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Developmental Aspects of Nonsolution in Adults

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DEVELOPMENTAL ASPECTS OF
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DEVELOPMENTAL ASPECTS OF NONSOLUTION IN ADULTS

BY

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DEVELOPMENTAL ASPECTS OF

NONSOLUTION IN ADULTS

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ABSTRACT

The relationship between the complete learning concept task and Piagetian tasks used to evaluate the presence and extent of formal operations was investigated with adult college students. The results of this study demonstrate that both solving and nonsolving in concept tasks are a subject related parameter and are stable over twenty-four to thirty-six hour intervals. The generality of formal operations in adult college students was found to be significantly less than that predicted by Piaget. The relationship between the concept task and the Piagetian formal operations tasks was assessed using correlations and was found to be significant. In addition, the type of conceptual strategy used by the subjects was found to be predictive of performance on the formal operations tasks. The results are discussed in terms of the cognitive skills used by the solvers and the cognitive deficits present in the nonsolvers. Theoretical implications of the analysis of formal operations as a subset of concept formation are discussed as are the educational implications. It is concluded that the concept paradigm represents a significant methodological improvement over the Piagetian tasks currently used for formal operations assessment.

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INTRODUCTION

In the typical laboratory concept identification task, a subject is instructed to respond to each of a series of stimuli with one of two responses: example or nonexample. In the presence of some stimuli, the response "example" is reinforced, while in the presence of others "nonexample" is reinforced. The well-known experimental finding under many such circumstances is that the frequency of correct stimulus classifications increases until the subject has identified the concept and is said to be in a criterion state. This phenomenon, however, is not absolutely reliable. Data from concept identification studies (e.g., Fink, 1972; Johnson & Toppino, 1974; Rapoport, 1975), as well as other types of discrimination learning tasks (e.g., reversal shift procedures, Lowenkron, 1969), indicates that some number of subjects are eliminated from the sample after they fail to reach solution, even after an inordinately large number of trials. Traditionally, these data on failure to solve are relegated to the subject subheading of method sections where it is noted that "x" number of subjects were eliminated from the experiment for failure to either solve the problem or to understand the instructions. Although the proportion of subjects eliminated varies from study to study and from paradigm to paradigm, the fact remains that some number of subjects do not solve the task. This finding becomes all the more puzzling when one realizes that the

subjects demonstrating this nonsolving behavior are generally sampled from university classes and the solutions to the problems are often quite elementary.

According to an extensive review of the pre-1966 literature on human problem solving (including concept identification), Davis (1966) isolated but one type of problem solving situation in which nonsolution was a factor of interest. This type of problem has become known as the Einstellung or water-jar problem after Luchins (1942). The basic idea behind Einstellung type problems is to present preliminary experiences to the subject which render him functionally blind to a subsequent simple solution. For example, Ress and Levine (1966) were able to demonstrate Einstellung during simple discrimination learning in the following fashion: subjects were presented with a series of 100 cards, each with two circles of different sizes. Subjects were given either zero, three, or six pretraining problems in which a position sequence was the solution. After the pretraining, the subjects were then given one more simultaneous discrimination in which the larger of the two circles was always correct. Results showed that subjects with zero pretraining solved the problem with an average of three trials. Subjects in the other two pretraining conditions solved with an average of 63 trials and almost half of these subjects failed to solve in 100 trials! Ress and Levine (1966) interpreted these results as dramatic evidence for the

deleterious effects of preliminary tasks which cause the subject to adopt a solution "set" inappropriate to subsequent problems.

From a theoretical standpoint, the above interpretation leaves a good deal to be desired as it amounts to little more than a description of the results. Accordingly, Levine (1971) has proposed a theory to account for nonsolution which is derived directly from vigorously developed hypothesis theory (for a review, see Levine, 1969). The work in general hypothesis theory suggests that in discrimination or concept identification laboratory tasks, adult human behavior is the result of hypothesis testing. Novel analyses (backward learning curves, Suppes & Ginsburg, 1963; blank trial probes, Levine, 1966; the Fink technique, Rapoport, 1975) imply that a subject has a set of hypotheses from which he repeatedly samples until he selects the correct hypothesis. The theory of insoluble and unsolved problems is as follows:

1. The basic assumption: The subject selects an hypothesis from some universe and then responds on the basis of that hypothesis.

2. The composition assumption: The universe from which the subject samples contains only those hypotheses corresponding to stimulus levels.

3. Presolution responding: Prior to solution, the subject samples neither the correct hypothesis nor the other hypothesis on the same dimension. This assumption deals with the possibility that responding on the relevant dimension, but the wrong value, would lead to a string of incorrect responses which would contain as much

solution information as a string of correct responses on the correct value.

4. Affirmative feedback: If the subject's response is followed by a positive outcome, he retains his hypothesis for the next trial.

5. Negative feedback: If the subject's response is followed by a negative outcome, he abandons his last hypothesis and resamples.

6. Changing of sets (or subsets): The reduction of a set to zero hypotheses serves as a signal to select a new set.

Of course, Levine (1971) provides ample empirical justification for each of these six assumptions; however, in the case of the Einstellung problems, it is assumption two which is the most important. Recall that the composition assumption states that the universe from which the subject samples his hypotheses contains only those hypotheses corresponding to stimulus levels. This assumption, clearly, is a function of the experimenter's instructions, or in the Einstellung case, of the preliminary practice problems. In the Ress and Levine (1966) study, the preliminary problems directed the subject to the universe of hypotheses containing complex sequence position solutions, such that as long as the subject was sampling from such a universe the possibility of a size related hypothesis would be overlooked. Furthermore, since complex position sequences constitute a virtually limitless universe, assumption six suggests that the subject, having never reduced his universe to zero, will never resample a new

universe of hypotheses.

Since the publication of his theoretical paper, Levine and his co-workers have further explicated many of the theoretical assumptions. Glassman and Levine (1972) have provided further evidence that subjects do in fact fail to solve certain types of problems because the solution hypothesis is not in their subset, and that subjects whose hypothesis set has been reduced to zero do in fact resample. Fingerman and Levine (1974), using the methodology of the Glassman and Levine (1972) study, were able to show dramatically that subjects learn nothing about hypotheses not in their hypothesis set, even when the nonsampled hypothesis is perfectly correlated with reinforcement and is later presented to the subject as a possibly overlooked solution.

Unfortunately, Levine's interest in nonsolution has been met with little enthusiasm by other investigators. A notable exception to this lack of interest on failure to solve has been the recent work of Scandura on the role of higher order rules in problem solving. According to Scandura (1974), "One of the most crucial questions in problem solving research is why some problem solvers succeed on problems for which they have all of the necessary component skills, whereas others do not" (p. 984). Although the details of Scandura's methodology for examining the role of higher order rules is beyond the scope of this introduction, what is important is Scandura's

specification of the "crucial question." Scandura is quite specific about his interest in problem solvers who ". . . have all of the necessary component skills. . ." An examination of Levine's (1974) theory indicates that he too assumes the presence of the necessary component skills, as he never specifies how a subject comes to possess the universe from which the subject allegedly samples.

In order to demonstrate that the assumption of the possession of component skills may be presumptuous, one need only scrutinize the subject subheading of the previously cited Fingerman and Levine (1974) study. Fully 22% of Fingerman and Levine's subjects were unable to solve the six preliminary position sequence solution problems which the authors repeatedly describe as simple. Furthermore, in order to research the role of higher order rules and nonsolution, Scandura (1974) first intensively and meticulously trains his subjects on these higher order rules and then views nonsolution in terms of the failure of the subject to correctly utilize the rules he has just been taught.

When viewed from this perspective, the question of interest changes from one of the conditions under which nonsolution may be induced (Levine, 1971) to why an apparently normal, well-motivated, college sophomore fails to solve a problem virtually irreducible in its simplicity. When the question is stated in such a fashion, a number of possibilities arise. One possibility is that the

subjects who fail to solve are deficient in test-measured intelligence. The possibility of deficient intelligence can most likely be ruled out; first, because the educational system, and certainly college entrance requirements, would certainly select out students of abnormally low measured intelligence and, secondly, attempts to find consistent relationships between measured intelligence and problem solving have largely been unsuccessful (Raaheim & Kaufman, 1974). Another possibility involves a deficiency in the development of the cognitive skills necessary to solve such problems. In the light of Piaget's theory of cognitive development, a possible deficiency of the prerequisite cognitive skills seems to be a very reasonable approach to the question of nonsolving in normal adult humans.

According to the stage dependent theory of the Geneva School, the progression from the child to the adolescent/adult stage involves the change from the use of "concrete" operations to the use of "formal" operations (Inhelder & Piaget, 1958). Inhelder and Piaget (1958) cite the age of about 11 years as that at which concrete operations are no longer adequate to the tasks faced by the child. At that time, disequilibrium disrupts cognitive balance and formal operations begin to emerge. This stage of formal operations is said to develop fully by the ages of 14 to 16 years and is characteristic of the years from middle adolescence onward, including adulthood. In short,

the formal operations stage represents the final equilibrium of cognitive development (for a detailed review of this theory, see Flavell, 1963).

In order to understand the structures characteristic of the formal stage, a brief discussion of the preceding concrete operations stage is helpful. Thinking in the concrete stage is limited almost exclusively to thinking about <u>things</u>. The fundamental building blocks are the logic of class and the logic of relations. The logic of class refers to the child's capacity to handle problems of classifications, such as whether something is, or is not, a member of a given class. The logic of relations refers to the child's capacity to relate things of differing size within the context of graded and ordered series, such as problems of seriation or one-to-one correspondence. By and large, however, the concrete stage child is limited to thinking about actual concrete situations and things as they are presented to him in the real world. To be sure, there is some limited capacity in the concrete stage to think about some abstractions (e.g., redness), but the degree is sufficiently limited and the "abstractions" are usually sufficiently close to concrete and perceptual realities to warrant the generalization that thought about abstractions does not appear until the formal stage.

In contrast to the concrete operations stage, the formal stage has as its most distinctive feature the

possible being considered as including reality as a subset, with the result that hypotheses may proceed from nonobserved and nonexperienced phenomena (Flavell, 1963). There are four basic characteristics of the formal stage:

1. _The changed relation of the real to the possible_: This is perhaps the most important hallmark of formal operations. New combinations can be, and are, derived from recombinations of the variables inherent in the problem without regard as to whether they were ever previously realized or experienced.

2. _The potential for combinatorial analysis_: In the concrete stage, the child faced with a multiple variable situation is limited to trying one:many correspondences or to testing unsystematically other possible correspondences, but the formal operator, able to employ combinatorial analysis, can consider all possible combinations of variables in a systematic fashion. This ability is a necessary condition for generating all possibilities and so determines the shift in orientation from the real to the possible.

3. _The hypothetico-deductive property_: The formal operator's reasoning is less "This is true, therefore. . ." and more "If this were true, then. . ." This kind of reasoning is essential if the possible is to include the real in the set of hypotheses. It also follows hand-in-hand with the ability to check all possible combinations. According to Piaget, the formal operator seeks hypotheses which are general and necessary, as he is not content with merely sufficient hypotheses.

4. _Propositional thinking_: The elements manipulated by the formal operator are propositions: statements containing raw data, but not the raw data itself. In other words, the formal operator may utilize concrete operations of the earlier stage by organizing reality into classes, but he then proceeds to form propositions and operate on these propositions via

> conjunction, disjunction, implication, negation, and equivalence. This type of thinking is what Piaget calls second degree thinking: operations which result in propositions about propositions.

The publication in which Piaget first put forth the properties of the formal stage (Inhelder & Piaget, 1958) leaves the impression that formal stage thinking is the rule in adolescence, since all adolescent protocols included in their report are at the fully formal level and because throughout their book they use adolescence and formal stage almost interchangeably. However, a closer look reveals that nowhere in the book do they make any explicit claim that all adolescents (or even adults) actually do function at the fully formal level, nor do they make an explicit claim that they are reporting all cases tested. Their presentation does, however, definitely leave the impression that full formal stage thinking _is the rule_ in adolescence.

Remarkably little empirical work has been done to verify or even establish the generality of the formal stage. However, since according to Piaget's theory, successive stages use prior stages as building blocks, the literature on the generality of the concrete stage should be highly relevant. Elkind (1961), using a population of normal high school students (mean age of 15 years), found that only 47% could conserve volume. Repeating this experiment with college freshmen, Elkind (1962) found the percent of volume conservers rising to

only 58%. A more recent replication of Elkind's (1961, 1962) experiments, done by Towler and Wheatley (1971) shows the percentage of volume conservers among college freshmen to have risen to 61%. In a study of unschooled rural adults presently enrolled in remedial education programs, Graves (1972) found that only 24% of his subjects could conserve volume. Thus, it seems possible, without recourse to the formal operations literature, to predict on the basis of the concrete operations studies alone, that formal operations will not be nearly so general as Piaget has led us to believe.

The prediction of formal operations generality suggested by the concrete operations literature is, in fact, quite accurate. Tomlinson-Keasey (1972), using five of Piaget's formal operations assessment tasks, found that only 67% of a female college student sample was formal operational whereas this figure fell to 54% for a group of adult women. In a far more detailed study of the generality of formal operations, Dulit (1972) tested groups of average young adolescents, average older adolescents, intellectually gifted older adolescents, and average adults. These groups were tested on two formal operations assessment tasks believed by Dulit to be the most characteristic of formal operations. The results are dramatic: none of the younger adolescents solved any of the problems; of the older adolescents, from 25% to 33% (depending upon laxity of the criteria) were formal operational; the

intellectually gifted older adolescents were 60% fully formal operational whereas the adults averaged from 25% to 33% formal operational. Clearly, these studies cast serious doubt on the generality of the formal stage as intimated by Inhelder and Piaget (1958).

In order to reply to the issues raised by the preceding studies, Piaget (1972) has recently reported his latest "reflections" on formal operations. Piaget feels that the reason why formal operations are not as ubiquitous as Inhelder and Piaget (1958) would lead us to believe is because the original data was taken from adolescents enrolled in the "better" schools in Geneva. Therefore, Piaget was sampling from a particularly narrow socioeconomic group, in short, a privileged population. What then should we expect from less privileged populations? Piaget cites the example of apprentices to trades persons whose formal education is limited but whose aptitude for trades is high. In this case, we would expect to find formal structures being applied to the area of the apprentice's specialty, but not in other settings where he might appear to be only concrete operational. Similarly, law or graduate students specializing in one particular narrow area would also be expected to demonstrate formal operations in their area of expertise but not necessarily in any other area ". . .that involves notions they certainly once knew but have long since forgotten" (Piaget, 1972, p. 10). However, Piaget is quite unequivocal in his theorizing that

adolescents still in school or, better yet, in college, would certainly have attained the formal operations stage. Unfortunately, little data exists which can either prove or disprove Piaget's thesis. The previously cited study by Tomlinson-Keasey (1972) used college freshmen, but only women were sampled. Similarly, the Dulit (1972) study jumped from high school students to a mixed group of adults (educational level unspecified). However, both of the above studies do provide sufficient reason for suspecting that even amongst college students, formal operations may not be so widespread. Even though Tomlinson-Keasey (1972) tested only females, Piaget gives us no cause to suspect sex differences and Dulit's (1972) older gifted adolescents (mean IQ of 135+) were specifically chosen from an advanced science course. National chauvinism aside, it seems unlikely that a group of privileged Swiss children would function at 100% formal operational while a group of carefully selected gifted American adolescents could do not better than 60% formal operational. Obviously, further data are needed if Piaget's theorizing vis-à-vis the frequency of formal operations is to be adequately evaluated.

In Inhelder and Piaget's (1958) book on formal operations, a series of tests are presented which are designed to assess the degree to which a given subject has mastered or attained the four characteristics of the formal stage that have been previously described. Although these tasks

are often cumbersome to administer, the logic behind their selection is usually quite obvious. Somewhat less obvious is that a methodology already exists which should allow for similar assessment; this methodology is a variation of the concept identification paradigm and is presented in detail in Rapoport (1975). Basically, Rapoport presented subjects with a reception paradigm complete learning task. The strategies used by the subjects for solution are objectively assessed by the use of the Fink (1972) technique. Using this approach, Rapoport (1975) was able to replicate previous findings relating solution speed (in trials to criterion) to strategy type as well as differentiate rote from conceptual solution modes (c.f. Lowenkron, 1969).

In terms of formal operations, Rapoport's task can be analyzed as follows: Rapoport found that the wholist or focusing strategy was significantly superior to all other strategy types. The wholist strategy necessitates the ability to form all possible combinations of stimuli or, in Piaget's terms, the subject must be able to use combinatorial analysis. Furthermore, since in the Fink technique, dimensions which are absent in the stimulus can be as important as those which are present, the subject must, in Piaget's terms, be able to deal with the possible as well as the real. In addition, since the task is complete learning, the subject must discern the combinatorial rule which, according to Piaget, involves

propositional thinking. And, finally, since the subject must abstract both a combinatorial rule and the relevant attributes, hypothetico-deductive thinking is implicated in the orderly reduction of possible solutions. Various forms of the concept identification paradigm have been used in prior studies of formal operations (e.g., Furth, Youniss, & Ross, 1970; Yudin, 1966); however, these studies either lacked the precision for strategy assessment, failed to establish a relationship between the concept task and the formal operations tasks, or else were concerned with other developmental questions (e.g., Elkind, Barocas, & Johnsen, 1969).

According to the above analysis, the optimal concept identification solver in the Rapoport (1975) study would have to be operating at the near maximal formal operations level. Those subjects who utilize less efficient, but still eventually successful strategies (e.g., partism or scanning) are most likely operating at an incomplete formal level characteristic of one of Piaget's lower levels prior to complete formal operations. Subjects who either solve by rote memorization, or else do not solve at all, are most likely not operating at the formal operations stage.

EXPERIMENT 1

The purpose of Experiment 1 was to assess the stability of solving and nonsolving behavior over time. Specifically, it is essential to demonstrate that nonsolving is not the result of transitory motivational or situational stresses but rather demonstrates the true abilities of the subject. Similarly, it must be shown that a subject who is able to solve a concept identification problem on day one is able to solve a similar problem on day two. Because nonsolvers never experience a long string of correct responses (i.e., the criterion run for solvers) the possibility exists that day two performance could be adversely affected by a phenomenon similar to that observed by Miller and Seligman (1974): that is, learned helplessness. In order to control for the possible contaminating effects of learned helplessness in nonsolvers, spurious reinforcements simulating a solution criterion run were administered to some nonsolvers while other nonsolvers experienced no such spurious criterion run. In order to assess the possible effects of learned helplessness, each subject was required to self-rate his performance on the task.

In terms of stability of solving and nonsolving behavior, there are two possible outcomes of such a demonstration: either nonsolving on day one implies nonsolving on day two, or else no clear implications can be drawn from day one performance as it relates to day two.

If performance on day one is, in fact, unrelated to performance on day two, then we would be forced to conclude that solving and nonsolving are not stable behaviors and are under the influence of variables not controlled in this study. If, however, it is shown that solution or nonsolution on day one implies solution or nonsolution on day two, and if spurious reinforcements show no effect on day two performance for nonsolvers, then it will be possible to proceed with Experiment 2 confident that the cognitive skills being assessed are not transitory or situational, but, in fact, accurately reflect the subject's concept problem solving abilities.

METHOD

Subjects and Design

Subjects were 43 volunteers from the introductory psychology classes at the University of New Mexico, who earned extra class credit for experimental participation. Subjects were randomly assigned to one of two groups constituted to counterbalance the relevant attributes of the concept task. A further reassignment of nonsolvers to either zero spurious reinforcements or ten spurious reinforcements groups was carried out after receiving 92 trials without solution. Subjects were tested individually and on day one were presented with one complete learning problem. Subjects returned 24 to 36 hours later and were presented with a second complete learning problem. The relevant dimensions in the two problems were counterbalanced across days.

Apparatus and Stimuli

Distributed stimuli were presented by illuminating three of six lights behind a translucent screen. The screen was divided into three columns and two rows with each of the six cells in the resulting grid comprising a 50 mm square. The columns represented dimensions and the rows represented values on the dimensions. Each cell was labeled by a letter (A, B, or C) corresponding to its column and by a number (1 or 2) corresponding to its row.

The current value of a dimension was indicated by

backlighting one of the two squares in each column. A dimension selection panel consisting of three buttons was located directly below the stimulus display so that each button was below its respective column.

Response buttons and feedback lights were located on a separate panel below the dimension selection panel. The left response button and feedback light were labeled "example" while the right pair was labeled "nonexample." Feedback was administered by indicating the correct response with the appropriate feedback light. An enable light above the stimulus display was switched to green to signal the start of a trial and switched back to red concurrent with the offset of feedback.

Stimulus sequencing was programmed by means of a paper tape reader and was constructed as follows: one set of 32 stimuli was arranged so that each of the eight possible stimuli appeared four times and no stimulus was repeated in less than five consecutive trials. The sequence was further constrained to prevent any one attribute from appearing more than three times in succession.

Procedure

The subject instructions began with a detailed description of the distributed stimulus set using a sample stimulus as an example. When the subject understood the nature of the stimulus display, he was told that he must learn which stimuli were examples and which were non-examples. The subject was then shown how to operate the

stimulus selection buttons. Throughout the reading of the instructions, the subject was never told how many dimensions were relevant or the nature of the combinatorial rule. At the conclusion of the instructions, the subject was shown that the solution could involve all three dimensions, some combination of two dimensions, or else only one of the dimensions.

For both day one and day two problems the combinatorial rule was affirmation. Group One had C_1 as the relevant attribute on day one and B_2 on day two. Group Two had B_2 as the relevant attribute on day one and C_1 relevant on day two. For nonsolvers, Groups One and Two were further subdivided such that half the nonsolvers in each group received zero spurious reinforcements while the other half received ten spurious reinforcements at the conclusion of the 92 trial termination point. Dependent variables were trials and errors to criterion as well as the subject's self-rating of his own performance. The trial-to-trial data were the dimensions selected and whether or not the classification response was correct.

A trial began when the enable light turned from red to green which signaled subjects to begin selecting dimensions. Immediately upon the subject's classification response, the feedback light directly above the correct response button lit up and remained on, along with the stimulus, for a period of 4 sec. Concurrent with the offset of feedback, the enable light would turn back to

red for a 3 sec duration until the start of the next trial. A solution criterion of ten consecutive correct responses was used. Nonsolvers were allowed 92 trials before the session was terminated and the spurious reinforcements were presented. At the conclusion of day one performance, each subject was asked to rate how he felt he performed on a ten point scale; "one" being very poor and "ten" being excellent. In order to avoid the overall appearance of failure, nonsolvers were told at the conclusion of day two performance that the data of interest was their dimension selections and that attainment of solution was irrelevant for this study.

RESULTS AND DISCUSSION

Stability of Solving and Nonsolving

Table 1 shows the mean trials and errors to criterion for solvers and nonsolvers on day one and day two performance. All subjects who solved the concept problem on day one also solved the problem on day two. Similarly, all subjects who failed to solve the concept problem on day one failed to solve the problem on day two. A significance level of .01 was adopted for all statistical tests reported. A chi-square analysis of the data in Table 1 was significant, $\chi^2(1) = 43.00$.

A Pearson Product-Moment correlation between days calculated on the errors to criterion across solvers and nonsolvers yielded an $r = .944$. In order to test the hypothesis that $r = 0$, a critical ratio z test was performed and was significant, $z = 6.118$. It appears, therefore, that solution probability on the concept task is a subject related parameter which is stable at least for the 24 to 36 hour period as assessed in this experiment.

Order Effect of Relevant Attributes

Table 2 shows the mean trials and errors to criterion for solvers and nonsolvers on day one and day two grouped according to order of relevant attributes. Group One, day one, relevant attribute was B_2 and on day two was C_1. Group Two, day one, relevant attribute was C_1 and on day two was B_2. Both errors and trials to criterion were submitted to analyses of variance; however, since the

TABLE 1

Mean Trials and Errors to Criterion for Solvers and Nonsolvers for Day 1 and Day 2 Performance

	Day 1		Day 2	
	Errors	Trials	Errors	Trials
Solvers	7.56	17.74	5.00	12.43
Nonsolvers	39.50	92.00*	35.95	92.00*

*subjects terminated at 92 trials

TABLE 2

Mean Errors and Trials to Criterion for Solvers and Nonsolvers for Day One and Day Two Performance According to Order of Relevant Attributes

	Group 1	Day 1	Group 2	Day 1
	errors	trials	errors	trials
Solvers	7.27	19.91	7.83	15.75
Nonsolvers	40.90	92.00	38.10	92.00

	Group 1	Day 2	Group 2	Day 2
	errors	trials	errors	trials
Solvers	5.55	12.55	4.50	12.33
Nonsolvers	35.30	92.00	36.60	92.00

error data more closely approaches equal variability across cells and because the trials data represents a ceiling effect due to nonsolver termination at 92 trials, only the less constricted error data analyses will be presented. For solvers, a univariate *F* test showed no significance between the order of relevant attributes, $F\ (1, 21) = .008$, $MS_e = 1.349$. Similarly, for nonsolvers a univariate *F* test showed no significant difference attributable to order of relevant attributes, $F\ (1, 18) = .083$, $MS_e = 11.251$. Apparently then, order of relevant attributes does not affect performance for either solvers or nonsolvers.

Learned Helplessness

Table 3 shows the mean errors to criterion on days one and two for nonsolvers with zero or ten spurious reinforcements. A 2 x 2 analysis of variance of days by reinforcements was performed on these data. The effect of days was nonsignificant, $F\ (1, 36) = 2.033$, $MS_e = 43.63$; reinforcements were nonsignificant, $F\ (1, 36) = .006$, $MS_e = 43.63$; and the interaction was nonsignificant, $F\ (1, 36) = 2.978$, $MS_e = 43.63$. Apparently, the introduction of spurious reinforcements in the form of a pseudo criterion run did not alter second day performance.

The mean self-rating score for subjects who solved the day one problem was 6.89. For nonsolvers, those receiving zero spurious reinforcers had a mean self-rating of 5.58 while those receiving ten spurious reinforcers

TABLE 3

Mean Errors to Criterion for Nonsolvers on Day One and Day Two for Zero and Ten Spurious Reinforcements

	Day 1	Day 2
0 reinforcements	38.4	35.1
10 reinforcements	40.6	36.8

showed a mean score of 5.35. A one-way analysis of variance was performed on the three levels of self-ratings with a resultant significant between-groups effect, F (2, 32) = 10.60, MS_e = 2.044. In order to determine the locus of the effect, a t test was run on solvers versus nonsolvers collapsed across reinforcement conditions with a resultant significant effect, t (38) = 4.028. Solvers therefore rated their performance significantly higher than did the nonsolvers.

In order to determine whether the spurious reinforcements had any effect on subjective self-ratings, an additional t test was carried out between the nonsolvers receiving zero spurious reinforcements and those receiving ten such reinforcements. The results were nonsignificant, t (14) = 1.442, indicating that although half the nonsolvers received ten spurious reinforcers, this manipulation did not significantly affect their self-rating of their performance.

EXPERIMENT 2

The purpose of Experiment 2 was to provide data which would shed light on a number of questions including: the proportion of the sample operating at the formal operations level, the specific empirical relationship between the formal operations assessment tasks and the concept identification paradigm, and the relationship between conceptual strategies and the level of formal operations attainment.

Due to the fact that Experiment 2 involves the testing of subjects on Piagetian formal operations tasks selected for their closeness to the concepts defining the stage (Dulit, 1972), data will result which will allow preliminary normative statements with regards to the proportion of the sampled population which is operating at the formal operations level. Although little literature exists currently which might suggest what this proportion might be, that which is available indicates that between 25 to 60% of the sample can reasonably be expected to be formal operational. This possibility is of particular interest because of Piaget's prediction that amongst college students, formal operations are all but universal.

Despite the fact that the concept identification paradigm has been used in prior formal operations studies (Furth, Youniss, & Ross, 1970; Yudin , 1966), the empirical relationship between this paradigm and Piagetian assessment tasks has yet to be established. The logical formal analysis of the concept task presented in the

general introduction indicates that the cognitive skills necessary for its solution are the same cognitive skills necessary for the solution of the formal operations tasks. In order to assess the relationships, analysis of the task data will involve the use of correlations between the errors to criterion scores on the concept task and separate and combined formal operations scores. Scores on the Piagetian tasks correspond to stage levels discussed in the procedure section such that on a given task, scores could range from 1.0 to 5.0. It was predicted that subjects making few errors on the concept task would also achieve the highest formal operations level scores. This prediction should manifest itself in significant negative correlations between concept and formal operations scores.

In the course of the above analysis of the relationships between the tasks, statements relating nonsolution and failure to attain formal operations will be derived. Specifically, the possibility that the nonsolving behavior observed in concept studies is related to the failure of the nonsolver to operate at the formal level will be assessed. Therefore, it is predicted that nonsolvers on the concept task will also prove to be either not operating at the formal level or else operating at a level which is a precursor to fully formal functioning. In the event that the predicted relationship between formal operations and concept identification is found, the implications would be significant as the concept identification

literature is a very comprehensive analytical body with much to say about development, process, and training.

Unlike many concept identification tasks, the one used in this study allows for an unbiased assessment of the strategies used in the solution of the concept task (see Rapoport, 1975). The analysis of reception strategies provided in the general introduction strongly suggests a relationship between strategy type and degree of formal operations attainment. It was therefore predicted that subjects who solve the concept task using the wholist strategy are operating at the fully formal level because the skills underlying the wholist strategy appear to be the same skills underlying formal operations. Similarly, subjects who either fail to solve the concept task or else solve the concept task by rote memorization do so because they do not possess the formal skills necessary to use a more highly evolved strategy. Finally, subjects who use a successful, but less efficient, strategy as manifested by solution with a large number of errors to criterion will be expected to exhibit lower level values on the formal operations assessment tasks.

METHOD

Subjects and Design

Subjects were 45 volunteers from the introductory psychology classes at the University of New Mexico who earned extra class credit for participation in experiments. Subjects were randomly assigned to one of four groups constituted in order to partially counterbalance the order of presentation of the concept task and the Piagetian tasks. In order to avoid fatigue, testing took place over a two day period. Group I received the concept task on day one. On day two, the two Piagetian tasks were presented; the liquids problem was given first and the rings problem second. Group II also received the concept task on day one; however, on day two, the two Piagetian tasks were presented in the reverse order, i.e., the rings problem first and the liquids problem second. Group III received the Piagetian tasks on day one with the liquids first and the rings second. On day two the concept task was presented. Group IV also received the Piagetian tasks on day one; however, the rings problem was presented first and the liquids second. On day two, the concept task was presented. No subjects were eliminated since nonsolution was a topic of interest; however, nonsolvers were declared as such after 92 trials without reaching criterion.

Apparatus and Stimuli

The concept identification task. Apparatus and stimuli for the concept identification task are presented

in detail in the method section for Experiment 1. The only modification necessary for this experiment was that the concept task was administered only once as opposed to twice for Experiment 1. Because the relevant attribute did not prove to be a significant variable in Experiment 1, C_1 was the relevant attribute for all subjects in all groups.

The liquids task. The apparatus consisted of five large plain bottles, each filled to the same level with fluids that all looked like clear water. The bottles were distinguished only by the labels 1, 2, 3, 4, and G. Bottle 1 contained distilled water; bottle 2 contained potassium iodide; bottle 3 contained distilled water, bottle 4 contained dilute acetic acid and bottle G contained dilute potassium plus starch. With the bottles thusly labeled, bottles 2, 4, and G had to be combined to yield "blue water." Bottles 2, 4, and G represented the necessary combination; however, 1, 2, 4, and G; 2, 3, 4, and G; or, 1, 2, 3, 4, and G represented sufficient conditions for blue water since bottles 1 and 3 contained distilled water. Along with the five labeled bottles, the subject was provided with eyedroppers for sampling the liquids and paint mixing trays in which to mix the chemicals.

The rings task. The apparatus consisted of a graded series of rings, each on a stalk. Piaget and Inhelder (1958) used rings of 5, 10, 15, and 20 cm in diameter; however, Dulit (1972) suggests the inclusion of 8, 13,

and 17 cm rings in order to make the task somewhat more demanding. The projection of the shadows of the rings involved a baseboard with a screen attached to one end, a light source, and the various diameter rings. The rings could be moved along the baseboard by inserting the ring stalks into the holes which ran the entire length of the baseboard. The subject's task was to produce two shadows of the same size with different sized rings. In order to solve this task, the subject had to generate the principle of proportionality; that is, the size of the shadow is directly proportional to the diameter of the ring and inversely proportional to the distance between the ring and the light source.

Procedure

The concept identification task. The procedure for the concept identification task is presented in detail in the method section for Experiment 1. The only modification necessary for this experiment was that the concept task was presented only once as opposed to twice for Experiment 1. Because the relevant attribute was not a significant variable in Experiment 1, C_1 was the relevant attribute for all subjects in all groups.

The liquids task. The subject was brought into a small experimental room and seated in front of a table upon which were the bottled chemicals, the eyedroppers, and the mixing trays. The subject was shown a tray with blue water and was told that the blue water was made by

combining some number of the chemicals from the five available bottles. The subject was then instructed that his task was to "figure out" how to obtain blue water, using all the bottles, or any combination of the bottles, as the subject saw fit. The performance of the subject was scored on a five point scale. Stage 1: at this stage, the subjects are limited to randomly associating two elements at a time and explaining the results by simple phenomenalism or by other forms of prelogical causality. Stage 2: in stage 2, the subject spontaneously and systematically associates the G bottle with all the others, but without any other combinations. Stage 3: the stage 3 reactions are analogous to the stage 2 behavior but with visible progress in that N x N combinations appear. However, the subject does not yet discover any system and uses only tentative empirical efforts. Stage 4: stage 4 represents almost formal function and is characterized by a systematic N x N combination and an understanding of the fact that the color is due to the combination as such. Stage 4 differs from stage 5 in that some combinations are missed. Stage 5: the criterion for full formal function is the capacity to generate all the combinations in a systematic fashion without duplication.

The rings task. The subject was brought into a small experimental room and seated in front of a table upon which was located the rings apparatus and the rings themselves. To begin the task, the experimenter showed the

subject one of the rings and explained that if the light source were on and the ring was placed in between the light source and the screen, the ring's shadow would be cast on the screen. The subject was then handed the two smaller rings (5 cm and 8 cm) and told that his task was to figure out how to place the two rings in such a way that the shadows would be cast on top of each other and be of the same size. The subject was then told to try to figure out how this could be accomplished. The light source and apparatus were used only to test the solution hypotheses generated by the subject. The subject had to generate superimposed shadows of equal size for the remaining ring pairs in a similar fashion: theorize, then test. As in the liquids task, the subjects were scored on a five point scale. _Stage 1_: at this stage, subjects do not understand the formation of shadows and as such make no sense of the problem at all. _Stage 2_: in stage 2, the subject knows that the size of shadow depends on the size of the object but this knowledge goes no further. _Stage 3_: subjects at this stage establish an empirical correspondence between the decreasing sizes of the shadow thrown by the same object and the increasing distances from the light source. Also, they begin to predict the effect of divergent light rays. _Stage 4_: stage 4 represents almost fully formal functioning and is characterized by an inverse metrical proportionality between distances and diameters, but it is not yet generalized to all

possible cases. The subject measures the diameters and the distances and looks for a metrical hypothesis based on the divergent structure of light rays, taking into account the distance between the light source and the first ring. Stage 5: the criterion for full formal functioning is the explication of the law of proportionality and the generalization of this law to all cases.

RESULTS AND DISCUSSION

Proportion of Solvers

A total of 45 subjects participated in Experiment 2. Of these 45 subjects, eight, or 18% of the sample, achieved scores of 5 on both formal operations tasks. Using a less stringent criterion of an average across the two formal operations tasks of between 4.5 to 5.0, the number of subjects was 13, or 29%, of the sample. Using the less strict or "relaxed" criterion suggested by Dulit (1972) of an average score across tasks of between 4.0 to 5.0, the number of subjects was 22, or 49%, of the sample who were operating at the formal level of functioning. It should be noted that these percentages are considerably lower than those expected on the basis of Piaget's theory.

The number of subjects who solved the concept task was 25, or 55%, of the sample. Collapsing across both Experiment 1 and Experiment 2, the number of subjects solving the concept task was 48 out of a total of 88 subjects, or 55% of all subjects across both experiments.

Order Effects of Problem Presentation

All subjects in Experiment 2 were randomly assigned to one of four groups in order to partially counterbalance the order of presentation of the concept task and the two formal operations tasks. Group I received the concept task on day one and the formal operations tasks on day two; the liquids task was given first and the projections task second. Group II also received the concept task on

day one but on day two the order of the formal operations tasks was reversed: projections first and liquids second. Group III received the formal operations tasks on day one with the liquids first and the projections second and the concept task on day two, while Group IV also received the formal operations tasks on day one but in the reverse order: projections first, liquids second, and the concept task on day two.

As in Experiment 1, a significance level of .01 was adopted for all statistical tests reported. For subjects who solved the concept task, the order of problem presentation showed no significant effects. Three separate F tests were performed, one for each dependent measure, across the four groups. The results of the univariate F tests were: F (3, 21) = .027, MS_e = 2.595 between the four groups on the concept task; F (3, 21) = .162, MS_e = .090 between the four groups on the liquids task; and, F (3, 21) = 2.785, MS_e = 1.268 between the four groups on the projections task.

Similar results were seen with the nonsolvers where again order of presentation was not a significant factor. Again, three separate univariate F tests were performed, one for each dependent measure across the four groups. Between the four groups on the concept task, F (3, 16) = 1.868, MS_e = 100.849; between the four groups on the liquids task, F (3, 16) = .182, MS_e = .050; and, between the four groups on the projection task, F (3, 16) = .091,

MS_e = .050. It can therefore be concluded that regardless of whether or not the concept was solved, the order of problem presentation was not a significant variable.

Intertask Relationships

Table 4 shows the contingency relationship between formal operations and the concept task. A chi-square analysis of the data in Table 4 was significant, $\chi^2(1) = 30.628$, indicating that there was a reliable relationship between the two variables. In order to specify in greater detail the nature of the relationships, scores were collapsed across solvers and nonsolvers and the intertask correlations were computed between the concept task and each formal operations task. All correlations were tested for significance against an $r = 0$ hypothesis using a critical ratio z test; all reported correlations are significant. The correlation between the concept task and the liquids task was $r = -.813$, critical ratio $z = 5.393$. The correlation between the concept task and the projections task was $r = -.762$, critical ratio $z = 5.054$. The correlation between the concept task and the mean scores on the two Piagetian tasks was $r = -.838$, critical ratio $z = 5.558$. Finally, the correlation between the two Piagetian tasks themselves was $r = .760$, critical ratio $z = 5.041$. Because all the above correlations were significant, it can be concluded that the concept task is highly correlated with both formal operations tasks separately and with the average scores across both

TABLE 4

The Number of Subjects who Passed or Failed the Concept Task and the Formal Operations Tasks

	Concept Task	
Formal Operations Task	Solve	Nonsolve
Pass (> 4.0)	22	1
Fail (< 4.0)	3	19

formal operations tasks. Furthermore, when errors to criterion on the concept task is a covariate with the two Piagetian tasks as dependent measures, the within-cell regression is significant, F (2, 41) = 8.281, indicating that the errors to criterion on the concept task is a good predictor of the formal operations tasks outcome for both solvers and nonsolvers.

Table 5 shows an analysis of subjects' performance on the formal operations tasks as they related to scores on the concept task. This table shows visually the sources of the significant correlations reported above. Scrutiny of Tables 4 and 5 shows why the relationships between concept performance and formal operations performance deviates from r = 1.0. The discrepancy from a perfect relationship between concept and formal operations performance appeared to be more often in the direction of solution on the concept task but failure on the formal operations task. Since three subjects did this, while only one subject passed the formal operations tasks and did not solve the concept task, this appears to account for the discrepancy. This also accounts for the fact that although 55% of the sample solved the concept task, only 49% were classified as formal operational.

Concept Strategy and Formal Operations

The Fink technique (1972) employed in this study for strategy assessment assesses strategies only for solvers, as nonsolvers show generally chaotic response patterns

TABLE 5

Subjects' Performance on Formal Operations Tasks

Related to Concept Task Performance

	Liq. Score	N	$\bar{X}$ E/C Concept Task	N N/S	% Nonsolvers
Nonformal	2	7	40.570	7	100
	3	16	36.688	13	81
Formal	4	9	13.000	0	0
	5	13	8.310	0	0

	Proj. Score	N	$\bar{X}$ E/C Concept Task	N N/S	% Nonsolvers
Nonformal	2	4	38.000	4	100
	3	19	36.420	14	74
Formal	4	12	15.420	1	8
	5	10	6.700	1	10

	$\bar{X}$ Piaget Score	N	$\bar{X}$ E/C Concept Task	N N/S	% Nonsolvers
Nonformal	2.0	4	38.000	4	100
	2.5	3	44.000	3	100
	3.0	14	37.360	11	79
	3.5	1	38.000	1	100
Formal	4.0	10	16.000	1	10
	4.5	5	11.000	0	0
	5.0	8	4.5	0	0

and since criterion is never reached, terminal response strategy is unmeasurable. Therefore, the analysis between strategy and formal operations is for concept task solvers only.

Subjects employing the wholist/partist strategy (Rapoport, 1975) solved the concept task with a mean errors to criterion score of 5.14 and a mean formal operations score of 4.93. Subjects using any other strategy type solved the concept task with an average of 14.61 errors to criterion and a mean formal operations score of 4.06. A $\underline{t}$ test for independent means was performed on the mean formal operations scores between wholist/partist subjects and those using other strategies and was significant, $\underline{t}$ (23) = 3.796. Therefore, subjects employing the optimal wholist/partist strategy on the concept task earned a significantly higher mean formal operations score than those subjects utilizing an empirically less efficient conceptual strategy.

DISCUSSION

The body of psychological research concerning problem solving has traditionally dealt with the behavior of those subjects who, in fact, solve the problem (Davis, 1966). As early as 1942 (Luchins, 1942), however, it began to become clear that under certain circumstances, subjects could reliably be manipulated by instructions such that they would fail to solve even "simple" problems. The problem solving behavior under study here does not concern manipulated nonsolution, but rather the fact that in any concept identification task, some proportion of the sample will fail to solve the problem even though it is generally assumed that the subjects possess ". . .all the necessary component skills" (Scandura, 1974). In theorizing about the nature of the component skills necessary for concept identification solution, the most promising theory is that of Piaget (Inhelder & Piaget, 1958). The analysis of the concept task presented in the general introduction indicates that the cognitive skills necessary to solve a concept identification problem are virtually identical to those skills subsumed by Piaget's developmental stage of formal operations. The purpose, then, of these preceding experiments has been to test the generality of formal operations, to determine the relationship between solution or nonsolution on a concept task and the attainment of formal operations, and, finally, the relationship between certain concept task strategies and performance on tests designed to measure

the presence and level of formal operations.

The purpose of Experiment 1 was to examine the stability of the solving and nonsolving behavior over time. Furthermore, since nonsolvers experience a large number of negative outcome trials, the possibility of learned helplessness was also examined. In terms of stability over time, the results were unequivocal; that is, all the subjects who solved the concept task on the first day also solved the concept task on the second day. Similarly, all subjects who failed to solve on the first day also failed to solve on the second day. In discussing the stability of performance on the concept task within subjects, it may be noted that it is possible to make a distinction between a type of qualitative stability (solution versus nonsolution) and a quantitative stability (rate of solution). The present results indicated that both types of stability were present.

The finding of quantitative and qualitative stability over a twenty-four to thirty-six hour time delay on the concept task appears to be at odds with certain theories of concept formation which hold that a subject makes no use of memory and/or samples hypotheses at random in attempting to solve a conceptual task (Bower & Trabasso, 1968; Levine, 1974; Restle, 1962). The "no memory" assumption proposed by Trabasso and Bower (1964) suggests that it is possible to solve a problem by chance alone simply by testing one hypothesis after another until the correct one is found. Although some empirical evidence exists for the no memory

assumption (Trabasso & Bower, 1964), Bourne, Ekstrand, and Dominowski (1971), as well as Levine (1970), point out that this assumption "has since been disavowed by everyone" (Levine, 1970, p. 397). The assumption that hypotheses are sampled at random is, however, a core assumption of hypothesis testing theory and would indicate that since the sampling of the correct hypothesis is a random event, solution or nonsolution would also be a random event and, as such, stability of solution over time would also be random. In Levine's most recent statement of hypothesis testing theory (Levine, 1974), he reiterates previous theorizing and suggests qualifications to the above random sampling or "basic assumption." The first qualification is called the composition assumption which assumes that the universe from which the subject samples contains only those hypotheses corresponding to stimulus levels. The second qualification is the changing of sets assumption in which the reduction of a set of hypotheses to zero serves as a signal to the subject to select a new set. In terms of the current evidence for stability, it is possible that on day one, solvers were either sampling from a universe containing the correct hypothesis or else, having exhausted the hypotheses in a universe not containing the correct hypothesis, were able to select a new universe of hypotheses in which was contained the correct solution hypothesis. Similarly, nonsolving could either involve the subject's sampling from a universe of incorrect hypotheses, or

additionally, his inability to logically reduce the set of incorrect hypotheses to zero and therefore, resample a new universe of hypotheses containing the solution hypothesis. Day two performance viewed in terms of Levine's (1974) theory would suggest that a positive transfer phenomenon would lead solvers to sample hypotheses from the same universe that was successful on day one which, in this case, would lead to solution on day two. Nonsolvers would be expected to continue sampling from the universe of hypotheses not containing the solution hypothesis, and if they are not able to logically reduce the incorrect universe to zero and resample a universe containing the solution hypothesis, they would be expected to not solve on day two.

The work of Bruner, Goodnow, and Austin (1956) on strategies used in concept problems relates to the findings of stability and the assumptions of Levine's (1974) theory described above in that solvers' solution rates would be expected to be a function of the type of strategy utilized, but that the utilization of any systematic strategy would allow the testing of hypotheses and the changing of hypothesis universes when all hypotheses in an incorrect universe were tested and rejected. On the other hand, nonsolvers would not be expected to change universes and thus find the correct one if they were not using a systematic strategy that would allow the logical elimination of incorrect hypotheses. Evidence that subjects may be classified as using systematic or analytic strategies versus unsystematic or nonanalytic

strategies comes from a study by Kagan, Moss, and Sigel (1963), in which the relationships obtained between performance on concept tasks and a measure of analytic versus nonanalytic style suggested remarkably stable individual differences. Subjects who solved concept tasks analytically did so regularly and consistently in contrast to the more variable performance of the nonanalytic subjects. Furthermore, Kagan et al. (1963) also showed this analytic versus nonanalytic classification to hold up over a wide variety of other tasks.

The possibility of a learned helplessness type of effect occurring with the nonsolvers was examined using two procedures. The first procedure involved the insertion of a spurious criterion run on ten consecutive correct feedback trials at the conclusion of the 92 trials without solution. Half of the nonsolvers received nothing while half received such spurious feedback. In terms of second day performance, the insertion or noninsertion of such trials did not significantly affect performance on the day two concept task.

The second way in which learned helplessness was assessed was by the use of subjects' subjective self-ratings of their performance. At the conclusion of the first concept problem, all subjects were required to rate their performance on a ten point scale with zero being very bad and ten being superior (Miller & Seligman, 1974). The results showed that, in fact, there was a significant between-groups difference and that the locus of the effect resides in the

solvers seeing themselves as doing significantly better than nonsolvers. The results further show that within nonsolvers, the introduction of a spurious criterion run did not significantly affect self-ratings as those subjects experiencing the spurious criterion run did not rate themselves any higher than did those subjects not receiving the criterion run.

The findings relative to learned helplessness are best understood in terms of a recent theory of learned helplessness proposed by Seligman (1974), in which the development of the phenomena is seen as dependent on three factors: (1) a past history of experience with uncontrollability; (2) discriminative control over stimulus situations in which controllability and uncontrollability are learned; and, (3) the transfer of helplessness from more to less traumatic events but not vice versa. In terms of the present situation, the subject's remote past history may or may not contain helplessness inducing experiences; however, since no pretest was used to assess the presence, absence, or degree of helplessness, the subjects' past histories were not controlled in this study. Factor 2, or the discriminative control over situations in which controllability and uncontrollability are learned, can be viewed in terms of the uniqueness of the experimental setting, with which few subjects have any experience, in which helplessness could have been learned or not learned. In terms of factor 3, or the transfer of helplessness from more to less traumatic events,

it is unlikely that the subjects in this study would have had experiences in experiments sufficient to induce helplessness by traumatic events. This is most unlikely due to recent changes in principles governing the use of human subjects where experimental manipulations tantamount to trauma are not permitted.

An attempt was made in this experiment to prevent a helplessness inducing experience in nonsolvers from affecting day two performance and the analysis of the zero and ten spurious reinforcement conditions showed that regardless of this manipulation, second day performance was not affected. This does not mean that helplessness was not a factor in nonsolvers, as nonsolvers reliably rated their own performance lower than did the solvers. These findings do, however, suggest direction for future studies in which a history of helplessness would have to be assessed prior to the problem solving phase. What can be concluded from these data is that solvers rated their performance more highly than did nonsolvers and the effect of apparent success or failure did not affect second day performance in the nonsolvers.

Taken together, the results of Experiment 1 show that solving or nonsolving is to some degree a subject related parameter and that the ability to solve, or the lack thereof, is a stable phenomenon, at least over a twenty-four to thirty-six hour period. In terms of the possibility of contamination from learned helplessness, the manipulation of the appearance of success did not affect second day

performance in nonsolvers and solvers rated their performance significantly higher than nonsolvers. This finding could either indicate a pre-existing generalized helplessness in nonsolvers (not controlled for in this study) and/or show that the zero or ten spurious reinforcements did not fool anyone as the nonsolvers knew that they simply did not do very well and the solvers were well aware of their success.

In Piaget's original presentation of the characteristics of the formal operations stage (Inhelder & Piaget, 1958), the strong impression is made that formal operations are the rule in late adolescence and adulthood. As recently as 1972 (Piaget, 1972), Piaget reiterated his position on the generality of formal operations, adopting the position that college students in particular would most certainly be operating at the formal level. The results of the current study, as well as the other available literature, clearly show that the extent of the generality of formal operations has been greatly overestimated by Piaget. Using the "relaxed" criteria suggested by Dulit (1972), the current results showed that 49% of the sampled subjects in this experiment could be considered formal operational. This figure of 49% seems to fall somewhere in between the figures of 29% found by Lee (1976) in college students, 33% found by Dulit (1972) in randomly selected adults, 54% of randomly chosen female adults found by Tomlinson-Keasey (1972), 60% found by Dulit (1972) in intellectually gifted adolescents and, finally, 67% found by Tomlinson-Keasey in female college

students. Some of the variability in the proportion of formal operators can be accounted for by the different populations sampled and by the criterion used in determining formal operations (e.g., in 1976, Lee used an extremely rigorous criterion in coming up with the figure of 29% formal operational in college students); however, regardless of the experimenter's criterion, or nature of the sample, it is clear that the ubiquity of formal operations suggested by Piaget is not empirically justified. In all likelihood, Piaget's overestimation of the proportion of formal operators is due to the fact that the data presented in Inhelder and Piaget (1958) were taken from an admittedly "privileged" population and were meant to constitute exemplary descriptions of behavior, not experimental data describing the average performance of specified populations. Additionally, Piaget's theorizing is generally just that as he rarely provides experimental evidence for his theories, preferring instead, to leave that task for others.

That there is a relationship between the concept identification task used in Experiment 1 and Piaget's tasks for formal operations has been suggested by many authors (e.g., Youniss & Ross, 1970; Yudin, 1966). Most recently, Lee (1976) has also argued for the efficacy of the concept task in assessing formal operations; however, as with previous logical analyses (including the current one presented in the introduction), no empirical data has been offered. In order to provide such empirical data, it was necessary to

eliminate possible order effects due to the order of presentation of concept and formal operations tasks. The results show that for both solvers and nonsolvers, no significant results due to order of problem presentation were found.

The results in the form of correlations generated by this study apparently confirm the logical analysis of the relationship between the concept task and the formal operations tasks. The correlations between the concept task and the formal operations tasks, either separately or together, were all in excess of $r = \pm.76$. This finding, although extremely interesting, is not particularly surprising because the two Piagetian tasks selected for use in this experiment were chosen specifically because between the two, all major theoretical aspects of formal operations would be assessed. Furthermore, the logical analysis of the concept task showed that within the one complete learning concept task, all major theoretical attributes of formal operations would be operating if the subject were to solve the problem. An overall test of the relationship between solving or nonsolving on the concept task and passing or failing on the formal operations tasks was significant and demonstrates further that successful solution of the concept task is highly related to successful performance on the formal operations tasks and that failure to solve the concept task is significantly related to failure to pass the formal operations assessment problems.

In order to provide a more analytical perspective on the relationship between concept identification and formal operations, solvers on the concept task were grouped according to findings by Rapoport (1975) that speed of solution (in terms of errors to criterion) is related to the type of strategy employed by the subject. Specifically, Rapoport (1975) found that subjects who began the problem by responding to the entire stimulus set (wholists), but who finished the problem by responding only to the relevant dimension (partists), solved the concept task in significantly fewer trials than subjects employing any other strategy type. This analysis was utilized in the current study by comparing the mean formal operations scores of wholist/partist subjects with the formal operations scores of others solvers who used some other strategy type (e.g., wholism exclusively, partism exclusively, rote memorization, etc.). The results show quite clearly that subjects using the wholist/partist strategy solve the concept task with fewer errors to criterion (a replication of Rapoport, 1975), but more importantly, these subjects also showed a significantly higher mean formal operations score across both formal operations tasks. This result suggests that not only is solution on the concept task related to formal operations, but the way in which the concept task is solved by the subject (strategy) is also related to the quantitative aspects of formal operations. The superiority of the wholist/partist subject on the concept task is consistent with the findings of Bruner,

Goodnow, and Austin (1956) and Rapoport (1975), that this type of strategy yields the fastest solution rate in terms of errors to criterion. This is most likely the case because the alternative strategies (wholism, partism, rote memorization, etc.) involve a greater strain on memory and a less systematic approach to the reduction of possible hypotheses. It is for these reasons as well, that the wholist/partist subject also shows the highest mean formal operations score as, in terms of formal operations, the wholist/partist subjects are demonstrating the optimal facility in the use of combinatorial analysis.

The implications of the findings presented in this study possess a great deal of relevance regarding developmental theory, educational approaches and expectations, and suggestions for future research. To begin with, it is clear that modifications in Piaget's specifications of the formal operations stage are necessary; not just from the results of this study, but similar findings from other authors indicating that formal functioning simply is not as ubiquitous as Piaget theorized. The current study, sampling from a "privileged" population (college students), indicates that about half the sample is formal operational. This finding is consistent with results from other studies sampling from other populations, all indicating that in adults formal operations is not the rule but rather a highly desirable potential possibility to be attained.

A second theoretical implication involves the clear

relationship between the concept identification task and the theoretical components of formal operations assessed by the Piagetian tasks. According to Piaget (Inhelder & Piaget, 1958), the fundamental theoretical components are:

1. Combinatorial analysis: or the ability to consider all possible combinations of variables in a systematic fashion.

2. The changed relation of the real to the possible: or the ability to form recombinations of the variables in a problem without regard as to whether or not they were ever previously experienced.

3. Hypothetico-deductive thinking: or the ability to reason that "If this were true, then. . . ." The formal operator seeks hypotheses which are general and necessary, not merely sufficient.

4. Propositional thinking: or the ability to deal with statements containing the raw data but not the raw data itself. This is what Piaget calls second degree thinking, operations which result in propositions about propositions.

Theoretically, the concept solver must bring these four attributes into play in order to solve the complete learning problem. Combinatorial analysis is employed by the solver in the course of forming and then testing all possible stimulus combinations in the orderly reduction of possibly significant stimulus combinations. The solver must also deal with the real as well as the possible in that the current concept task demands that the presence or absence of stimuli be responded to. Propositional thinking is implicated in solution of the complete learning task as the solver, having developed a proposition as to the relevant

attributes, must now derive the combinatorial rule by forming a proposition about a prior proposition (e.g., if A and B are present in examples, then the combination of A and B is necessary in all examples, therefore, the rule is conjunction). Finally, hypothetico-deductive reasoning is implicated in solution as, in the orderly reduction of possible stimulus combinations, the subject must find the necessary as opposed to the merely sufficient hypothesis. In the current study, the empirical finding of a significant relationship between the concept task and the formal operations tasks serves to lend empirical credibility to the above logical analysis. This analysis speaks to the theoretical abilities of the solver; however, it also speaks to the possible deficiencies present in the nonsolver.

Although this study indicates that nonsolvers are also not formal operational, the specific deficits in the nonsolver are unspecified. This lack of specificity as to exactly what deficits are operating points up another important aspect of this study; that is, that while the formal operations literature, and thereby our understanding, is in an embryonic state, the literature on concept formation and identification is even now a comprehensive detailed body of information covering virtually all aspects of the phenomenon. The finding of a significant relationship between these two areas therefore means that formal operations, or the lack thereof, can be studied parametrically from the point of view of concept formation instead of as

an isolated aspect of a general theory of cognitive development.

Using the nonsolver as an example, the concept task could be parametrically varied in an attempt to pin down the specific deficiencies operating to contribute to the subject's inability to solve. According to Haygood and Bourne (1965), the complete learning problem used in this study is significantly more difficult than problems in which just the combinatorial rule or just the relevant attributes must be discerned. Accordingly, a nonsolver who is able to solve an attribute identification problem (rule given) could be suffering from an inability to use propositional thinking, as propositional thinking is implicated in the derivation of the combinatorial rule. Similarly, in a rule learning task (attributes given), a nonsolver could be expected to solve if his deficit were in the area of hypothetico-deductive reasoning which is implied in the formation of necessary as opposed to sufficient attributes for solution. If experiments designed to test these contingencies showed positive results, a more analytic understanding of why complete learning is more difficult than its component processes would be available as well as some insight into the specific deficits of the nonsolver.

Complete learning versus its components (attribute identification and rule learning) is not the only manipulation of the concept task which would be expected to uncover possible cognitive deficits. For example, it is known that

increasing the number of relevant or irrelevant dimensions tends to make solution more difficult (Bourne, Ekstrand, & Dominowski, 1971). In the current context, this could be viewed as involving the subject's capacity for combinatorial analysis which would be increasingly taxed as the number of relevant or irrelevant dimensions is increased. Furthermore, if a subject solves a problem with a minimal number of relevant and irrelevant attributes, but cannot solve a problem with a greater number of such attributes, a deficit in the presence or development of combinatorial analysis could be operating.

These and other manipulations in the concept task such as attribute saliency, nature of feedback, etc., could be expected to be related to the components of formal operations if the underlying processes can be shown to represent specific deficits in any one, or a combination of, the theoretical attributes of formal operations. These relationships between paradigm manipulations and performance related to theoretical cognitive skills are empirical questions yet to be addressed. What is important is that drawing attention to the relationship between the concept paradigm and formal operations cognitive skills provides a pre-existing body of literature within which to plan and execute such research.

If parametric variations in the concept task can lead to the determination of the specific deficits in formal skills, then it should also be possible to understand

nonsolution and the relative difficulty of certain concept paradigms or variations in terms of the formal operations skills which theoretically would be operating. Looking at the concept task from this point of view, many well established phenomenon could be explained. Complete learning is known to be more difficult a task than either rule learning or attribute identification (Haygood & Bourne, 1965). This could be understood in terms of formal operations as complete learning involves combinatorial analysis, propositional thinking, and hypothetico-deductive reasoning whereas rule learning itself involves primarily propositional thinking and attribute identification itself involves primarily hypothetico-deductive reasoning. Similarly, it is known that an increase in relevant or irrelevant dimensions or attributes increases the difficulty of the problem (Bourne, Ekstrand, & Dominowski, 1971). From the formal operations perspective, this could be interpreted as reflecting the subject's ability to use combinatorial analysis which would be increasingly taxed as the number of dimensions or attributes increases. This reciprocal relationship also suggests that the number of nonsolvers will, to a certain extent, be a function of the specific paradigm as many concept variations can be shown to involve a greater or lesser number of formal skills or a greater or lesser degree of difficulty in the utilization or deployment of these formal operational skills. The relationship then between the concept task and the formal operations tasks can be seen as reciprocal; that

is, parametric variations of the concept task can lead to specification of the deficits in formal operations and formal operations theory can be applied to concept formation to help explain the relative difficulty of many concept paradigm variations.

A second area of implications from this study is in the realm of educational expectations and procedures. Rather than viewing formal operations as the inevitable adult resolution of cognitive disequilibrium, results of this study indicate that formal operations is a cognitive potential; that is, something to be achieved through education or critical experiences. As Piaget sees it, the attributes of formal operations are learned incidentally in the high schools or in undergraduate university programs. If that is, in fact the case, then the high school curriculum needs to be modified from a fact orientation to one directed at the concepts underlying the facts or, how it is that hypotheses become fact through scientific research. That this is not currently happening is one possible explanation for the attrition rates in introductory science courses at universities. As a result of this and other studies (Lee, 1976), the University of New Mexico introductory psychology laboratory course now has an initial component directed towards insuring the students' understanding of hypothetico-deductive reasoning and combinatorial analysis. Initial reports on this curriculum modification indicate that it is highly beneficial, particularly in helping students

understand the logic of the scientific method and such constructs as dependent and independent variables.

Obviously, if formal functioning is the case in only half of a randomly sampled college student population, experimental methods aimed towards the teaching of formal operations need to be developed and tested. Towards that end, a recent doctoral dissertation by Lee (1976) tested a comprehensive modeling training program for formal operations with notable success. Lee (1976) used both component and modeling conditions and found significant improvement using either system, but with modeling showing the greatest increase in formal operations scores, reporting a gain of 54% in proportion of formal operators. Studies such as this one will be necessary if formal operations are to be effectively taught and integrated into curricula.

The questions raised and answered in this study do themselves raise additional questions to be addressed. For example, it has been stated that one advantage of viewing formal operations as a subset of concept formation is that the literature on concept formation is far more comprehensive. It has been noted that the concept paradigm used here is only one of many different types and therefore, a program of research is called for in which the relationship between Piagetian formal operations tasks and other concept formation paradigms is explicated. Similarly, the strategies assessed in this study are unique to the reception paradigm and therefore, further research examining the relationship

between the more thoroughly researched selection paradigms (Bruner, Goodnow, & Austin, 1956) and formal operations would also be important. Having drawn attention to the concept-formal operations relationship also presupposes that variables found to be important and/or effective in concept formation may also generalize to the formal operations perspective.

The advantage of the usage of the concept task in assessment of formal skills has been viewed in terms of the richness of the concept literature; however, other good reasons exist as well. Piaget's formal operations tasks are many and varied and are usually designed to test some formal operational subcomponent; furthermore, they are often difficult to administer and possibly culturally biased. The concept task, on the other hand, eliminates past experience with known physical laws and provides a task in which the various dimensions known to affect performance can be independently and systematically manipulated. In addition to the advantage of independent and systematic manipulation of variables, the concept task also provides for much more adequate performance measures. The Piagetian tasks' performance measures are generally in terms of discrete levels describing successive approximations to the component skill under investigation whereas the concept task and its variations utilize continuous performance measures such as trials and errors to criterion, the trial-by-trial effects of confirming or infirming feedback, and

trial-by-trial mapping of hypotheses (see Bruner, Goodnow, & Austin, 1956; Bourne, Ekstrand, & Dominowski, 1971).

In summary, if the relationship found between the current concept task and formal operations holds up using other standard concept formation paradigms, then we would have at our disposal a well researched and documented tool for the assessment and training of the final equilibrium stage of formal operations.

In conclusion, the observation of nonsolution seen so often in concept tasks does appear to be a subject related variable which is related to deficiencies in cognitive skills heretofore assumed to be present in all college students. The specific type of deficient cognitive skills appear to be those discussed by Piaget in terms of his formal operations stage. Studies such as Lee's (1976) indicate quite clearly that teaching techniques for formal operations components exist and are viable. In the event that the proposed program of research is successful and the teaching methods suggested are implemented, then perhaps nonsolution can again be viewed in terms of simply confusing the subject with instruction sets that draw attention away from the answer.

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APPENDICES

APPENDIX I

REVIEW OF THE LITERATURE

Nonsolution: Systematic Study

Research in human problem solving has, according to a review by Davis (1966), a well earned reputation for being the most chaotic of all identifiable categories of human learning. The outstanding quality which leads to this conclusion is the diversity of experimental procedures called "problem solving" tasks. Regardless of the tasks utilized, however, Davis (1966) was able to isolate but one type of problem solving situation in which nonsolution was the factor of interest. This type of situation has become known as the "water jar" or Einstellung type problem. Einstellung translates from German into "set" or "expectation" and this is precisely what is manipulated by this type of problem. In an Einstellung problem, the subject is presented with preliminary experiences which render him functionally blind to subsequent solutions. In a critique of the Luchins (1942) paper, Aftanas and Koppenaal (1962) correctly pointed out that Luchins' instructions produced Einstellùng by failing to inform the subject that more than one solution might be available. Unfortunately, Aftanas and Koppenaal (1962) chose not to go beyond this criticism in an attempt to integrate this finding into a more general theory.

Ress and Levine (1966), using methodology similar to Luchins' (1942), were able to demonstrate the Einstellung phenomenon during simple discrimination learning. The task

involved the subjects being presented with a series of 100 cards each with two circles of different sizes. Subjects were given either 0, 3, or 6 pretraining problems in which the solution involved some complex position sequence. After pretraining, all subjects were then given one more problem in which the larger of the two circles was always correct. Results showed that subjects with 0 pretraining solved the problem in an average of three trials. The subjects in the other two pretraining conditions solved with an average of 63 trials and almost half of these subjects failed to solve after 100 trials. Because the methodology and conclusions of this experiment are similar to those of Luchins' (1942), the critique of Aftanas and Koppenaal (1962) would be appropriate in this case as well except that Levine (1971) incorporated this criticism into a general theory of insoluble and unsolved problems.

Levine's (1971) theory of insoluble and unsolved problems stems directly from hypothesis theory (for a review, see Levine, 1969) and incorporates the Einstellung situation by stipulating that the universe from which the subject samples his hypotheses contains only those hypotheses corresponding to stimulus levels. This theoretical assumption clearly is a function of the experimenter's instructions or the preliminary experiences of the subject. In the Ress and Levine (1966) study, the preliminary problems directed the subject to the universe of hypotheses containing position sequence hypotheses only and as long as the subject samples

hypotheses from this universe, the problem will never be solved as some hypotheses reside in a different universe of possible solutions. Since the publication of this theory, Levine has continued to investigate the phenomenon of nonsolution. Glassman and Levine (1972) provided direct evidence that nonsolution can be manipulated by directing the subject to a universe of hypotheses not containing the solution. Fingerman and Levine (1974), using the methodology of the Glassman and Levine (1972) study, showed that subjects learned nothing about hypotheses not in their hypothesis set, even when the nonsampled hypothesis was perfectly correlated with reinforcement and even when the correct hypothesis was later presented to the subject as a possibly overlooked solution.

Unfortunately, beyond the work of Levine (1971), little interest in nonsolution has been manifest in the problem solving literature, with the exception of a recent paper by Scandura (1974) in which he addresses the question of why subjects fail to solve a problem even when they possess ". . .all of the necessary component skills." The assumption of the possession of the necessary component skills is dealt with by Scandura by intensive training sessions in which the component skills are taught. Scandura (1974) then views nonsolution in terms of the subject's inability to use the rules he has just been taught. Levine (1971) also appears to assume the existence of necessary component skills as he never specifies how a subject comes to form the universe

of hypotheses from which he samples.

In order to demonstrate that the presence of component skills may be presumptuous, one need only to read the method sections of problem solving studies and note the number of subjects dismissed for failure to understand directions or failure to solve the pretraining problems. In the Fingerman and Levine (1974) study, for example, 22% of the subjects were dismissed because they were unable to solve the pretraining problems which the authors repeatedly describe as "simple." The dismissal of subjects for inability to understand directions or inability to solve the problem is quite a general and accepted procedure (e.g., Fink, 1972; Johnson & Toppino, 1974; Rapoport, 1975); however, it does serve to make the point that many subjects come to the problem solving experiment without the component skills necessary for solution.

Stability of Problem Solving

The preceding discussion of nonsolution primarily involved situations in which nonsolution has been manipulated by instruction sets which direct attention away from the solution. Scandura (1974) demonstrates his interest in component skills underlying problem solving by teaching such skills; however, as we have seen, some subjects are not able to utilize these trained-in component skills. In studies where the component skills are assumed to be present, there is, however, always some group of subjects who simply do not solve. The question can therefore be restated as

follows: Why does an apparently normal, well motivated college student fail to solve problems, some of which are virtually irreducible in their simplicity?

One possible explanation for this nonsolving behavior is that the ability to solve a problem is not a stable within-subject factor. That is, on a given day, a subject may solve a given task but tomorrow he may not. According to current hypothesis testing theory in concept formation (Levine, 1974), hypotheses are sampled at random so that the sampling of a correct hypothesis and, therefore, solution is also a random event. This assumption would seem to suggest that solving ability is random and, therefore, not stable. Levine (1974), however, qualifies the above random sampling notion by first assuming that the universe from which the subject samples contains the solution hypothesis and, if it does not, then having logically reduced the universe to zero successful hypotheses, the subject would sample a new universe which hopefully would contain the correct hypothesis.

Given Levine's (1974) qualifications of the random sampling notion, a solver would be a person who would be able to logically test the hypotheses present in the currently sample universe, and in the event that solution is not found, would be able to recognize the current universe as an empty set and resample a new universe.

The mechanisms by which this set reduction and resampling would occur are most likely the strategies identified by

Bruner, Goodnow, and Austin (1956). The findings on strategies in concept learning indicate that type of strategy is related to solution rate, but in the case of set reduction and resampling, presumably any systematic strategy would allow for the testing of hypotheses and the changing of hypothesis sets when logically indicated. In this perspective, the nonsolver could be an individual whose stategy is so illogical or unsystematic so as to prevent the accurate testing of all hypotheses in the set and the subsequent resampling of a new universe of hypotheses. When viewed thusly, nonsolution, slow solution, and ultimate rate of solution could be placed on a continuum dependent on the quality and logic of strategies used. In terms of stability in the use and deployment of strategies, Schwartz (1967) concluded that systematic formulation and trial-by-trial revision of hypotheses are basic skills in solving conceptual problems and that groups of subjects were clearly separable on this dimension. This study demonstrates that quality of solution is a within-subject parameter, but it does not directly test the stability of this parameter over time. A study by Kagan, Moss, and Sigel (1963) also found evidence for the within-subject nature of solution quality but demonstrated that the relationship between within-subject parameters and performance on concept tasks was remarkably stable over tasks. Subjects who solved concept tasks analytically did so regularly and consistently in contrast to the more variable performance of the nonanalytic subjects. Kagan

et al.'s (1963) data are even more impressive because the within-subject stability held up not only over a number of different types of tasks but even seemed to be related to the subject's style of life outside the laboratory.

In summary, certain assumptions about the random nature of hypothesis testing would argue against stability; however, Levine's (1974) qualifications of the random selection assumption show that a concept problem should be solved if a systematic strategy is used. Bruner, Goodnow, and Austin (1956) have demonstrated that type of strategy is related to speed of solution and Kagan, Moss, and Sigel (1963) have shown stability across tasks in the use of strategy types. From this analysis, solution and nonsolution can be seen as falling on a continuum with nonsolution caused by an inability to use a strategy or the use of a hopelessly unsystematic one, and rate of solution being determined by the quality of the systematic strategy used. According to Bourne, Eckstrand, and Dominowski (1971), what still remains to be done is the repeated presentation of the same, or closely related, tasks over some period of time in order to show that solution and nonsolution are stable in the same way that Kagan et al. (1963) demonstrated the stability of strategy type across problems.

Within-Subject Variables Affecting Performance

The preceding research seems to indicate that the ability to solve a given type of problem is dependent upon the subject's possession of the necessary component skills

(strategy). Furthermore, the possession or nonpossession of these skills appears to be a stable subject related parameter. The obvious question then becomes one of how it is that the subject comes to possess or not possess these skills.

One possibility is that subjects who fail to solve are deficient in test-measured intelligence. The possibility of deficient intelligence can most likely be ruled out; first because the educational system, and certainly college entrance requirements, would certainly select out students of abnormally low measured intelligence and secondly, attempts to find consistent relationships between measured intelligence and problem solving have been largely unsuccessful. Raaheim and Kaufman (1974) investigated the relationship between problem solving and intelligence and concluded that in males, intelligence correlated with success, but in females, intelligence was not related to problem solving ability. Denny (1966) related intelligence to problem solving ability, but found that anxiety level was more predictive of performance than intelligence itself in that low intelligence-low anxiety subjects did as well as high intelligence-low anxiety subjects. Finally, Flaherty and Flaherty (1974) examined the relationship between various concept paradigms and intelligence but found significant intelligence by paradigm interactions such that on some paradigms, a low intelligence quotient facilitated performance whereas with other paradigms, a high intelligence quotient predicted performance.

Denny's (1966) findings of a relationship between intrapsychic characterological variables (anxiety) and problem solving success suggests that even in the presence of the necessary component skills, nonsolution may occur. This is the essential thrust of a body of research on learned helplessness (Seligman, 1975) in which a series of performance measures are seen as related to the subject's prior experiences with repeated success or failure. According to Seligman (1975), as well as Hiroto (1974), the development of helplessness is seen as dependent on three factors: (1) a past history of experience with uncontrollability; (2) discriminative control over stimulus situations in which controllability and uncontrollability are learned; and, (3) the transfer of helplessness from more to less traumatic events but not vice versa. Helplessness could, therefore, affect problem solving in that prior experiences with helplessness or the stimulus situation itself, could prevent the subject from performing optimally even given the presence of the necessary component skills.

Throughout the discussion of the effects of intelligence and helplessness, it appears that these variables are being viewed in relationship to their effects on success in problem solving, not the development of problem solving skills per se. Even Scandura (1974) is not concerned with the development of such skills, as he first trains his subjects in these skills prior to testing. Therefore, the original question, that is, how these component skills

develop, or do not develop, remains unanswered by this line of inquiry. The cognitive developmental theory of Piaget (Inhelder & Piaget, 1958) does, however, deal directly with the development of cognitive skills and therefore should provide at least the theory of how such skills come to be and precisely what these skills are.

Development of Component Skills

According to the stage dependent theory of the Geneva School, the progression from child to the adolescent/adult stage involves the change from the use of "concrete" operations to the use of "formal" operations (Inhelder & Piaget, 1958). Inhelder and Piaget (1958) cite the age of about eleven years as that at which concrete operations are no longer adequate to the tasks faced by the child. At that time, disequilibrium disrupts cognitive balance and formal operations begin. This stage of formal operations is said to develop fully by the age of 14 to 16 years and is, in short, the final equilibrium of cognitive development (for a detailed review of this theory, see Flavell, 1963).

In order to understand the structures and skills characteristic of the final formal stage, a brief discussion of the characteristics and generality of the preceding concrete stage is helpful. Thinking in the concrete stage is limited almost exclusively to thinking about things. The fundamental building blocks are the logic of class and the logic of relations. The logic of class refers to the child's capacity to handle problems of classification, such as

whether something is, or is not, a member of a given class. The logic of relations refers to the child's capacity to relate things of differing size within the context of graded and ordered series, such as problems of seriation and one-to-one correspondence. By-and-large, however, the concrete stage child is limited to thinking about actual concrete situations and things as they are presented to him in the real world. Because in Piaget's theory, successive stages use prior stages as building blocks, the literature on the generality of concrete operations should be highly relevant to the generality of formal operations. Furthermore, Bart and Airasian (1974) have demonstrated experimentally that the antecedent concrete operations do in fact precede the development of formal operations.

Elkind (1961), using assessment tasks of concrete operations, showed that high school seniors (mean age of 15 years) were only 47% concrete operational on a task measuring conservation of volume. Using the same task with college freshmen, Elkind (1962) found that only 58% could conserve volume. A more recent replication of Elkind's (1961, 1962) experiments by Towler and Wheatly (1971) show the percentage of volume conservers (and hence, concrete operations) among college students to have risen to 61%. In a study of unschooled rural adults presently enrolled in remedial education programs, Graves (1972) found that only 24% of the subjects could conserve volume and could therefore be classified as concrete operational. Based

on this review of the generality of the concrete operations stage, it is clear that the final equilibrium of the formal (adult) stage, although built upon the concrete stage, may not be a terribly general phenomenon.

As opposed to the limitations inherent in the concrete stage (thinking restricted to actual concrete situations), the formal stage has as its most distinctive feature the inclusion of the possible being considered as including reality as a subset with the result that hypotheses may proceed from nonobserved and nonexperienced phenomena. In other words, the individual is no longer bound by the real and experienced. The characteristics of the formal stage are: (1) combinatorial analysis or the ability to consider all possible combinations of variables in a systematic fashion; (2) the changed relation of the real to the possible, or the ability to form recombinations of the variables in a problem without regard as to whether or not they were ever previously experienced; (3) hypothetico-deductive thinking, or the ability to reason that "if this were true, then. . . ." Hypotheses must be general and necessary as opposed to merely sufficient; and, (4) propositional thinking, or the ability to generate propositions about propositions.

The publication in which Piaget first puts forth the properties of the formal stage (Inhelder & Piaget, 1958) leaves the impression that formal stage thinking is the rule in adolescence, since all reported protocols show the subjects to be functioning at the formal level.

A review of the literature on formal operations done by Farrell (1969) seems to provide evidence that Piaget is correct in his theorizing on the generality of the stage. Only the Elkind studies (1961, 1962) showing inability to conserve volume are presented as potential arguments against generality. In the previous discussion of concrete operations, however, the Elkind studies were not the only studies showing failure to attain concrete operations and, since the Farrell (1969) article, data questioning the generality of formal operations has been published. Tomlinson-Keasey (1972), using five of Piaget's formal operations assessment tasks, found that only 67% of a female college student sample was formal operational whereas this figure fell to 54% for a group of adult women. In a far more detailed study of the generality of formal operations, Dulit (1972) tested groups of average young adolescents, average older adolescents, intellectually gifted older adolescents, and average adults. These groups were tested on two formal operations tasks believed by Dulit to be the most characteristic of formal operations. The results are dramatic: none of the younger adolescents solved any of the problems; of the older adolescents, from 25% to 33% (depending upon the laxity of the criteria) were formal operational. The intellectually gifted older adolescents were 60% fully formal whereas the adults averaged from 25% to 33% formal operational. Clearly, these studies cast serious doubt on the generality of the formal stage as intimated by Inhelder and Piaget (1958).

In order to reply to the issues raised in the preceding studies, Piaget (1972) has reported his latest "reflections" on formal operations. Piaget feels that the reason why formal operations are not as ubiquitous as Inhelder and Piaget (1958) would lead us to believe is because the original data was taken from adolescents enrolled in the "better" schools in Geneva. However, Piaget is quite unequivocal in his theorizing that college students would certainly be operating at the formal level. Obviously, further research is necessary in order to prove, disprove, or qualify Piaget's statements on the generality of the formal stage.

Cognitive Assessment

Having described the formal operations stage in terms of its being built upon the preceding concrete stage, and having postulated the component skills underlying formal operations, Inhelder and Piaget (1958) describe a series of tasks which are designed to assess the degree to which a given subject has mastered or attained formal operations. These tasks are generally cumbersome to administer and often appear designed to test one component of formal operations per task. In a study by Yudin (1966), an attempt was made to determine the relationship between formal operations and intelligence. Although the results showed an interaction of age and intelligence quotient, Yudin (1966) utilized the concept paradigm in assessing formal operations without so much as providing an argument as to why this task might be appropriate to formal operations. Elkind, Barocas, and

and Johnsen (1969) also utilized the concept task to argue that concept production was a good metric in assessing cognitive development as did Furth, Youniss, and Ross (1970) in a study demonstrating the applicability of concept formation to Piaget's theory. Of the studies using the concept formation paradigms in cognitive assessment, only Neimark (1970) attempts to establish the correlations between formal operations tasks of Piaget and problem solving tasks. Unfortunately, the results of the Neimark (1970) study are questionable as she administered these tasks to subjects ranging from ten to twelve years old. On the basis of the results that the subjects did very poorly on all tasks, she critizes both the Piagetian task of chemical combinations and the problem solving task as being just too difficult. An alternative explanation is that the subjects were not preliminarily assessed as to their stage of development and, furthermore, subjects of that age group would not be expected to be able to solve these types of problems anyway as Piaget's age for the onset of formal operations is 14 to 16 years old.

Regardless of Neimark's (1970) failure to provide data on the relationship between Piaget's assessment tasks and the problem solving task, a sufficient number of studies make the assumption that the methodology of concept formation is potentially useful in the measurement and assessment of stage of cognitive development to justify an attempt at a precise formulation of the nature of such relationships.

In addition, logical analyses relating the concept task to the previously described attributes of formal operations further suggests this relationship. For example, Haygood and Bourne (1965) have shown that the complete learning concept task is more difficult than either the rule or attribute learning components. In terms of formal operations, complete learning involves propositional thinking in deriving the combinatorial rule, combinatorial analysis in forming and testing stimulus combinations, and hypothetico-deductive reasoning is used in attribute learning as merely sufficient hypotheses are not adequate. Since the rule learning component involves primarily propositional thinking and since attribute identification involves primarily hypothetico-deductive reasoning, then from the formal operations point of view alone, these findings on relative difficulty of concept tasks variations can be explained by the fact that fewer component skills are used in the rule or attribute learning cases as opposed to the many skills used in complete learning.

The logical analysis of the relationship between the concept task and formal operations skills is more general than just complete versus rule or attribute learning. Bourne, Ekstrand, and Dominowski (1971) have reported that an increase in relevant or irrelevant attributes tends to make the concept task more difficult. In terms of formal operations, this could reflect the taxing of the facility for combinatorial analysis. Together with this type of logical

analysis, as well as the previously cited literature, what is necessary are studies designed specifically to establish the relationship between the Piagetian formal operations assessment tasks and the more analytic and thoroughly researched concept paradigms.

Importance of Formal Operations

Up to this point, the attainment of formal operations has been discussed merely as a final cognitive equilibrium characteristic of adults. Although this is certainly the case, Lovell (1972) has pointed out that although formal operations undeniably underlie the natural sciences, formal operations are also apparent in other areas of functioning including history, literature, political science, and even bible study. In a more recent article, Lovell (1974) considers formal operations in terms of social and political concepts as well. According to Lovell (1974), the possession of formal operations skills should allow the individual to consider and evaluate differing social and political points of view without the necessity of committing oneself to a single one. Moreover, the individual can advance hypotheses, and build theories to explain the origins and outcomes of the issues in question. Lovell (1974) also feels that a good deal of miscommunication between adolescents and adults could be related to this difference in quality of thought. When people communicating are doing so at the formal level, the range of ideas that can be communicated increases enormously. In discussion, they can try to relate different

variables, realize a number of possible links in any issue, try out ideas in a systematic fashion, and go beyond the given data using hypothetico-deductive thought.

As early as 1967, Hallam (1967) provided evidence that Lovell's (1972) assumption that formal thought transcends the physical sciences is quite correct. Hallam (1967) showed that students' answers on a history exam could be classified according to Piaget's developmental stages. Formal operational answers tended to show movement from one point of view to another. The answers went beyond the concrete givens, showed reasons and hypotheses by implication, and realized a multiplicity of possibilities. It therefore appears that Lovell is quite correct in that formal operations is not bound to the natural sciences but is a far more generalized and important capability underlying thinking in a diversity of areas.

It is clear from these studies that formal thought is a very general characteristic across areas of specialization, a fact which Piaget (1972) himself acknowledges. Formal thought, however, has yet to be researched adequately with older adults (i.e., more than 65 years of age) to see if, in fact, formal operations is the final equilibrium. A review by Hooper, Fitzgerald, and Papalia (1971) reviews research showing that in some older adults there is a return to more concrete childlike thought patterns, although the evidence for this is preliminary. Hooper et al.'s (1971) review does imply a curvilinear relationship across the

total life span and raises a number of interesting points with regard to future research. One could predict, for example, a sequential order of functional regression which would involve the formal operations first and the concrete operations later. Perhaps, even a reversed order of horizontal decalage disappearences could be predicted. In any event, Hooper et al.'s (1971) point is well taken that cognitive development needs to be investigated over the entire life span, including the potential postulation of stages after the development of formal operations.

Training of Formal Operations

On the general topic of the training of the requisite skills for Piaget's cognitive stages, Piaget (1971) feels that there is no benefit to be derived from such efforts as the individual will eventually reach that stage anyway. With formal operations, we have seen that the attainment of the skills defining the stage is not necessarily a certainty. In fact, the studies reviewed indicate that perhaps only as many as half the adult population is operating at that stage. In view of this, Piaget's arguments (1971) against training are apparently invalid as many individuals will not reach this final stage.

Studies designed to train the component skills of formal operations have largely been quite successful. Siegler, Liebert, and Liebert (1973) were able to train performance on one of the formal operations assessment tasks by "playing it by ear" using a conceptual framework, and the presentation

of analogue problems. The authors found that using these two procedures allowed them to train ten and eleven year olds on the Piagetian task, although they did not look for generalization to other problems testing other components. Lee (1976) used both training of components and training by modeling with college students and found that significant improvements were possible using either method, but with modeling showing the greatest increase in formal operations scores. From an initial pretraining formal operations proportion of 29%, Lee (1976) found that after modeling training, 83% of the subjects could be classified as formal operational.

Compared to the volume of training studies on the concrete operations stage, the training literature on formal operations is as yet in its infancy; however, studies such as that of Lee (1976) will be necessary in order to train the component skills which appear to be so desirable across a number of different areas and for a number of different applications.

<u>Summary</u>

Areas reviewed in this paper include nonsolution, the stability of problem solving, within-subject variables affecting problem solving, component skills in problem solving, cognitive assessment, and the importance and training of formal operations. Although these areas seem quite diverse, the thread of continuity involves the basic observation that many intelligent, highly motivated students

are nevertheless unable to solve problems for which, theoretically, they possess the underlying component skills. The theory of cognitive development most fruitful in determining which component skills are absent is that of Piaget (Inhelder & Piaget, 1958). The concept task has been viewed as a potential tool in the investigation of cognitive deficits and potential training techniques are referenced. It is the hope of this author that the following quote will some time in the near future be incorrect, "Studies of mentality so well advanced for infants and so well begun for the lower grades are still meager for the adolescent (and adult) stages. . ." (Hall, 1908, p. 482).

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APPENDIX II-A

INSTRUCTIONS TO SUBJECTS

Experiment 1

For purposes of this experiment, you will be responding to stimuli which will appear on this grid as patterns of lighted and darkened squares (show subject the grid).

The grid is divided into three columns, A, B, and C, with two squares in each column, 1 and 2. Every complete stimulus will consist of one lit square in each column. The various patterns of lighted squares can be divided into two groups; those which are examples and those which are nonexamples. In this experiment, it will be your task to learn how to tell which patterns are examples and which are nonexamples.

When this light turns green (show enable light), you will be allowed to decide which column or columns you wish to look at by pushing one, two, or all three of these buttons (show the buttons). As soon as you have pushed the button or buttons indicating which columns you wish to see, one square in each selected column will light up. Columns which you do not select to see will, of course, remain dark although you should realize that a nonselected column could very well be influencing whether the pattern you selected is an example or a nonexample.

(Experimenter now turns enable light green. Experimenter presses columns A and C to demonstrate that one can push as many or as few lights as one wishes. Experimenter

now explains that even though B column is dark, it could be influencing the outcome. Experimenter now presses B to show the subject that even though B was not selected, it is still there. In other words, the experimenter demonstrates that what one does not see could be as important as what one does see).

At first, you will have to guess whether the stimulus is an example or nonexample. But, as soon as you decide, press either the example or nonexample button (show subject the response buttons). As soon as you press a response button, a light will come on above the correct button and tell you which answer is right. If the light comes on over the button you pressed, then you were correct. If the light comes on over the button you did not press, then, of course, you were wrong. Obviously, the information from these lights will be essential in order to solve the problem.

For example: (Experimenter now demonstrates a problem by lighting up columns A, B, and C. Experimenter tells the subject that if this pattern is an example, it could be because of the square lit in the A column, the B column, the C column, some combination of two columns, or else all three columns. Experimenter now presses example button to demonstrate response buttons and feedback lights. Experimenter tells the subject that he must figure out which square or squares in which column or columns, makes every pattern an example or nonexample. Experimenter now resets and pushes A and B columns. Subject is asked, "If this is

an example, can we be sure that A and B or A or B are important?" Subject, regardless of their answer is told "no" because C could be important and one doesn't know what square is lit in C because one chose not to look).

Are there any further questions?

In summary, your job is to discover which patterns of lights are examples and which are nonexamples. Try to be correct every time and continue to respond until I say that the experiment is terminated.

Remember the solution which will allow you to be correct 100% of the time may involve as few as one column, some combination of two columns, or as many as all three columns.

(The final paragraph was read to each subject at the close of the instruction set. At any point where the subject appeared to be bogged down or not progressing, the experimenter would reread this paragraph.

The instructions for the task on day one and day two were identical regardless of day one performance.)

Experiment 2

The Concept Task

Instructions to all subjects on the concept task were identical to those used in Experiment 1. The only difference was that in Experiment 2, the concept task was administered only once.

The Liquids Task

(Experimenter shows the subject a mixing tray with one well filled with colorless, odorless liquid) Before you arrived, I mixed some combination of the liquids in bottles one through four in this well. Now, I am going to place several drops of liquid from the bottle labeled "G" in the same well. You will notice that the contents of the well turned blue. Your task is to find out which of these four chemicals, or which combination of these four chemicals, is necessary in order to make blue water. You have an eye dropper for each chemical and as many mixing trays as you require. When you know which chemical, or combination of chemicals, is necessary for blue water, please tell me the numbers.

(Subject gives solution)

Are you sure that these are all necessary?

Thank you.

The Projections Task

(Experimenter shows the subject the projections apparatus and the various sized rings on stalks) If one of these rings were placed in a hole on the apparatus, and if I turned

on the light on the apparatus, the ring would project a shadow on the screen. (Experimenter dims the house lights, turns on the apparatus light and demonstrates the projection of a shadow.) Now here are two rings of different sizes. Your task is to place these rings in the holes in the apparatus such that the shadows from the rings are exactly the same size. You cannot turn on the apparatus light until you have placed the rings in the apparatus. (Experimenter and subject then go through the various unequal sized pairs of rings in the same sequence, theorize, test, theorize, test, etc., until all pairs have been placed such that the shadow size is identical.)

Now you have had a chance to place rings in this apparatus to generate identical shadows from different sized rings. Do you think that there exists a general rule to describe the placement of any two sized rings so that they will cast the same size shadow, or do you think that each pair must be looked on separately?

APPENDIX II-B

STIMULI AND ORDER OF PRESENTATION

Experiment 1

A distributed stimulus set was constructed using three two-valued dimensions. Each dimension was represented by one of three adjacent columns of 50 mm x 50 mm squares covered by translucent plexiglass. The current value of a dimension was indicated by backlighting either the top or bottom squares in that column. The same set of stimuli and order of presentation was used for both day one and day two. One set of 32 stimuli was arranged so that each of the eight possible stimuli appeared four times and no stimulus was repeated in less than five consecutive trials. The sequence was further constrained to prevent any one attribute from appearing more than three times in succession.

The stimuli are symbolized by indicating the attribute present on each dimension. The dimensions, reading from left to right, are labeled by the letters A, B, and C. The values of the dimensions are represented by: 1 = top square lit and 2 = bottom square lit.

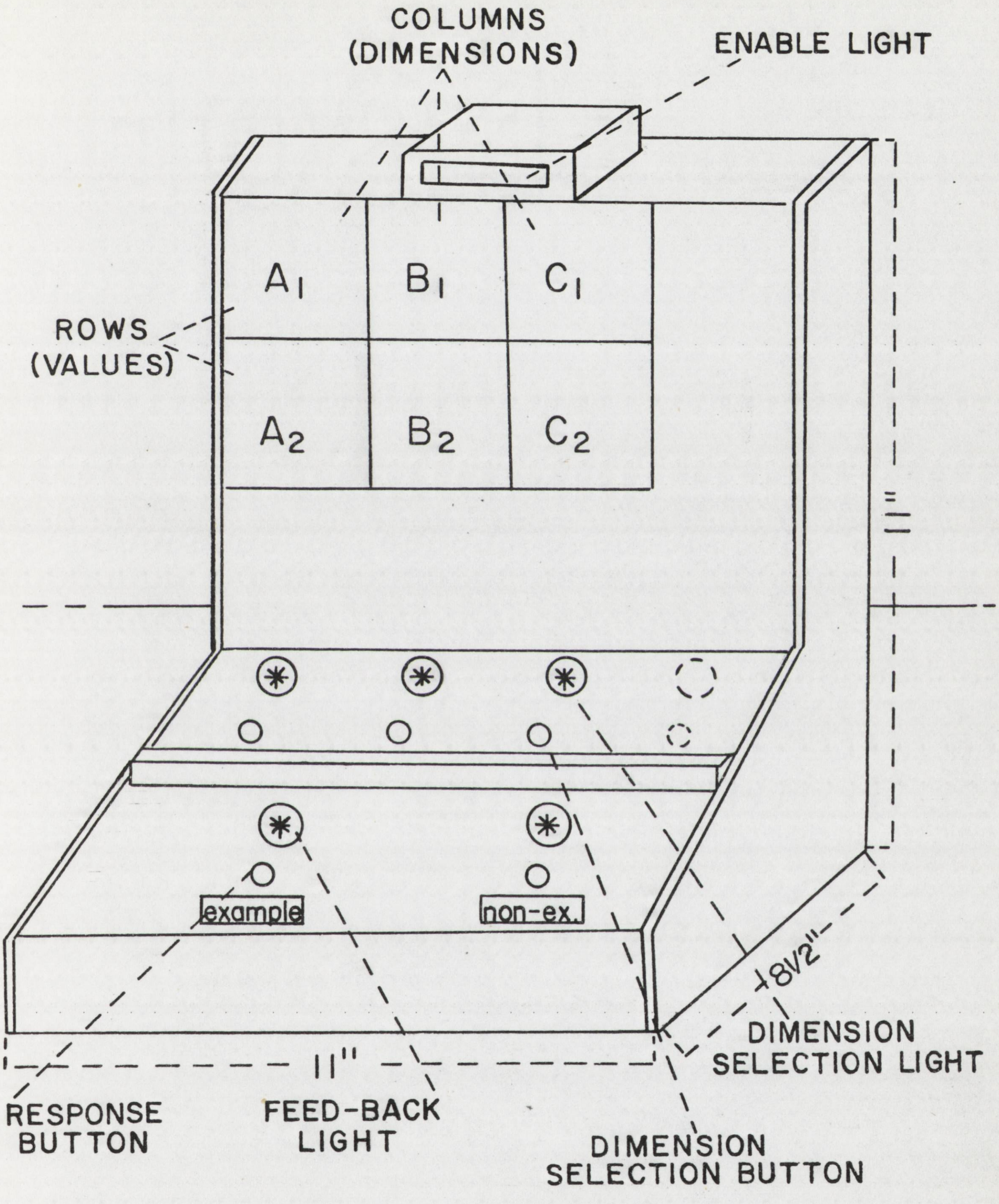

Figure 1. The Fink Grid.

TABLE 6

Stimuli and Order of Presentation for Experiment 1

Position in Sequence	Stimulus A	B	C	Position in Sequence	Stimulus A	B	C
1	1	1	2	17	1	2	2
2	2	1	1	18	2	2	2
3	2	2	1	19	1	2	1
4	1	2	1	20	1	1	1
5	2	1	2	21	2	1	1
6	1	2	2	22	1	1	2
7	2	2	2	23	2	2	1
8	1	1	1	24	1	2	1
9	2	1	2	25	2	1	1
10	1	2	2	26	1	1	2
11	2	2	1	27	2	2	1
12	1	1	2	28	1	1	1
13	2	2	2	29	1	2	2
14	2	1	1	30	2	2	2
15	1	1	1	31	1	2	1
16	2	1	2	32	2	1	2

APPENDIX III-A

DATA SUMMARY

TABLE 7

Concept Task Solvers, Performance over Days, Trials and Errors to Criterion, Self-Rating of Performance and Solution Strategy for Experiment 1: Raw Data

Day 1

Subject	Group	T/C	E/C	Self-Rating	Strat.
1	1	5	1	8.0	W/P
2	1	25	10	5.0	2/P
3	1	4	2	8.0	W/P
4	1	61	21	5.0	W/2
5	1	10	3	6.0	W/P
6	1	44	14	8.0	2/2
7	1	43	17	7.0	W/W
8	1	21	8	7.0	W/2
9	1	6	4	5.0	W/P
10	1	0	0	5.0	W/P
11	1	0	0	8.0	W/P
12	2	14	4	7.0	W/P
13	2	1	1	8.0	W/P
14	2	2	2	8.0	W/W
15	2	7	5	7.0	W/P
16	2	61	29	7.0	W/W
17	2	8	4	8.0	W/P
18	2	18	7	7.0	W/W
19	2	1	1	5.0	W/P
20	2	18	15	8.0	P/P
21	2	4	1	9.0	W/P
22	2	25	12	7.5	W/W
23	2	30	13	7.5	W/W

Table 7 (con't)

Day 2

Subject	Group	T/C	E/C	Strat.
1	1	8	2	W/P
2	1	14	7	P/W
3	1	3	1	W/P
4	1	42	16	W/2
5	1	7	2	W/P
6	1	19	7	2/2
7	1	4	2	W/W
8	1	22	13	W/W
9	1	10	6	W/P
10	1	8	4	W/P
11	1	1	1	W/P
12	2	16	4	W/P
13	2	0	0	W/P
14	2	0	0	W/P
15	2	5	2	W/P
16	2	59	24	W/W
17	2	4	2	W/P
18	2	10	1	W/W
19	2	0	0	W/P
20	2	15	8	P/P
21	2	7	3	W/P
22	2	10	3	W/W
23	2	22	7	W/W

TABLE 8

Concept Task Nonsolvers, Performance over Days, Trials and Errors to Criterion and Self-Rating of Performance for Experiment 1: Raw Data

		Day 1			Day 2	
Subject	Group	T/C	E/C	Self-Rating	T/C	E/C
1	1	92	44	4.5	92	31
2	1	92	42	8.0	92	35
3	1	92	38	5.0	92	28
4	1	92	46	4.0	92	45
5	1	92	36	7.0	92	41
6	2	92	48	5.0	92	41
7	2	92	42	7.0	92	39
8	2	92	30	4.5	92	32
9	2	92	52	1.0	92	31
10	2	92	31	5.0	92	30
11	3	92	31	4.0	92	29
12	3	92	28	6.0	92	40
13	3	92	40	6.0	92	36
14	3	92	30	4.0	92	27
15	3	92	49	5.0	92	39
16	4	92	42	5.0	92	45
17	4	92	33	5.0	92	29
18	4	92	46	4.0	92	46
19	4	92	41	5.0	92	33
20	4	92	41	2.0	92	42

TABLE 9

Concept Task Solvers, Trials and Errors to Criterion, Formal Operations Scores and Solution Strategy for Experiment 2: Raw Data

Subject	Group	T/C	E/C	Liq.	Proj.	Strat.
1	1	17	7	5	5	W/P
2	1	35	15	4	4	W/W
3	1	6	4	5	5	W/P
4	1	22	10	4	4	P/W
5	1	3	1	5	5	W/P
6	1	59	30	4	4	W/2
7	2	28	13	5	3	W/W
8	2	19	9	4	4	P/P
9	2	53	17	3	3	Rote
10	2	9	0	4	4	W/W
11	2	51	24	5	3	Rote
12	3	47	28	3	3	Rote
13	3	20	5	5	5	W/W
14	3	37	14	4	4	W/W
15	3	40	19	4	4	W/W
16	3	6	4	5	5	W/P
17	3	3	2	5	5	W/P
18	3	18	10	5	4	W/P
19	4	12	5	4	5	W/W
20	4	12	5	5	5	W/W
21	4	16	8	5	5	W/P
22	4	37	23	5	4	W/W
23	4	3	2	5	4	W/W
24	4	31	15	4	4	W/W
25	4	52	29	3	3	Rote

TABLE 10

Concept Task Nonsolvers, Trials and Errors to Criterion and Formal Operations Scores for Experiment 2: Raw Data

Subject	Group	T/C	E/C	Liq.	Proj.
1	1	92	52	3	3
2	1	92	32	2	2
3	1	92	38	3	4
4	1	92	37	3	3
5	1	92	34	3	3
6	2	92	40	3	3
7	2	92	24	3	3
8	2	92	43	3	3
9	2	92	33	2	2
10	2	92	41	2	3
11	3	92	38	2	3
12	3	92	53	2	3
13	3	92	44	3	3
14	3	92	52	3	3
15	3	92	45	3	3
16	4	92	40	3	3
17	4	92	38	3	3
18	4	92	26	3	5
19	4	92	46	2	2
20	4	92	41	2	2

APPENDIX III-B

STATISTICAL ANALYSES

TABLE 11

Analysis of Variance of Order Effects of Relevant Attributes: Errors to Criterion for Solvers for Experiment 1

Source	SS	df	MS	F	p
Order	1.349	1	1.349	.008	ns
Error	3626.302	21	172.681	--	--

TABLE 12

Analysis of Variance of Order Effects of Relevant Attributes: Errors to Criterion for Nonsolvers for Experiment 1

Source	SS	df	MS	F	p
Order	11.251	1	11.251	.083	ns
Error	2425.695	18	134.761	--	--

TABLE 13

Analysis of Variance: Days by Reinforcements, Errors to Criterion for Nonsolvers for Experiment 1

Source	SS	df	MS	F	p
Total	1786.25	39	--	--	--
Days	88.30	1	88.30	2.023	ns
Rf.	.30	1	.30	.006	ns
D x Rf.	129.95	1	129.95	2.978	ns
Error	1570.70	36	43.63	--	--

TABLE 14

Analysis of Variance: Mean Self-Rating Scores for Solvers and for Both Reinforcement Conditions for Nonsolvers in Experiment 1

Source	SS	df	MS	F	p
Total	112.87	34	--	--	--
Rfs.	43.37	2	21.68	10.60	.001
Error	69.52	32	2.044	--	--

TABLE 15

Analysis of Variance: Concept Task, Order Effects of Problem Presentation, Errors to Criterion for Solvers for Experiment 2

Source	SS	df	MS	F	p
Order	7.784	3	2.595	.027	ns
Error	2021.177	21	96.246	--	--

TABLE 16

Analysis of Variance: Concept Task, Order Effects of Problem Presentation, Errors to Criterion for Nonsolvers for Experiment 2

Source	SS	df	MS	F	p
Order	302.548	3	100.849	1.868	ns
Error	864.001	16	54.000	--	--

TABLE 17

Analysis of Variance: Liquids Task, Order Effects of Problem Presentation, Formal Operations Score for Solvers for Experiment 2

Source	SS	df	MS	F	p
Order	.271	3	.090	.162	ns
Error	11.729	21	.559	--	--

TABLE 18

Analysis of Variance: Liquids Task, Order Effects of Problem Presentation, Formal Operations Score for Nonsolvers for Experiment 2

Source	SS	df	MS	F	p
Order	0.150	3	.050	.182	ns
Error	4.400	16	.275	--	--

TABLE 19

Analysis of Variance: Projections Task, Order Effects of Problem Presentation, Formal Operations Score for Solvers for Experiment 2

Source	SS	df	MS	F	p
Order	3.803	3	1.268	2.785	ns
Error	9.557	21	.455	--	--

TABLE 20

Analysis of Variance: Projections Task, Order Effects of Problem Presentation, Formal Operations Score for Nonsolvers for Experiment 2

Source	SS	df	MS	F	p
Order	.150	3	.050	.091	ns
Error	8.800	16	.550	--	--

APPENDIX IV

VITA

Elliot Jay Rapoport

Personal History:

Born February 7, 1947, Chicago, Illinois

Education:

B.A., 1968, University of Illinois, Urbana, Illinois
Major: Psychology; Minor: Sociology/Philosophy

M.A., 1975, University of New Mexico, Albuquerque, New Mexico
Major: Psychology

Ph.D., (expected) December, 1977, University of New Mexico, Albuquerque, New Mexico
Major: Psychology

Academic Honors:

1973-1975 National Institute of Mental Health Trainee

Relevant Positions Held:

Staff Psychologist, New Mexico State Forensic Hospital, 1976 to present

Graduate Coordinator for introductory laboratory courses, Department of Psychology, University of New Mexico, under Dr. Dennis M. Feeney, 1972-1976

Teaching Assistant, Department of Psychology, University of New Mexico, 1970-1972

Publications:

Cave, S.E. and Rapoport, E.J. Evaluation and theoretical analysis of the Wilderness Program: A rite of passage. Accepted at the National Forensic Psychiatry Convention, Tyler, Texas, September, 1977