showing how the conjunctive problem would be solved in terms of the four-way truth-table classification, and indicating the possibility of other instance-noninstance combinations.

To ensure that the subjects receiving truth-table pretraining were not favored on the test task by instructions which may have produced a set to expect a rule other than the conjunctive one, all subjects were told to expect some other rule. In spite of these instructions, the first time a stimulus in the T-T category was presented during the test task, the majority of subjects that had received truth-table pretraining (63.3%) and subjects that had received dimensional pretraining (71.1%) gave an error response, suggesting that they still retained a conjunctive hypothesis (some other hypotheses are also not incompatible with such a response, but are unlikely). These percentages of errors also indicate that the type of pretraining did not appear to have any differential effect on the prevalence of the conjunctive hypothesis at the beginning of the test task. One additional characteristic of the task further indicates that possible differences between experimental conditions in the presence of a conjunctive hypothesis at the beginning of the test task would not be important. Since a T-T category item was the second item presented in the test task, the opportunity to discard a conjunctive hypothesis was present from the onset of the task. This means that whether or not the subject at the beginning of the test task expected a conjunctive or a non-conjunctive rule would make little difference in terms of trials to criterion.

Next, all subjects were presented with the test problem. The two relevant attributes, "blue" and "square" were specified and were displayed on top of the board holding the stimulus cards. The rule in this task was the exclusive disjunctive rule. As in the prior conjunctive task instances of the concept were called winners but now had happy faces under the stimulus cards, and noninstances were called losers and were matched with sad faces. Subjects were asked to predict the outcome of one trial at a time. Following a prediction the picture under the stimulus card was exposed. This picture and verbal feedback from the experimenter provided the subject with information about the categorization of the stimulus (whether it was a winner or a loser) and also with information about the correctness of the subject's judgment. All stimuli in the test problem were presented to the subject on a board (described in the Stimulus Material section). Stimuli were presented until the subject had successfully predicted the outcome of 15 out of 16 consecutive trials. After every row of nine stimuli the subject was asked to describe the winners. Subjects in the "No Memory-Aid" condition were visually exposed to only one stimulus and one outcome at a time. Subjects in the "Memory-Aid" condition were visually exposed to all previously presented stimuli and outcomes.

The dependent measures collected in this study were trials to criterion on the practice rule learning task, and, on the test rule learning task, errors, trials to criterion, and the number of category solution descriptions. Category solution description refers to the way in which the subject described the solution to the conceptual problem. Following every nine trials on the concept learning tasks the subjects were asked to describe the solution of the task. If the verbal description of the solution contained categories of instances (e.g., "all blue shapes") it was scored as a category solution description. If the verbal description of the solution contained only references to specific instances (e.g., "blue square") it was scored as a specific instance solution description.

Stimulus Material

The stimuli were geometric forms mounted on 3 x 5 inch cards. The stimulus population consisted of all 81 possible patterns generated by four three-valued dimensions: form (triangle, square, circle), color (blue, red, yellow), size (small or height of 1 cm., medium or height of 2 cm., and large or height of 3 cm.), and number (one, two or three forms). For the pretraining task and the practice problem task these cards were sorted manually by the subject and the experimenter. In the pretraining task the subject sorted the cards into a box divided into four compartments corresponding to the four categories of the truth-table. In the practice problem task the experimenter presented one card at a time to the subject on a table in front of the subject.

For the test problem task cards were presented on a 4.5 x 4.5 foot board. All 81 stimuli were on this board. Under each card was a picture of either a happy face which was colored green or a sad face colored white. Instances of the concept were matched with happy faces, noninstances with sad faces. Both the stimulus cards and the faces were covered by separate aluminum covers which could be easily snapped on and off by the experimenter. The subject was seated three to four feet in front of the board. The order of stimuli presented to the subjects was constant for all subjects.

Results

The results are presented in terms of five dependent variables: (1) trials to criterion on the practice problem; and for the test problem, (2) trials to criterion, (3) total errors, (4) error types, and (5) type of solution description. The second and third dependent variables are considered the major indices of conceptual performance in this study. The fourth and fifth dependent variables provide two ways of describing the process through which subjects solved the conceptual task. The variances of the first three of the five dependent variables were heterogeneous as indicated by the F-Max test (Winer, 1971). The reason for this heterogeneity appeared to be that the means and standard deviations tended to be proportional (the correlations between the means and standard deviations were $r = .95$, $r = .91$, and $r = .93$ for these dependent variables. Homogeneity of these variances were obtained when an inverse transformation was performed on the trials to criterion data on the practice task, and logarithmic transformations on the trials to criterion and total error data on the test task were performed as suggested by Edwards (1964, p. 130). Analyses of variances were carried out on the transformed data. The raw data, and the means and standard deviations of the transformed data are presented in the Appendix.

An analysis of variance of the transformed trials to criterion on the practice task indicated that both the grade level, $F(2,108) = 6.22$, $p < .01$, and type of pretraining, $F(1,108) = 18.54$, $p < .01$, significantly affected performance on the practice problem. The upper grade subjects performed better on this task than the lower grade subjects, and subjects that had received the truth-table pretraining performed better than those that had received dimensional pretraining. In addition there was a significant interaction between grade level and type of pretraining, $F(2,108) = 5.38$, $p < .01$, such that the effect of the truth-table pretraining was more effective in improving performance for the lower grades than for the upper grades. However, it should be pointed out that the grade twelve subjects were performing near the maximum level possible. The minimum number of trials to criterion was 16, and the data show that the grade twelve subjects performed near that level. The focus of the study was on the performance on the test task, but the results of the practice task indicate the effect of two of the independent variables even on a relatively simple conceptual task. Group means for this analysis are presented in Table 3, and complete analysis of variance tables for all analyses are presented in the Appendix.

The analyses of variance of trials to criterion and total errors on the test task (the exclusive disjunctive rule learning task) are presented separately, although both analyses yielded the same results except for one significant effect. Both of these measures are considered the major, and equivalent indices of performance on the conceptual task. Figure 1 presents the mean number of trials to criterion indicating grade level and type of experimental condition. All three independent variables affected the trials to criterion performance on the test task. Subjects who were in the upper level grades, the memory aid condition, and the truth-table pretraining condition reached criterion in fewer trials than subjects in lower grades, $F(2,108) = 12.85$, $p < .01$, the 'no memory' condition, $F(1,108) = 13.82$, $p < .01$, and the dimensional pretraining condition, $F(1,108) =$

Table 3

Mean number of trials to criterion on the practice task for the twelve experimental groups (standard deviations are in brackets below the means).

	Grade					
	2		7		12	
	Pretraining		Pretraining		Pretraining	
Memory	T	D	T	D	T	D
M	17.0	20.3	16.9	21.8	17.1	18.3
	(1.5)	(3.9)	(1.9)	(8.1)	(2.1)	(3.0)
N	17.2	25.3	16.7	17.5	16.9	16.3
	(2.3)	(8.7)	(1.6)	(3.6)	(1.4)	(0.7)

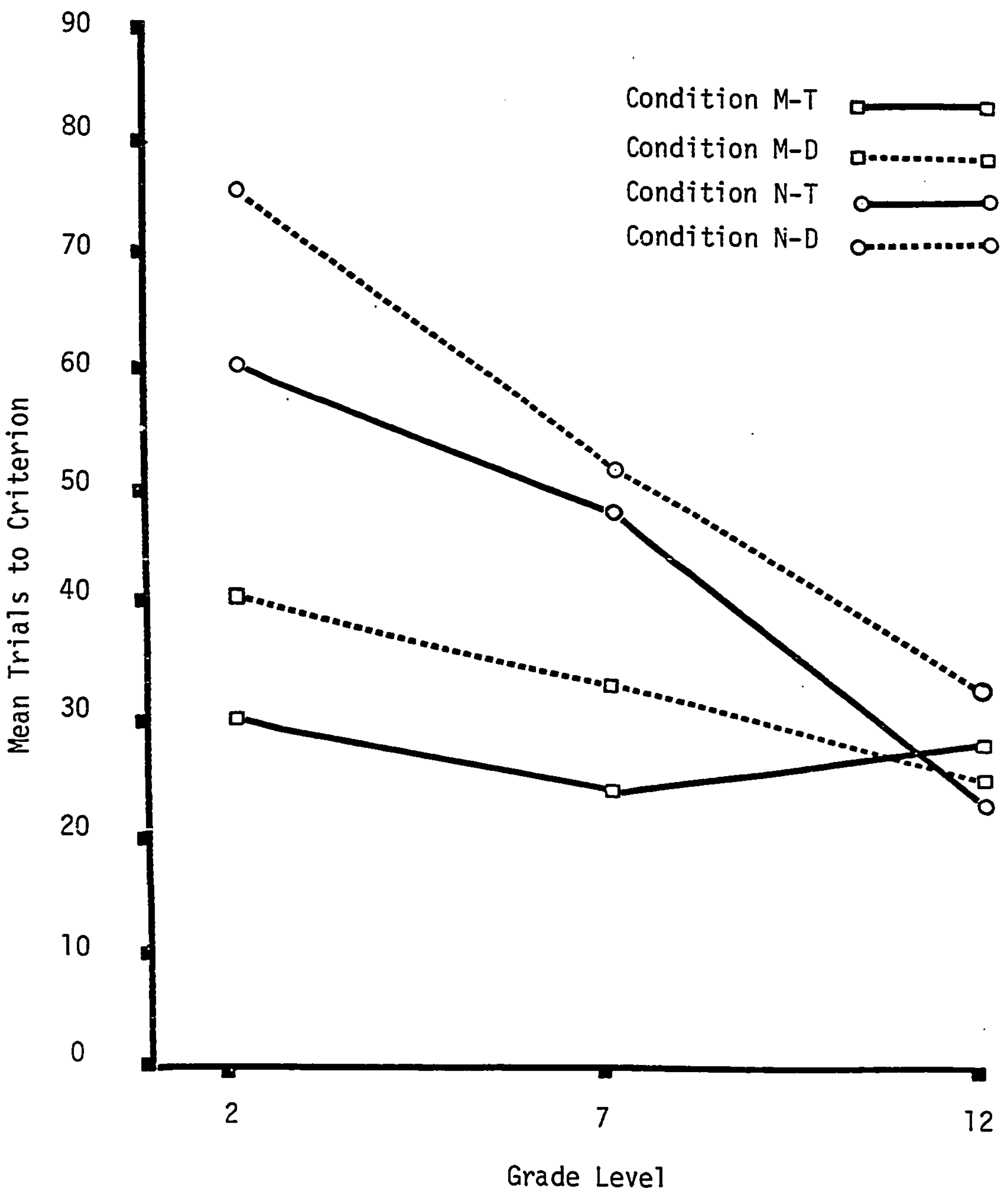

Figure 1. Mean trials to criterion on test task.

5.82, $p < .05$, respectively. In addition to these main effects there was a significant interaction between grade level and memory aid condition $F(2,108) = 3.19$, $p < .05$, such that the effect of the memory aid was greater for the lower grade subjects than the higher grade subjects. These results conform to the general expectations of the outcome of the study, except for the results involving the memory aid conditions, where an interaction between all three independent variables was expected.

The analysis of variance of the total number of errors on the test task similarly indicated main effects for grade level, $F(2,108) = 9.43$, $p < .01$, memory aid condition, $F(1,108) = 13.11$, $p < .01$, pretraining condition, $F(1,108) = 4.96$, $p < .05$; however the interaction between grade and memory condition was nonsignificant. Table 5 presents the means of the total number of errors. The analysis of total errors yielded equivalent results to the trials to criterion data (i.e., conditions that reached criterion in fewer trials made fewer errors) with the one noted difference in results.

A further analysis of variance was carried out on the type of solution description the subjects reported on every nineth trial. It was thought that the experimental groups would differ in these descriptions as a result of the three independent variables. The solution descriptions by the subjects were analyzed in terms of whether categorical responses were given or whether descriptions of individual stimuli were used to verbalize the solution to the conceptual problem. For each subject the number of category solutions and the number of specific stimuli solutions were determined and from these numbers the percentage of category solutions were calculated. An analysis of variance of the percentage scores

Table 4

Mean number of trials to criterion on the test task for the twelve experimental groups (standard deviations are in brackets below the means).

	Grade					
	2		7		12	
	Pretraining		Pretraining		Pretraining	
Memory	T	D	T	D	T	D
M	30.4	41.6	24.7	33.5	28.1	25.4
	(7.5)	(11.9)	(6.4)	(11.9)	(7.7)	(5.1)
N	60.4	75.1	47.2	52.1	23.7	31.8
	(40.5)	(58.1)	(34.2)	(29.9)	(4.6)	(12.6)

Table 5

Mean total errors on the test task for the twelve experimental groups (standard deviations are in brackets below the means).

	Grade					
	2		7		12	
	Pretraining		Pretraining		Pretraining	
Memory	T	D	T	D	T	D
M	6.0 (2.6)	10.9 (5.7)	4.7 (2.3)	7.3 (5.3)	4.5 (2.3)	4.4 (2.0)
N	19.8 (17.0)	24.3 (18.2)	13.0 (12.2)	12.2 (8.8)	4.9 (2.1)	6.5 (2.6)

indicated that higher grade subjects gave more categorized solutions, $F(2,108) = 10.85$, $p < .01$, than lower grade subjects. Table 6 presents the means of this analysis.

An additional analysis of the error data was suggested by the results of an experiment by Furth, et al., (1970) in which performance on a conceptual rule task was evaluated in terms of number of subjects correctly responding to stimuli within each of the four categories of the truth-table. This method of analysis gives more exact indications of the source of difficulty on such a task (i.e., what kind of stimuli provide the greatest difficulty). In the present experiment this method of analysis was modified by analyzing the number of errors within each category of the truth-table. For each subject error responses were categorized according to the four categories of the truth-table classification of the stimuli. For example, an error response to a stimulus that contained both relevant attributes (and therefore belongs in the first category of the four truth-table categories) was designed as a Type 1 error. Every subject therefore had four dependent variable scores since there were four error response categories. Table 7 presents the means for the four error types. This data was analyzed by a multivariate analysis of variance.[1] The multivariate analysis of variance is analogous to a regular, univariate analysis of variance in that it performs tests of significance of difference between means. However, whereas in the univariate analysis of variance there is a single mean for every condition (since there is only one dependent variable), in the multivariate analysis of variance there may be several means in each condition (since there may be more than one dependent variable). The aim of the multivariate analysis of variance is to

Table 6

Mean percent of category solutions on test task for the twelve experimental groups (standard deviations are in brackets below the means).

	Grade					
	2		7		12	
	Pretraining		Pretraining		Pretraining	
Memory	T	D	T	D	T	D
M	29.0	53.3	32.5	32.3	72.2	76.8
	(41.7)	(44.2)	(47.2)	(27.1)	(40.9)	(32.3)
N	38.7	40.6	33.7	60.7	72.3	86.0
	(44.1)	(44.3)	(43.8)	(43.3)	(42.4)	(31.7)

Table 7

Mean number of errors in each category for the four experimental groups and the three grade levels (N = 10 for each entry)

Condition		Grade 2, Type of Error 1	2	3	4	Grade 7, Type of Error 1	2	3	4	Grade 12, Type of Error 1	2	3	4
MT	$\bar{X}$	1.10	1.70	1.70	1.50	0.90	1.90	1.00	0.90	0.90	1.70	1.30	0.60
	SD	0.87	0.95	0.82	1.08	0.56	0.99	0.82	1.10	0.99	0.94	0.48	0.84
MD	$\bar{X}$	3.10	2.20	2.80	2.80	2.20	2.40	2.20	0.50	1.30	1.70	1.20	0.20
	SD	1.73	1.13	1.40	2.53	1.23	1.57	2.57	0.85	0.94	1.05	0.92	0.42
NT	$\bar{X}$	4.10	4.00	4.30	7.40	3.20	2.90	2.20	4.70	1.10	2.00	0.90	0.90
	SD	2.18	4.32	5.77	6.31	2.04	2.68	2.04	6.29	0.74	0.82	0.56	1.19
ND	$\bar{X}$	6.70	6.10	4.20	7.30	3.90	3.60	3.00	1.70	2.40	1.60	1.60	1.00
	SD	4.08	3.87	4.30	9.01	2.42	2.79	3.82	3.05	0.96	0.96	1.77	0.94

Condition codes: M = memory aid T = truth-table pretraining

N = no memory aid D = dimensional pretraining determine if the string or vector of means within one condition differs significantly from the vector of means of another condition. Individual comparisons between means may then be carried out to determine the locus of these differences. The analysis indicated that all three main effects were significant. (F-ratios are in terms of Raos Approximate F-test using Wilks Lambda.) The vector of means of the four types of errors differed for the three grade levels, $F(8,210) = 4.27$, $p < .001$, memory condition, $F(1,105) = 9.00$, $p < .001$, and training condition, $F(1,105) = 8.18$, $p < .001$. Figure 2 presents the four error type means of each grade level. Figure 2 indicates that there is a general decrease in all errors as grades increase, as was previously indicated in the analysis of total errors. In addition however, Figure 2 indicates that the one error type that changes drastically in difficulty across age is error Type 4. Type 4 instances are most difficult for the grade 2 subjects and least difficult for the grade 12 subjects. Tables 8 and 9 present the mean error types for the two memory conditions and the two pretraining conditions.

The multivariate analysis of variance of the four error type scores indicated that the vector of four means differed significantly for the three independent variables, grade level, memory condition, and pretraining condition. However, this analysis does not indicate the locus or form of these differences, particularly for the grade effect, since it could be meaningfully interpreted. In order to gain more information about the form or pattern of differences of means for the three grade levels, a one-way profile analysis was carried out on the effect of grade level on error type scores.[2] This analysis provides a test of parallelism of the four independent variables for the three values of the grade variable.

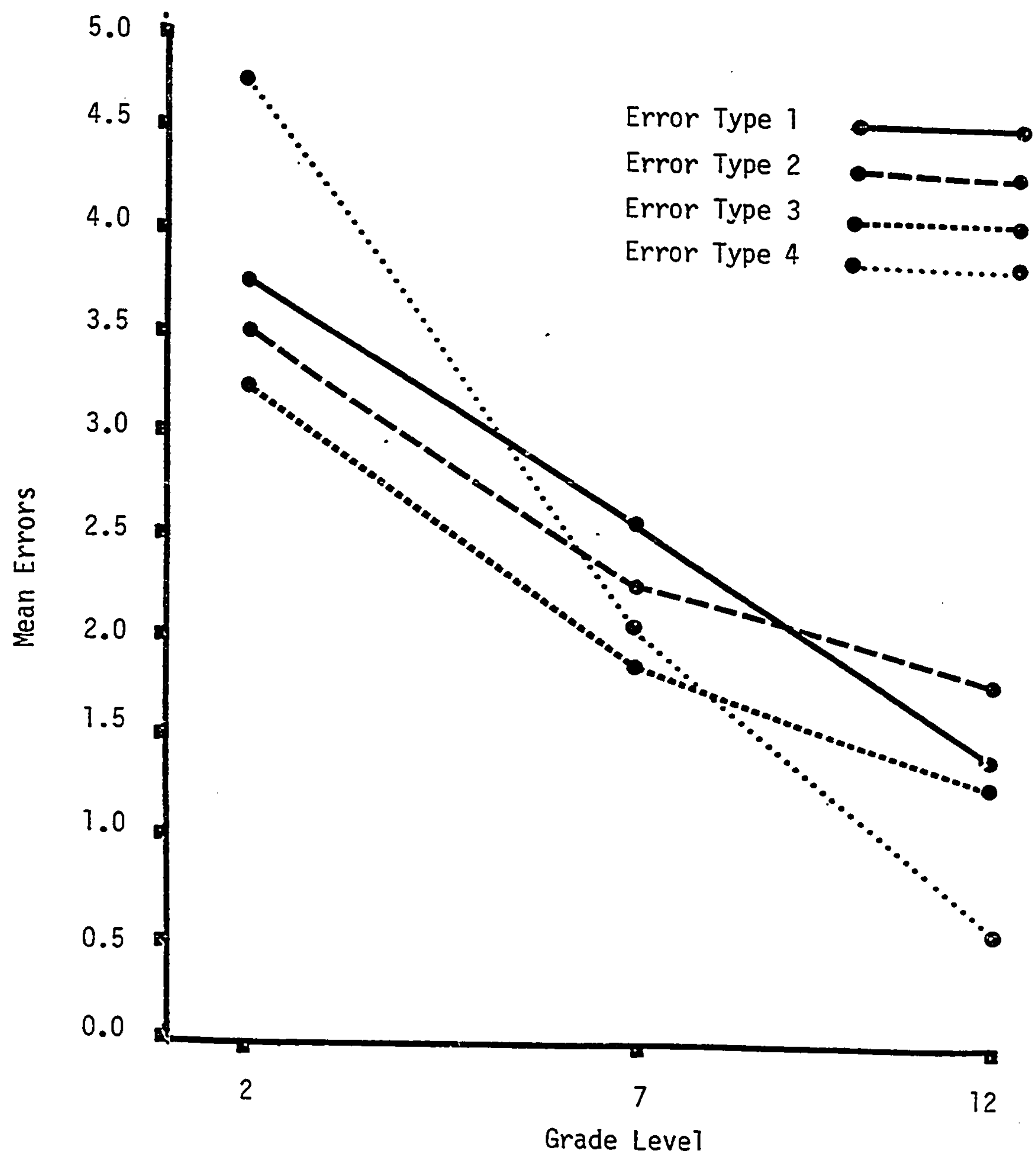

Figure 2. Mean number of errors within each error type category for the three grade levels.

Table 8

Mean number of errors in each error category for the two memory conditions.

	Memory Aid				No Memory Aid			
	Type of Error				Type of Error			
	1	2	3	4	1	2	3	4
$\bar{X}$	1.58	1.93	1.70	1.08	3.56	3.36	2.68	3.83
SD	1.34	1.11	1.44	1.53	2.83	3.14	3.59	5.84

Table 9

Mean number of errors in each error category for the two pretraining conditions.

	Truth-table Pretraining				Dimensional Pretraining			
	Type of Error				Type of Error			
	1	2	3	4	1	2	3	4
$\bar{X}$	1.88	2.36	1.90	2.67	3.27	2.93	2.50	2.25
SD	1.85	2.28	2.71	4.39	2.73	2.61	2.83	4.58

The test for parallelism indicated a marginally significant deviation from parallelism (Raos Approximate, $F(6,230) = 2.05$, $p < .06$). Reference to Figure 2 shows that this effect is mostly due to the changes of the number of Type 4 errors across the three grade levels (the other three error types decrease parallel across the three grade levels).

No further tests were performed on the other two main effects, memory and pretraining condition, since they could not be meaningfully interpreted.

Discussion

The general aims of this study were to characterize cross-sectionally the developmental progression of one type of conceptual behavior (conceptual rule learning), and to attempt to modify this progression by experimental manipulations.

The results indicate that for the particular conceptual behavior observed there are regular developmental changes. On the practice task, which involved the rule learning of a conjunctive concept, small but consistent grade or age effects were found in terms of trials to criterion. The differences between the grade levels were small probably because the task was easy for most subjects, as is indicated by the means of the trials to criterion scores. Even for the grade two subjects the mean trials to criterion was just a few trials above the minimum value (16 trials).

Larger grade differences were found on the test task, which involved the rule learning problem of an exclusive disjunctive concept. This task is moderately difficult even for grade twelve students, as is indicated by the mean number of trials to criterion for the grade twelve students that received neither truth-table pretraining nor the memory aid. The mean for this group was 31.8 trials to criterion and a mean of 6.5 errors. These errors were distributed evenly across the four error categories except for the first category which contained more than the others. Since the conceptual problem could be solved with a minimum of 4 errors (one in each error category) or less, the data indicate the difficulty of this task and also that the subjects were less than optimally efficient in their solution of this problem.

The difficulty of the exclusive disjunctive rule is also indicated by the results of other studies. In difficulty it lies between the easier inclusive disjunctive rule and the more difficult conditional rule. For example, Neisser and Weene (1962), using verbal material, found that college students required a median of 68 trials to criterion on an exclusive disjunctive rule learning task (21.0 for inclusive disjunctive, more than 100 trials for conditional). In a study using materials and procedures similar to the present study, Denny (1969) found that college students required a mean of 53.4 trials to criterion in a high memory load condition and 22.8 trials in a low memory load condition (i.e., with an artificial memory aid). For the former condition the mean trials to criterion is considerably higher than in the present study. The reason for this discrepancy may be that in the present study all subjects first solved a practice problem, which facilitated performance on the test (exclusive disjunctive) task by familiarizing the subjects with the general solution procedure.

Both in terms of trials to criterion and in terms of total errors grade two subjects in the control condition (no memory aid - no truth-table training) required considerably more trials to reach solution on the conceptual task than the grade seven or grade twelve subjects. The mean trials to criterion for the three groups were 75.1 for grade two, 52.1 for grade seven and 31.8 for grade twelve. The grade two subjects required more than twice as many trials to criterion than the grade twelve subjects, indicating that this task was of high difficulty for the younger subjects. Such age-related differences are obvious and expected and have been previously found on conceptual tasks involving conjunctive and inclusive disjunctive rules (King, 1966; King and Holt, 1970; Snow and Rabinovitch, 1969; and Guy, 1969), and conjunctive, inclusive disjunctive, conditional and biconditional rules (Bourne and O'Banion, 1971). The typical finding in these studies is that subjects older than 12 years considerably out-perform subjects at ages 6 - 8 years. For example, King and Holt (1970) found that 6 year olds made six times as many errors as 12 year olds on a disjunctive rule conceptual task. King and Holt attributed these differences to the poor encoding strategy of the younger subjects. They found that the younger subjects tended to respond unidimensionally by focussing on one dimension of the stimulus set at a time, while the older subjects' encoding was characterized by the efficient bidimensional encoding strategy. Bourne and O'Banion (1971) attributed such age differences to the transition in children's thinking from concrete to formal operational as theorized by Piaget (1957).

The present experiment also demonstrated such age-related differences in conceptual behavior, but in addition evaluated the effect of two independent variables, type of pretraining and memory load, on these differences. The results indicated that low memory load and truth-table training facilitated performance on the conceptual tasks across all three grades in terms of trials to criterion, and also in terms of the total errors on the test task. In addition, the facilitative effect of the memory aid was greater for the younger students than for the older students. These results extend the results of previous studies (Bourne et al., 1969; Pishkin, 1967; and Denny, 1969) that found facilitative effects of a memory aid on conceptual performance for adult subjects to the rule learning task in children. A similar finding has been reported by Eimas (1969) for the effect of a memory aid on the attribute learning of grade two subjects. Eimas concluded that the poorer performance of young children in attribute learning is due to their inability to remember sufficient relevant information. However, Eimas employed only one grade level thereby precluding direct age comparisons. The fact that in the present experiment the lower grades benefited more from the low memory load condition than the higher grades could be interpreted as attesting to the greater importance of this factor in the conceptual behavior of the younger subjects. This then indicates that one of the important differences in the conceptual behavior between younger (grade two) and older (grade twelve) subjects is that the younger subjects are less successful in remembering relevant information about the conceptual task than the older subjects. With a memory aid the conceptual behavior of the younger subjects becomes more like that of the older subjects in terms of trials to criterion and total errors.

The effect of truth-table training on performance in the test task was significant in terms of trials to criterion and total errors, but the effect was not very large when compared to the memory or grade effects. One reason for these small effects in the present experiment may be that the practice task decreased the advantage of the subjects in the truth-table pretraining groups relative to the dimensional pretraining group by providing all subjects with the opportunity to acquire some of the skills necessary for solving the problem. Evidence for this conclusion is two-fold: (1) the facilitative effect of truth-table training on performance on the test task was, as expected, highly significant, and (2) previous studies by Bourne (1969a; 1968) have shown that both for children and for adults practice in solving conceptual rule problems leads to increasing competence in the truth-table strategy and also better performance in terms of trials to criterion on rule learning problems. Together, these two pieces of evidence suggest that truth-table pretraining was effective in inducing the truth-table strategy both in the practice problem and subsequently in the test task, but that the experience of the practice task also yielded some of this effect and thereby equalized the initial advantage of the truth-table pretraining groups. The expected greater facilitory effect of the truth-table pretraining on the performance in the test task for the younger subjects relative to the older subjects was non-significant probably for the same reasons. Evidence for this explanation is that the grade by training interaction was significant in the predicted direction on the practice task. However, even taking into account the effect of the practice task on the development of the truth-table strategy, the effect of the truth-table training on the test task performance was small. It may be that especially the younger subjects could benefit from a more extensive truth-table training program.

The expected interaction between type of pretraining, type of memory aid and age was nonsignificant. It was hypothesized that for the younger subjects the memory aid would be of little value in solving the conceptual problem, since they would lack the efficient means of utilizing this information. With the truth-table classification training these younger subjects should be able to code the diverse information available from the memory aid into categories relevant to the solution of the conceptual task. The results however indicate that the facilitative effect of memory aid is significantly larger for the younger subjects than for the older subjects, regardless of pretraining conditions. This may mean that (a) these young subjects are able to effectively categorize the visually available information from the prior trials as the older subjects, or (b) that the sum of the pretraining and practice tasks effects was sufficient to induce the proper coding strategy in all subjects. Since Bourne (1969a) found that children at the age of 6 - 7 years do lack in these coding strategies, alternative (b) is probably more likely. Further evidence for this conclusion comes from the fact that truth-table training did increase, although nonsignificantly, performance on the test task for the grade two subjects that had the memory aid conditions. The cumulative effect of both the truth-table training and the memory aid was to equate the performance of the grade two subjects with the performance of the grade twelve control condition subjects (no memory aid - dimensional pretraining) both in terms of mean trials to criterion (30.4 vs. 31.8 trials) and mean total errors to criterion (6.0 vs. 6.5 errors).

These equivalences indicate that the combined effect of the two experimental variables makes the conceptual performance of the grade two subjects indistinguishable from the grade twelve control subjects in terms of two major indices of conceptual performance. However more detailed analyses of the subject's responses indicated that there were qualitative differences in the conceptual behavior of the three grade level groups, regardless of experimental condition. The analysis of the subjects' reported hypotheses showed that the grade twelve subjects significantly more often reported category hypotheses than the grade two and seven subjects. This may be interpreted as indicating that these older subjects more often attained solution by categorizing diverse stimuli into common categories, whereas the younger subjects tended to persist in treating stimuli as separate and specific. These grade differences in categorization in hypotheses were expected on the basis of experiments that have shown that categorizations and clustering in recall of verbal and nonverbal material increases with age (Bousfield, 1953; Belmont, 1968; Neimark, 1971). The data however indicate that training in categorization (via truth-table classification training) did not increase this behavior among the younger subjects.

The results of the analysis of the categorization data are complicated by the fact that three of the grade seven groups (7MT, 7MD, 7NT) showed numerically equivalent or lower mean number of categorization responses than equivalent grade two subjects. Only the control condition (7ND) was higher than the corresponding grade two group (2ND). On the basis of the foregoing reasoning it was expected that the grade seven groups would be intermediate between the grade two and grade twelve groups in terms of category responses. The data indicate that this occurred for the control condition, but not for conditions that had received either truth-table pretraining or the memory aid. Assuming that these orderly changes in categorization do occur, two interpretations of these discrepancies are possible: (1) in some ways the experimental manipulations depressed these kinds of responses at the grade seven level, or (2) that the measure chosen to describe the underlying hypothesis selection behavior was not sensitive enough to adequately represent it. The first alternative is simply supported by the fact that the control condition (7ND) conformed to expectations in being intermediate between grade two and grade seven groups. However, why truth-table pretraining and memory aid should depress categorization responses is not clear (in fact, the truth-table pretraining was expected to increase such behavior). The second alternative seems more likely. The criterion chosen for deciding that a particular response was a categorization response might have been too strict; the criterion was that the hypothesis should be phrases in terms of the categories of the truth-table. The problem with this criterion is that other categories may have been used and that the overt behavior did not reflect such underlying categories. A more direct measure of such categorization behavior would have been available if a procedure were used in which the subject described the dimensions and attributes of the hypothesis in terms of specified symbols (as in Furth et al., 1970). Through such a procedure the form of hypothesis that a subject holds (i.e., whether they are categorical) could be more accurately specified without relying on verbal descriptions.

The method of obtaining information about the subject's hypotheses in the present experiment relied on the subject's verbalization of these hypotheses. While such a procedure of obtaining knowledge about the subject's covert states has been critized (Archer, 1964; Levine, 1969, 1970), a recent comparison (Karpf and Levine, 1971) of an objective method (blank trials method) and the present method of obtaining the subject's current hypotheses indicates that both methods yield the same description of the hypotheses underlying the subject's overt behavior. This indicates that the method of verbal reports is a valid way of specifying these underlying states.

Another analysis of performance on the test task that yielded qualitative age differences was the analysis of error types. Each error was categorized into one of the four categories of the truth-table. For example, an error on an item that contained neither relevant positive attributes was classified as a Type 4 error. This kind of analysis has been performed previously on errors in conceptual rule learning tasks. The intent of these analyses have been to identify sources of rule difficulty by locating which particular category of stimuli presented the greatest difficulty for the various conceptual rules (e.g., Bourne and O'Banion, 1971; Bourne and Guy, 1968), or to document the presence of the truth-table strategy (Bourne, 1969). The intent of the present error analysis however was to present evidence for the developmental changes in the type of errors subjects made. Since with this method of error analyses there are four dependent scores for each subject, a multivariate analysis of variance and a profile analysis was performed on these error scores. All three main effects were significant. The analysis indicated clearly that the three grades differed in the kind of error they made. For the grade two subjects the Type 4 error was the most common error, while for the grade twelve subjects the Type 4 error was the least common error. This grade effect can be interpreted as indicating that the grade twelve subjects were better able to differentiate the Type 4 stimulus from other kinds of stimuli than the younger subjects. The grade twelve students made on the average less than one error in this category, indicating that they easily classified all items in this category as negative stimuli. For the grade twelve students the stimuli that contained one or both relevant attributes posed more difficulty in assignment.

The grade two students on the other hand made considerably more Type 4 errors than other types of errors, possibly reflecting the composition of the stimulus set: there were more Type 4 stimuli than any other type. The fact that the grade two students made an average of 4.5 errors in this category indicates that this type of stimulus was not treated as one easily defined category. The error data provide further evidence for the increase in the ability to categorize items into the four truth-table categories with increases in age as hypothesized by Bourne (1969a).

The findings of this study also have implications for Piaget's (1953) theory of intellectual development. Piaget is primarily concerned with describing the normal course of developmental changes in intellectual functioning rather than with the effects of special training and experience on developmental progressions. Piaget and Furth, et al. (1970), who have applied Piaget's theory to conceptual rule learning, have specified the kinds of changes in the understanding and use of concepts to be expected for the age range and type of procedures used in the present study. The youngest subjects (grade 2, age 7 years) should experience difficulties in the proper understanding and use of logical connectives of the type used in the present study. Furth (1970) makes the more specific prediction that it would be discordent truth value items (TF or FT items) rather than concordent truth value items (TT or FF items) that would be difficult for children of this age. These children are characterized as lacking 'mobility' or the ability to differentiate the truth value of items. They can properly apply connectives to concordent truth value items, but in the case of discordent truth value items they will tend to improperly classify an item as either completely true (TT) or completely false (FF). The reason for this is that for these children symbolic behavior is not yet 'interiorized' or dissociated from external or personal constraints. Only when 'interiorized' symbolic functioning has been attained (at about age 11 - 12 years) is their behavior characterized by propositional thinking. At this (propositional thinking) level of symbol use, symbols and connectives can be manipulated properly regardless of the content of the proposition.

On the basis of such reasoning the youngest children in the present experiment should do poorly on the conceptual task involving a connective of intermediate difficulty for adults. This was found, but it was also shown that special training and memory requirement reductions greatly improved these children's performance. It is not clear whether this training and manipulation effect has implications for the theory, because Piaget has not ruled out local improvements in conceptual performance as a result of such special conditions. Early interpretations of Piaget (Flavell, 1963), assumed that no improvement could be effected for conservation concepts by special training. Piaget (1970) has essentially retained this position. In analyzing an experiment designed to train children on a conservation concept, Piaget concludes that training is only effective in strengthening existing development, and that "...learning is subordinate to the subjects' levels of development. To summarize, learning appears to depend on the mechanisms of development and to become stable only insofar as it utilizes certain aspects of these mechanisms, the instruments of quantifications themselves, which would have evolved in the course of spontaneous development" (Piaget, 1970, p. 716-717). However, a review of the literature on training conservation concepts (Brainerd and Allen, 1971) concluded that such training can lead to specific transfer. A similar conclusion has been made for the development of concept learning. For example, Youniss and Furth (1964) found that transfer of learning of logical connectives such as conjunction and disjunction from one task to another could be increased by training for children aged nine to fourteen years. But age, and therefore the level of intellectual development, determined the amount of transfer. The older children gained more transfer than the younger ones, suggesting that some aspects of the task were not amenable to training at the lower ages.

In another context Furth has made Piaget's position on the effect of training on conceptual development more specific. Furth has stated that specially training children on concepts cannot lead to a complete mastery of concepts.

> For Piaget, therefore, while some particular aspect of conceptual behavior can be readily observed within a paradigm of training or learning, the more general and more vital aspects of conceptual skill develop imperceptibly over years of gradual growth (Furth et al., 1970, p. 56).

While the implication of training effects in this study of Piaget's theory are not definite, the analysis of error types does have implications for Piagetian treatment of the development of propositional thinking. The analysis of error types for the grade two subjects indicates that the category of greatest difficulty was the "F F" category, which is a concordent truth value category. In fact, the two discordent categories (FT and TF) produced numerically fewer errors than either of the concordent categories. This finding puts some doubt on Piaget's assertion regarding the manipulation of symbols at this stage of development (as stated by Furth et al., 1970). What may be more important in conceptual development than the distinction between concordent and discordent categories is a clear comprehension of all of the possible items in a particular category (i.e., an extensive definition of a category). Such an understanding of a concept has been thought (Bourne, 1969a) to be based on several component abilities, such as the ability to learn stimulus equivalences, negations, and at a higher level, the truth-table strategy. A similar view of cognitive behavior has been proposed by Berzonsky (1971) for the problem solving and conceptual behavior of children. By factor analyzing a number of diverse tasks (causal reasoning, conservation and problem solving tasks) Berzonsky found several underlying component abilities, which were more important in determining the performance on these tasks than a single factor of 'logical understanding'.

So far, grade differences in error types distributions have been considered apart from the effect that a particular conceptual rule may have on such distributions. Bourne and Guy (1968) have shown that the distribution of errors for the four types of stimuli (of the truth-table categories) depends on the particular rule employed, at least on an initial rule learning problem. Bourne and Guy found that for the conjunctive and disjunctive rule problems the discordent truth value items (TF and FT items) produces more errors than concordent truth value items (TT and FF items) for adult subjects. A similar finding has been reported by Furth et al., (1970) for grade one to six students. On the basis of their findings (and Piagetian theory) Furth suggests that the difficulty of these children with the discordent truth value items is a developmental phenomenon, indicating a general lack of 'mobility' of the thinking of children of this age. The present study however has shown that for exclusive disjunctive rule the most difficult kinds of items for grade two subjects are those with concordent truth values, especially 'F F' category items, while for the grade twelve students these items were of least difficulty (although not statistically significantly). This clearly indicates a developmental change in the distribution of types of errors, which can be accounted for in terms of the present analysis of the developmental progression of conceptual development. A lack of an efficient way of categorizing the large diversity of the 'F F' category items into a single overall category based on the truth-table schema may be the likely reason why these stimuli proved difficult to the youngest subjects. With the experimental manipulations the difficulty of this category of stimuli was no longer present.

One aspect of the results of the present experiment that is consonent with Piaget's theory is the age-related difference in the extent of categorical verbalization of the concept. Furth et al., (1970) have made the point that the understanding of a concept implies the ability to verbally describe that concept. The extent to which the grade two subjects phrased the concept in categorical form was low, compared to the two higher grades. This may indicate a level of intellectual functioning that fails to involve a complete understanding of the concept.

The problem of training effects on conceptual development are of course broader than to decide whether a <u>specific</u> training procedure can produce increases in performance at a given age to reach the level of performance of some later age on a <u>specific</u> task. It would be more desirable to show that such training effects are not specific and limited but are general and applicable to many different situations. The truth-table strategy employed in the present study may contain such generality for a variety of conceptual behaviors. Bourne's (1969a) and the present study, have provided some evidence for the generality of the truth-table strategy across age levels. However, the large memory load effect differences between grades, regardless of training conditions, may indicate a major limitation of the conceptual behavior of young children. Yet it may be that such memory limitations of the younger subjects could be reduced by more extensive classification training, especially since the data of this study indicate a deficiency of proper categorization at the lower grades.

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Footnotes

[1]The multivariate analysis of variance was carried out by a computer program from the Division of Educational Research at the University of Alberta.

[2]The profile analysis was carried out by a computer program from the Division of Educational Research at the University of Alberta.

APPENDICES

Appendix I. Instructions Used in This Experiment

1. General Introduction to Tasks.

Have you ever played cards before? We are going to play a game of cards here, and let me show you how we play this game. First I will show you what the cards look like. (Demonstrate). The shape of the figure on the card can be a triangle, a square, or a circle. The color can be blue, yellow, or red. The size can be small, medium, or large, and the number of figures on the cards can be one, two, or three. (Grade two subjects were asked to name the last two attributes of each dimension after the first attribute was identified.)

2. Truth-table Pretraining Instructions.

The first thing we will do is to divide the cards into four piles depending on two important things. The two important things are "red" and "triangle". (Demonstrate). If a card is red and a triangle - that is a red triangle - then it will go into this box (T-T category). If a card is red, but not a triangle, such as a red circle or a red square, it will go into this box (T-F). If a card is a triangle, but not a <u>red</u> triangle, but a blue triangle or a yellow triangle, it will go into this box (F-T). And if a card is not red and not triangle, for example a blue circle, it will go into this box (F-F). The names of the four boxes are "red triangles", "reds", "triangles", and "nothings", the last box is called "nothings" because the cards in it do not have any of the important things in it, i.e., red or triangle.

Can you remember the four names of the boxes? Can you name them? Now sort these cards into the four boxes. (During sortings the S was corrected for misnaming a category and for placing a card in a wrong category. After completion of the first sorting problem, the subject was given a new set of relevant attributes and asked to sort with these values.)

In the next sorting we will do the same thing as before, except that the two important things are "yellow" and "square". Can you think of the four names for the four boxes?

3. Dimension-pretraining Instructions.

The first thing we will do is to divide the cards into three piles depending on the shape of the figures on the card, such that there will be one pile for triangles, one for squares and one for circles. (The same instructions are given for the other dimensions, i.e., color, size, and number of figures.)

4. Instructions for Conjunctive Rule Learning Task (Practice Problem).

Now that you've got to know the cards a little better we can start playing the first game. In this game there are two important things: the first important thing is "red" and the second important thing is "square". I am going to show you one card at a time, and you see if you can figure out which cards are called winners and which cards are called losers.

5. Instructions to the Groups Receiving Truth-table Pretraining Following the Conjunctive Task.

If you think about "red" and "square" in terms of these four boxes (from the truth-table pretraining task), which ones were the winners? You can see that in other games we could have other boxes winners, whichever ones we wanted to. For example, we could have the "squares" as winners, or the "squares" and "red squares" as winners. This is a good way to think about the cards if you try to figure out winners and losers in such a game.

6. Instructions for the Exclusive Disjunctive Rule Learning Task (Test Problem).

In our next game we are going to play with the cards on this board. Under each card will be one of these faces. (Demonstrate). If a card is a winner there will be a happy face under it, and if a card is a loser there will be a sad face under it.

The two important things in the next game are "blue" and "circle". Now this game will not be the same as the "red-squares" game we just played. The two important things are different, i.e., they are blue and circle now, and the kinds of winners will also be different. Let's try the first one.

(Subjects in the truth-table pretraining condition are asked prior to the first trial): Can you think of the names of the four boxes with "blue" and "circle" as the important things?

(After each row of nine cards): Now remember the two important things in this game are "blue" and "circle", and which ones do you think are always the winners?

Appendix II. Analysis of Variance Tables

Table A

Analysis of variance of trials to criterion on the practice task.

Source	SS	df	MS	F	p
Grade (G)	7.62	2	3.81	6.22	.01
Memory (M)	.38	1	.38	.62	-
Training (T)	11.36	1	11.35	18.54	.01
G x M	4.30	2	2.15	3.51	.05
G x T	6.59	2	3.29	5.38	.01
M x T	.25	1	.25	.40	-
G x M x T	3.52	2	1.76	2.87	-
S(GMT)	66.16	108	.61	-	-

Table B

Analysis of variance of trials to criterion on the test task.

Source	SS	df	MS	F	p
Grade (G)	.96	2	.48	12.85	.01
Memory (M)	.50	1	.50	13.38	.01
Training (T)	.22	1	.22	5.82	.05
G x M	.24	2	.12	3.19	.05
G x T	.05	2	.03	.61	-
M x T	.01	1	.01	.12	-
G x M x T	.06	2	.03	.76	-
S(GMT)	4.04	108	.037	-	-

Table C

Analysis of variance of total errors on test task.

Source	SS	df	MS	F	p
Grade (G)	2.12	2	1.05	9.44	.01
Memory (M)	1.47	1	1.47	13.11	.01
Training (T)	.56	1	.56	4.96	.05
G x M	.15	2	.08	.68	-
G x T	.16	2	.08	.73	-
M x T	0	1	0	.02	-
G x M x T	.11	2	.05	.46	-
S(GMT)	12.12	108	.11	-	-

Table D

Analysis of variance of percent of category solutions on test task.

Source	SS	df	MS	F	p
Grade (G)	35973.22	2	17986.61	10.95	.01
Memory (M)	1074.01	1	1074.01	0.65	-
Training (T)	4236.40	1	4236.40	2.56	-
G x M	1355.13	2	677.56	0.41	-
G x T	122.56	2	56.28	0.03	-
M x T	161.00	1	161.00	0.10	-
G x M x T	3149.96		1574.98	0.95	-
S(GMT)	178972.90	108	1657.16	-	-

Appendix III: Raw Data

Table E

Trials to Criterion on Practice Task for the

Twelve Experimental Groups.

2MT	2MD	2NT	2ND	7MT	7MD	7NT	7ND	12MT	12MD	12NT	12ND
16	20	16	24	16	16	16	16	16	16	19	16
16	16	23	19	16	16	16	16	16	16	16	16
18	25	16	34	16	16	16	16	17	16	16	16
19	18	18	21	20	16	16	16	16	21	16	16
16	16	16	16	16	18	21	16	21	16	16	17
20	25	19	23	16	23	16	16	16	25	16	16
16	23	16	25	16	28	16	20	16	20	19	18
16	19	16	25	21	22	16	16	21	19	19	16
17	16	16	46	16	42	18	16	16	18	16	16
16	25	16	20	16	21	16	27	16	16	16	16

Table F

Trials to Criterion on Test Task for the

Twelve Experimental Groups.

Memory		No Memory		Memory		No Memory		Memory		No Memory	
2MT	2MD	2NT	2ND	7MT	7MD	7NT	7ND	12MT	12MD	12NT	12ND
33	43	16	71	25	31	53	45	38	25	19	18
33	25	36	88	16	61	18	25	25	25	18	30
39	61	37	59	25	33	22	76	26	25	18	54
32	45	119	75	38	25	33	88	31	33	25	33
38	54	16	16	25	25	25	25	25	18	26	20
25	35	75	114	25	25	125	25	44	25	25	25
16	34	125	33	25	43	33	33	17	18	25	33
25	43	82	125	19	25	33	86	25	33	33	50
25	25	25	45	31	25	40	25	25	28	22	18
38	51	73	125	18	42	90	93	25	24	26	37

Table G

Total Errors on Test Task for the

Twelve Experimental Groups.

2MT	2MD	2NT	2ND	7MT	7MD	7NT	7ND	12MT	12MD	12NT	12ND
1	4	1	2	1	4	3	6	2	2	3	4
5	3	1	6	3	5	2	6	2	6	3	4
6	9	2	11	3	3	6	3	5	2	2	5
4	9	14	12	5	5	6	5	3	5	3	5
4	13	16	28	5	7	10	7	2	4	6	6
10	7	29	24	3	7	8	9	4	2	7	7
8	12	23	21	6	4	13	19	5	5	5	5
9	15	21	35	6	6	19	28	7	4	8	7
7	15	38	61	6	11	20	24	7	6	7	11
6	22	53	43	9	21	43	15	8	8	5	11

Appendix IV: Transformation of Data

Table H

Means of the logarithmic transformation of total errors on the test task for the twelve experimental groups (standard deviations are in brackets below the means).

	Grade 2		Grade 7		Grade 12	
	Pretraining		Pretraining		Pretraining	
Memory	T	D	T	D	T	D
M	.716	.972	.612	.791	.597	.596
	(.286)	(.269)	(.268)	(.244)	(.239)	(.222)
N	1.01	1.23	.956	.981	.650	.785
	(.655)	(.444)	(.399)	(.323)	(.204)	(.159)

Table I

Means of the inverse times 100 transformation of trials to criterion on the practice task (standard deviations) are in brackets below the means).

	Grade					
	2		7		12	
	Pretraining		Pretraining		Pretraining	
Memory	T	D	T	D	T	D
M	5.92	5.09	5.98	5.02	5.92	5.58
	(.48)	(.97)	(.58)	(1.34)	(.62)	(.81)
N	5.89	4.29	6.03	5.87	5.95	6.14
	(.65)	(1.15)	(.49)	(.86)	(.48)	(.24)

Table J

Means of the logarithmic transformations of trials to criterion on the test task (standard deviations are in brackets below the means).

	Grade 2		Grade 7		Grade 12	
	Pretraining		Pretraining		Pretraining	
Memory	T	D	T	D	T	D
M	1.47	1.60	1.38	1.50	1.43	1.40
	(.12)	(.13)	(.11)	(.14)	(.11)	(.09)
N	1.68	1.81	1.59	1.65	1.37	1.47
	(.34)	(.28)	(.26)	(.25)	(.08)	(.17)