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The Effects of Quantitative Information Content on Selection Strategies in a Complex Concept Formation Design

Tony B. Croke
Western Michigan University

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THE EFFECTS OF QUANTITATIVE INFORMATION CONTENT ON SELECTION STRATEGIES IN A COMPLEX CONCEPT FORMATION DESIGN

by

Tony P. Croke

A Thesis Submitted to the Faculty of The Graduate College in partial fulfillment of the requirements for the Degree of Master of Arts Department of Psychology

Western Michigan University Kalamazoo, Michigan April 1984

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Thirty adult undergraduates and graduate students were placed in one of three quantitative information content groups. The Ss received either High, Medium or Low Information Content (IC) in a concept formation paradigm designed to study the types of problem solving strategies used by Ss under varying amounts of information content. High IC Ss produced the optimal strategy—focusing—sooner and more often than Medium or Low IC Ss. Medium IC Ss did better than low IC Ss. High IC Ss increased their use of focusing over trials, while Medium and Low IC Ss only used focusing intermittently. Medium and Low IC Ss used a non-optimal strategy called hypothesis checking more than any other strategy. There was more variability in performance among Low IC Ss than among High IC Ss. All Ss in High IC were using focusing consistently by the last four problems, while some Low IC Ss showed development of focusing and others did not.
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Tony P. Croke
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CHAPTER I

INTRODUCTION

Over the last half century, the major dependent variables of most research conducted by those who can collectively be called "behaviorists" have consisted of simple, gross and overt topographies (Wisocki, 1977). While early researchers required simple and arbitrary topographies to avoid confounding (Skinner, 1953, 1969, 1976), and to accurately extract the basic principles of behavior, we have rapidly approached a time when more subtle and complex private behavior must be analyzed if we are to understand human behavior in its total complexity. That persons "talk" to themselves, "visualize" and use "strategies" when solving problems and other complex tasks is taken for granted, but the specifics of what these behaviors are and how they interact with one another, overt responses and consequences are not well understood. That such mediating behavior is possible arises, at least in part, from the fact that once the individual becomes a member of the verbal community he may direct his own behavior as he would others. Skinner (1976) mentions the reinforcing effects of such self directing behavior.

(verbal behavior) has a special character only because it is reinforced by its effects on people--at first other people, but eventually the speaker himself. As a result, it is free of the spatial, temporal, and mechanical relations which prevail between operant behavior and nonsocial consequences...the important consequence is that the speaker also becomes a listener and may richly reinforce his own behavior (p. 88).
It is clear that such behavior is of paramount importance. Yet, in a literature review of research in the area of private mediational behavior, Ericsson and Simon (1980) cite only two studies of the 108 they reviewed that could be said to be done by behaviorists. And these two studies, by Verplank (1962) and Greenspoon (1955), were criticized as methodologically simplistic. Not surprisingly, it is the cognitive psychologists who now dominate this most important area of research: it has long been their traditional domain.

Though there has been a dearth of behavioral experimentation on such behavior, the leading philosophers of a scientific-behavioral-analysis of such behavior have theorized about it liberally. Both Skinner (1953, 1957, 1976) and Kantor (1949, 1971) have pointed out the importance of such behavior, and alluded to the need to make a scientific—versus a mentalistic—analysis of it. For example, Skinner (1976) speculates about why there is such a plethora of covert behavior.

Covert behavior has the advantage that we can act without committing ourselves; we can revoke the behavior and try again if private consequences are not reinforcing... Covert behavior is also easily observed and by no means unimportant, and it was a mistake for methodological behaviorism and certain versions of logical positivism and structuralism to neglect it simply because it was not "objective" (pp. 114, 115).

Later when discussing problem solving Skinner (1976) alludes to the fact that people engage in strategies or patterns of responding—which can be covert—in order to solve problems.

Solving a problem is, however, more than emitting the response which is the solution; it is a matter of taking steps to make that response more probable, usually by changing the environment (p. 123).

And, in more behavioral speculation, Day (1977) has argued that there are three ways in which private events may affect overt behavior.
1) Feelings— or states of the body, as when we say we have a pain because of private stimulation; 2) covert talking— a person may comand his own behavior and be subsequently reinforced by its effects; 3) images— perceptual behavior or conditioned seeing may affect overt responses as when we imagine a scene in order to describe it to someone. Any or all of these phenomena may be involved in complex mediating behavior.

The body of evidence demonstrating that persons are engaging in various forms of covert and non-covert behavior in order to supplement responding is well founded. Cognitive psychologists have been concerned with demonstrating that awareness (defined as the ability to describe the contingencies of the experiment), is important to learning. Hirsch (1955) and others (Philbrick & Postman, 1955) showed that in a Thorndikian paradigm (saying "right" following a specified response in a free association task), Ss who could verbalize the contingencies performed better than those who could not. They also showed how experimental conditions can affect the number of aware subjects and performance. (Such as, Ss who discover the contingencies rather than being made aware through instructions perform better.) But why does being able to verbalize the contingency have this effect? The Behavioral objection could be that awareness is simply a byproduct of learning; those who learned became aware because there was something to be aware of.

Farber (1963) conducted an experiment where some Ss received failure statements and others neutral statements following the first 20 trials in a study where Ss could pick the pronoun to be used in a
statement. The pronouns were "I", "You", "he" and "they". The experimenter said "good" whenever S in either group used the pronoun "you". The group with failure statements had fewer aware Ss and made fewer correct statements. He showed there were aware Ss who could be classified as conforming versus nonconforming. The nonconforming Ss reported discovering the contingency and then not putting it to use. Such as the S who stated, "I first said 'you' a few more times to prove I was right, then attempted to continue as before and give all the pronouns equal utterance." The conforming Ss also reported discovering the contingencies, "thinking" about it, and then deciding what they were going to do about it. One S stated, "At first I purposely avoided using 'you' any more than any other pronoun because I felt like I was being conditioned into saying it. Finally on the last five cards I purposely used 'you' because I felt that possibly by not using it they would feel I had missed the whole point of the experiment." Clearly this S's overt responses must be viewed in light of what he had to say privately about the experiment.

To be sure, the evidence does not argue for cognitive (mental?) mediational states—or should it—but it does argue that humans engage in complex, subtle and often covert activities which supplement their "targeted" responses which are measured by the experimenter. Farber (1963) states about verbal reports that:

This does not mean the reports obtained need be regarded as the manifest proof of an autonomous cognitive machinery guiding our every action. These reports and the private events to which they may point have their own determinants, as susceptible to investigation as any other. But while insisting that these events must themselves be accounted for, we can use them to good advantage in predicting other kinds of behavior and discovering the laws concerning them (p. 195).
Behaviorists have also contributed to our knowledge about supplemental behavior and contingencies involved therein. Verplanck's now famous paper "Unaware of Where's Awareness" (1962) offered a series of experiments on awareness and the conditioning of verbal responses. He showed that verbal responses concerning a task and the task itself could be differentially reinforced. It was shown that the task and statements about it could be functionally independent. Of course, that statements can be independent does not mean they always are. In any case, the paper has been mired in controversy and fomented much debate. (See for example, Ericsson et al., 1980.)

Catania (1982) has shown that the manner in which one acquires verbal behavior about a task effects one's performance on that task. He instructed some Ss to make statements about contingencies and shaped statements about them in another group. His major finding was that Ss who were shaped into talking about contingencies acted in a manner consistent with their verbal behavior regardless of the contingencies. Ss merely told what to say did so, but this did not carry over to responding to the contingencies; verbal responses and non-verbal responses were independent. We may argue from Verplanck and Catania that verbal responses about a task may be supplemental depending upon how such behavior is acquired.

The term "information" is often used in connection with consequences--and other contingencies--relating to problem solving, concept formation, mathematics and other complex tasks that often involve the above sorts of mediating behaviors. But the term easily suffers from a lack of specificity. Place (1982) points out that
Skinner—and perhaps the rest of the behavioral community—have overlooked the complex effects stimuli can have on the listener while emphasizing the behavior of the speaker. He notes that:

Whether we talk, as Skinner does, about tacts "extending the listener's contact with his environment" or about information stimuli "providing information about the situation in which behavior occurs," the process whereby verbal stimuli can convey information to the listener, and thus enable him to make contact with aspects of his environment which would otherwise be beyond his reach, remains mysterious and unexplained (p. 121).

A useful way to talk about information, in a manner both empirical and quantitative, was introduced by Shannon and Weaver (1949). Information could be thought of as stimuli which reduce uncertainty, that is the number of possible solutions is reduced. If there are four possible solutions to a given problem then reporting two of them reduces the uncertainty by half; likewise we could say half the necessary information was given.

A number of studies relating the effects of quantities of information to task performance have been done. The classic study in this area was performed by Trowbridge and Cason (1932). They used Thorndike's paradigm whereby Ss were blindfolded while attempting to draw lines of a specified length. The four Information Feedback (IF) quantities were no IF, nonsense syllable, right/wrong—the right being any response an eighth of an inch from the target—and the fourth group received IF concerning deviations within an eighth of an inch. The latter two groups showed increasing accuracy while the first two did not; greater quantities of IF improved performance. But the interesting fact was that on post experiment interviews Ss in the
latter three groups reported using covert strategies—cues as they were called—while doing the task. The authors report that:

The principal cues used were kinaesthetic cues from the arm and hand. A "timing" method was also frequently employed in which the Ss estimated the time required for the whole movement of the arm. Of the 47 Ss who used cues, 9 listened to the sound of their pencil as they moved it across the paper, and 7 counted at a regular rate and tried to determine the number of counts which they made while they drew a line of the correct length. At the beginning of the experiment, 37 Ss attempted to estimate the 3-inch line by thinking of a ruler, by thinking of an inch and then taking it three times, or by estimating the width of the hand or the length of the thumb, etc. In the "blank" and "nonsense" procedures, a number of Ss attempted to use visual imagery (p. 252).

It is clear that even in this simple task humans engaged in covert behavior and strategies in order to facilitate the task. Annett (1969) reports a series of studies done for the Navy concerning positioning levers and rudders, where quantities of IF did not significantly improve responding. But Annett (1969) showed with his own lever pulling experiment that high quantities of IF were not greatly improving scores because Ss were not "using" all the available IF. He states (p. 144), "using" may be a reference to covert behavior; greater quantities of IF may be useful only when they supplement mediating behavior.

While there is some evidence that quantities of IF effect performance on some tasks, all of this research has been done with manual tasks. The quantitative effects of IF on conceptual tasks and their related behaviors is not nearly as detailed.

Many researchers have looked specifically at how information presentation and strategies for concept formation interrelate. Bruner, Goodnow & Austin (1956) have presented a series of experiments
demonstrating that Ss in concept formation tasks use different strategies to discover the solution. Different strategies provide various amounts of information per trial, and the strategies used are influenced by the experimental conditions. Bruner manipulated, for example, temporal variables and instructions to Ss and found, as expected, that the types of strategies used varied; when the task was made more difficult more conservative strategies were employed, when the task was made easier Ss tended to try riskier strategies that supplied more information when they were correct. Yabe (1981) examined how Bruner's strategy types were affected by feedback conditions rather than antecedent manipulations as Bruner had done. His Ss received either consistent feedback across trials, feedback that minimized the number of possibilities that could be eliminated, or received random feedback that might or might not allow the elimination of possibilities. Ss in the first group maintained their initial strategies throughout the study. Ss in the second group developed more cautious strategies as the experiment progressed, and—contrary to expectation—Ss in the third group maintained consistency in their selections across problems like the Ss in the first group.

Other researchers have shown how even in extremely complex concept formation designs Ss use strategies to discover solutions. Laughlin, Lange & Adamopoulos (1982) used a game, Mastermind, to look at problem solving strategies. The Ss had to discover the solution to a four positional by three color pattern of stimuli. Although this meant there were 81 possible solutions to sort through, Ss demonstrated the use of two kinds of strategies he called Focusing
and tactical. Ss using Focusing would first discover the four correct colors and then their proper respective positions. Ss using a tactical strategy would systematically discover the correct color for each successive position. Both strategies were difficult, requiring ten or more trials to solve. Raaijmakers (1981) demonstrated systematic elimination of disconfirmed hypotheses—local consistency—occurs as often in more complex concept problems as in simpler ones. One group had to solve four dimensional by two feature problems, another four dimensional by four feature problems where Ss were told which dimension contained the solution, and another group solved four dimension by four feature problems where the solution could belong to any of the dimensions and Ss were not informed of which one. All groups showed consistent use of logical elimination by local consistency.

Levine (1975) and his associates have done a series of experiments on the developmental nature of strategies used to discover concepts. Levine and Phillips presented Ss with pairs of stimuli that varied across four dimensions with two values to each dimension—hence 8 possible solutions. The S would then pick the stimulus that they thought contained the correct feature. The E would supply IF by indicating the correct stimulus. The stimuli were arranged such that half the possible remaining solutions were eliminated on each selection, so that by the fourth IF the S should know the solution if he is using the correct strategy. The most efficient strategy of narrowing the possibilities down to 8, 4, 2 and 1 possibilities respectively is called focusing. There are other strategies that are less efficient. Dimension Checking consists of picking a feature of one of the dimensions
until told "incorrect", and then going on to another feature from another dimension in the same manner until the problem is solved. **Hypothesis Checking** entails the systematic elimination of each dimension by selecting one of the features of the dimension until told "wrong" and then selecting the other feature of that dimension until it too is eliminated. Neither of these strategies is as efficient as focusing. Levine's results indicate that children do not use efficient strategies while most adults do. He did not, however, manipulate information quantity; all his studies involved IF that eliminated half the remaining possibilities on each subsequent trial with only eight possibilities in all.

Gholoson & O'Connor (1975) used Levine's technique but they employed a four dimensional three valued paradigm. Ss were presented with three stimuli at a time, each of which contained four of the possible solutions that the other two did not; all 12 possible solutions were distributed evenly between the three stimuli. Ss in the partial IF group were only told "right" or "wrong" when they made their selections, so if they were wrong only a third of the possible solutions were eliminated. In the complete IF group the E pointed to the correct stimulus at each IF, so that eight possibilities could be eliminated on any given trial regardless whether they were right or wrong. His results showed children did not use efficient strategies in the partial IF group while the other Ss in the complete IF--higher information feedback--group did.

Some researchers--most working with children--have looked at how qualitative differences in information presentation can affect...
strategies in concept formation. Anderson (1977) taught sixth graders
to discriminate four dimensional problems by giving either the correct
solution at each feedback, or giving the correct solution with an explana-
tion of how to discover the solution, or by giving the correct answer
and requiring the child to verbalize the correct steps in solving the
problem. Ss in the third condition solved problems more efficiently
(though there was no statistical significance) than Ss in the first
group. Rosser and Brody (1981) looked at how different modeling proce-
dures affected the generalization of concept formation skills in
preschoolers. Ss were exposed to one of four modeling situations in
which they were shown how different lengths of wood were to be put in
a specified pattern. In one group Ss had a model show four examples
and four non-examples, an explanation of what was to be done, a
description of the individual stimuli, and were told the rule for
proper sorting. In the second group Ss were given the examples and
non-examples along with the rule. In the third group Ss were given
only the examples and non-examples. The fourth group was a control
where Ss merely were allowed to play with the blocks for a few moments.
Ss then did the modeled task five times. Following this the Ss were
shown the stimuli in random order and three pictures of the stimuli.
Two of the pictures showed the stimuli disordered and the third the
stimuli in the correct order; Ss had to pick the correct picture.
Also, when given a randomly ordered set of stimuli Ss had to draw a
picture of how the stimuli would look in correct order. All groups
did well on the first generalization problem, but only the first
group could generalize solutions to the drawing problem.
While we know Ss use strategies in problem solving, and that quantitative information is a way of treating stimulus presentation, the relation between the two has not been methodically analyzed for more complex behaviors. The present research will look specifically at how varying quantities of information in a complex concept formation design affect the problem solving strategies of adults. Other researchers have used qualitative measures of information presentation to look at strategies in concept formation, but this makes it difficult to generalize across studies. A quantitative analysis will allow for greater precision in the control of independent variables, specifically supplying a method for looking at how amounts of information affect strategy behavior in concept formation.
CHAPTER II

METHOD

Setting

The experiment was carried out in a small observation room at Croyden School. The room was sealed off by two way mirrors and contained a desk with two chairs. S sat on one side of the desk, directly across from the experimenter (E), about three feet apart.

Subjects

There were 30 subjects (S) in the study, 27 undergraduates and 3 graduate students who worked at the school. The school, Croyden Avenue School, specializes in the educating of severely retarded children and young adults. Ss were teachers and tutors who implemented educational procedures for this population. Ss were tested between December and January. Ss were placed randomly into one of three conditions, ten Ss to a condition. The conditions were Low, Medium and High Information Content (IC) groups.

Procedure

Prior to the start of the experiment each S was shown the first stimulus card, and was then presented with the following set of instructions.

- This is a concept formation study.
- There are 15 problems in the study.
- Each problem consists of 20 stimulus cards presented one at a time. There are 2 stimuli on each card, between them all 16 concepts can be found.

- The object is for you to discover as fast as possible which of the possible concept features is the correct solution. (E then describes the 16 possible solutions)

- This is how you will get information:

- On each trial you will be allowed to look at the stimulus card for 5 seconds.

- You will then select the stimulus which you think contains the correct concept, left or right.

- I will then tell you if you have selected the correct stimulus or not.

- If you have a hypothesis, you will then tell me what you thought the correct solution is.

- After you have correctly stated the correct solution a certain number of times, I will inform you and we will go on to the next problem.

- After the conclusion of the experiment, I would like you to fill out a questionnaire.

E then modeled the appropriate behavior for the S by picking a possible solution and showing the S how he/she would point to the stimulus containing that feature, wait for feedback and then state the concept he/she thought was the solution.

The S was prompted by the E to state all 16 possible solutions prior to each problem. Ss were informed of any feature they forgot.

The E would place a stimulus card in front of the S who had five seconds to study it. The S then would point to the stimulus that he/she thought contained the solution. The E would respond by saying "correct" if S picked the stimulus with the correct feature, or "incorrect" if S chose the stimulus that did not contain the solution. If S did not respond within five seconds, E would give one
prompt to respond by saying "choose please". If the S did not respond immediately the next card was presented. Following feedback, the S would inform the E of what he/she thought the correct solution was. The card was then moved to the left of the S and left face up so that it could be easily seen. The next card was then presented in the same manner. After S responded to each subsequent card it was placed face up next to the previously exposed cards in serial order. This continued for the first eight cards of every group. Following this the lowest numbered card would be turned over prior to exposing the next card; hence, card one was turned over just prior to exposing card nine. This established a pattern of allowing the S to observe the last eight cards that had been turned up to that point.

The S was considered to have solved the problem when he/she stated the solution four times in a row. Once the S had solved the problem he/she was informed and went directly to the next problem. If the S did not solve the problem in the allotted 20 trials he/she was informed of the answer and went immediately to the next problem. All solutions were selected randomly, and any given solution could occur more than once. Following completion of the experiment each S was asked to fill out a questionnaire consisting of seven questions (see appendix B).

**Materials**

Each S, tested individually, was presented with a series of 15 problems, with each problem consisting of 20 separate stimulus cards. Each card was 5 x 8 inches and had two stimuli on it. Each stimulus was 3½ x 3 inches in size. The two stimuli differed from
one another on eight different dimensions: alphabetic letter, T or X; color of letter, black or white; size of letter, large or small; type of letter, script or block; position, left or right; number of borders, one or two; line position, line on top or line on bottom; and star position, star on left or star on right. The eight dimensions always varied between the two stimuli. Hence, one stimulus is always black the other is white, one script and the other block, etc. This produces 16 possible solutions, eight of which are in one stimulus, and eight of which are in the other. (See Fig. 1.)

![Sample Stimuli Diagram](image)

**FIGURE 1 - SAMPLE STIMULI**

Fig. 1 shows a typical stimulus card. The 16 possible solutions are present in every stimulus card, 8 of them in the stimulus on the left, and 8 of them in the stimulus on the right. The 8 solutions in the stimulus on the right are small letter, t, block letter, white, 2 borders, line on bottom, star on right, and position right. The 8 solutions in the stimulus on the left are large letter, x, script letter, black, 1 border, line on top, star on left, and position left.
The way in which the cards differ between the experimental groups is in the number of features that change from card to card. In the High IC group half the remaining unchanged features are altered on each subsequent card. So, on the first card the correct feature would be paired with seven other incorrect ones (which would leave eight possible solutions). On the next card the correct feature would be paired with only three of the seven previous features (which would narrow the possible solutions down from eight to four). On the third card the correct feature would be paired with only one of the three remaining incorrect features (which would narrow the possible solutions from four to two). The fourth card would contain the correct feature without the last incorrect feature. A S using a Focusing strategy in the High IC group can then discover the solution in the first four cards regardless of his/her selections. (See Fig. 2.1.) Stimulus cards for the Medium IC group will allow the elimination of two of the remaining possibilities on each card following the initial card. Hence, card one will leave eight possible solutions, card two will leave six possible solutions, card three will leave four possible solutions, card four will leave two possible solutions, and card five will leave one solution if the S is using a focusing strategy. A S using Focusing in the Medium IC group will need to see the first five cards to solve the problem. (See Fig. 2.2.) Stimulus cards for each problem in the Low IF group will allow the elimination of only one feature per card following the initial card. The first card will leave eight possibilities, the second card seven, the third card six...and the eighth card only one if the S is using focusing. A S in the Low IF group using a Focusing strategy will need to see the first eight cards to solve the problems. (See Fig. 2.3.)
FIGURE 2 - STIMULI PRESENTATION ORDER
Fig. 2.1 shows the first 2 cards of a typical problem in the High IC group. A S using a focusing strategy can narrow the number of possible solutions down to 4 by the second card. If the solution is x, then a S using focusing will know that 1 of the eight features on the left is the solution after the first feedback: black, small, script, x, 2 borders, position left, star right or line on bottom. Card 2 pairs only 2 borders, script and position left with x, so black, small, line on bottom and star on right can be eliminated after the second feedback.

Fig. 2.2 shows the first 2 cards of a typical problem in the Medium IC group. A S using a focusing strategy can narrow the number of possible solutions down to 6 by the second card. If the solution is star on right, then a S using focusing will know that 1 of the eight features on the right is the solution after the first feedback: T, block, white, large, 1 border, line on top, star on right or position right. Card 2 again pairs T, block, white, large, and position right with star on right, so 1 border and line on top can be eliminated after the second feedback.

Fig. 2.3 shows the first 2 cards of a typical problem in the Low IC group. A S using a focusing strategy can narrow the number of possible solutions down to 7 by the second card. If the solution is black, then a S using focusing will know that 1 of 8 features on the left is the solution after the first feedback: black, script, x, large, 1 border, line on top, star on left or position left. Card 2 again pairs script, large, 1 border, star on left, line on top and position left with black, so only x can be eliminated after the second feedback.
The remainder of the 20 cards for each problem vary the features randomly with the stipulation that no two features are paired together for more than four cards in a row. This allows the S to use other strategies, but only the first 4, 5 or 8 cards--depending on the IC group--are structured to allow the S to use a focusing strategy. A single set of secondary cards is used for all three groups.

Dependent Variables

The data for each problem consisted of a "correct" or "incorrect" selection on each trial, and the Ss hypothesis of what he/she thought the answer was, such as "black." (See the appendix for a sample data sheet.) From these data it was possible to extract the main dependent variables, which were the strategies consistent with Ss behavior in solving the problems. There were 4 such strategies categorized in the present study.

Focusing

In a focusing strategy the S logically eliminates all the remaining possible solutions that any given card allows, and his/her selections are only those possibilities that have not yet been logically eliminated. Hence, it is the most efficient manner in which to discover the solution. For the present research a S was considered to be using focusing in the High and Medium IC group if, a) the Ss hypotheses consist only of those possibilities that have not yet been logically eliminated right through the end of the problem, and b) the S does not state the correct solution before the 3rd trial of the problem. Stating and
maintaining the correct solution before the 3rd trial for the high and medium IC groups is merely considered a lucky guess. For the low IC group a S was considered to be using focusing if a) the Ss hypotheses consisted only of those possibilities that had not yet been logically eliminated right through the end of the problem, and b) the S does not state the correct solution before the 5th trial of the problem. Stating the solution prior to the 5th trial when the S is showing a focusing strategy in the Low IF group is considered a lucky guess.

Dimension Checking

This is a less efficient strategy, the S does not respond to all the available IC, so it will take longer for the S to discover the solutions with dimension checking. A S using dimension checking picks a feature from a dimension and continues to pick that feature until he/she is told "incorrect", then the S picks another feature from another dimension and picks that feature until told "incorrect"; the S does this until he/she finds the solution. For example, a S might try the size dimension and pick "large", the S will continue to pick "large" until told "incorrect", and then try another dimension such as color. The S would then pick "black" until told "incorrect", then proceed to another dimension until the problem is solved. In the present research a S was considered to be using dimension checking if he/she followed the above pattern of responding, and did not deviate from it on more than one trial per problem, by either changing hypotheses after being told "correct", or by keeping the same hypotheses after being told "incorrect".
**Hypothesis Testing**

Like dimension checking, hypothesis testing does not involve the use of all the available IC, so it takes Ss longer to solve a problem with this strategy than it would with focusing. In hypothesis testing a S picks a feature from a dimension until told "incorrect", and then picks the other feature of that dimension until told "incorrect". In this manner every dimension is systematically eliminated. For example, a S using hypothesis testing might first eliminate the letter dimension by picking "T" until told "incorrect", and then picking "X" until told "incorrect". The S would then go on to another dimension until he/she solved the problem. In the present research a S was considered to be using hypothesis testing if he/she went through at least 2 dimensions in the above manner, from the start of the problem, before solving it.

**Illogical Responding**

A S was using an illogical responding pattern when either, 1) the S was using dimension checking, but the S made more than 1 mistake by either picking a hypothesis again after being told "incorrect", or changing a hypothesis after being told "correct"; or 2) the S was using hypothesis testing, and either picked a hypothesis again after being told "incorrect", or changed a hypothesis after being told "correct" at any time in the problem.

The other dependent variable was the trial on which the S "solved" the problem. Since the problem was considered solved when the S stated the solution 4 times in a row, the first trial of the 4 was considered the one on which the problem was solved. So if a S
states the solution on the 3rd trial, but on either the 4th, 5th or 6th trial changes his/her response, then the problem is not solved. If then on the 11th, 12th, 13th and 14th trials the S goes back to the correct solution the problem will be considered "solved" on the 11th trial.

Reliability

Reliability was measured by having an assistant take data along with the E on two randomly selected Ss from each IC group. (Each datum consisted of a correct or incorrect selection and what the S thought the solution was). The assistant sat about five feet to the right of the E, making it difficult for her to see the Es data sheet. Reliability was measured by dividing agreements plus disagreements into agreements. The overall reliability for all six Ss was 98%.

Pilot Subjects

One Pilot S was run from each experimental group to 1) assess the effects of leaving cards face up, versus turning cards over right after S gets IC; and 2) assess the amount of time required for Ss to make a choice following presentation of the cards. The necessity of leaving cards face up after feedback was assessed by using the above procedure until S had completed the first ten problems. The very next problem was then presented with only one card observable at a time. No S was then able to exhibit a focusing strategy, and all three Ss reported that they merely resorted to guessing—dimension checking—under such circumstances. The time required was measured by using the above procedure, but letting S respond whenever they were ready. The High, Medium and Low IF Ss averaged 3.3, 3.6 and 2 seconds respectively.
CHAPTER III

FINDINGS

Main results indicate that Ss with greater amounts of IC developed the most efficient strategy—focusing—sooner, and used it more often, than Ss who received less IC per trial. As can be seen in Fig. 3, 60% of all the problems solved by the High IC group were done so with a focusing strategy. Focusing dropped to 36% of the solutions in the Medium IC group, and to 28% in the Low IC group. None of the three conditions generated appreciable amounts of hypothesis checking. In fact, the 1% shown by the Medium IC group and the 4% shown by the low IC group are each data from 1 S on 1 problem; out of 450 total problems in the study only 2 showed the use of hypothesis checking.

Dimension checking was used in 26% of the total problems by the High IC group—less than half the number of times focusing was used. In the Medium IC condition the amount of dimension checking is 42%, 6% more than the amount of Focusing. Interestingly, S who only need to use one more card for an optimal strategy—5 cards for Medium IF, versus 4 for the Low IF group—nonetheless now use non-optimal strategies more often than they use the optimal one. Ss in the Low IC group used dimension checking 34% of the time. Although, like the Medium IC group, this means Low IC Ss used dimension checking 6% more than they used focusing, there is not a consistent trend of more dimension checking as IC amounts decrease. The low IC
High IC

- Focusing: 0%
- Hypothesis Checking: 26%
- Dimension Checking: 5%
- Illogical: 9%
- Other: 5%

Med IC

- Focusing: 1%
- Hypothesis Checking: 36%
- Dimension Checking: 12%
- Illogical: 9%
- Other: 4%

Low IC

- Focusing: 28%
- Hypothesis Checking: 34%
- Dimension Checking: 19%
- Illogical: 15%
- Other: 12%

Key: F = Focusing; HC = Hypothesis Checking; DC = Dimension Checking; ILL = Illogical; O = Other

Figure 3 - Cumulative Graph of Strategies
group has less focusing and less dimension checking than the Medium IC group. The difference is accounted for by the large percentage of illogical and other strategies exhibited by the Low IC group. Illogical strategies—those in which responding patterns were inconsistent (see METHODS)—were 19% for the Low IC group. This was 7% more than the Medium IC group, and nearly 4 times greater than the number of illogical strategies shown by the High IC group.

A comparison between an average S in each of the three conditions is presented in Fig. 4. The important datum from this figure is the trial on which the focusing strategy first appeared. For High IC Ss the average trial on which the focusing strategy appeared was Number 3. Ss in the Medium IC group did not show focusing until the 5th trial on average, and the Low IC group did not show it until the 7th trial on average; this is more than twice the number of trials it took the High IC group to develop the optimal strategy. This distinction is further borne out by the fact that every High IC S exhibited the Focusing strategy by the 6th trial, while there were 2 Ss in the Low IC group who did not show the optimal strategy until the last problem, and 1 S who did not show it at all.

Fig. 5 lets us see the differences produced by the three conditions. The graphs present the number of trials it took the best and the worst S from each IC group to solve all the problems; the best S using the least total trials, and the worst using the most. Except for problems 6 and 7 and 10 and 11, where the worst S in the High IC group faltered, the two curves are similar. The graph of the worst S is typical of most Ss in the High IC condition. The Ss improved
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**FIGURE 4 - TYPICAL SUBJECTS**

F = Focusing; HC = Hypothesis Checking; DC = Dimension Checking; ILL = Illogical
rapidly, but faltered a few times during the middle problems, before
showing consistency in the last quarter of problems. As was already
noted, by the 3rd trial focusing was occurring in the High IC group,
but it was the last 4 trials where all the Ss showed consistency.
If we look at the strategies used by the 10 Ss in the High IC group
on problems 12, 13, 14 and 15 we see that 37 of the 40 problems were
solved with a focusing strategy. On problems 7, 8, 9 and 10 the High
IC Ss used Focusing 27 of 40 times. Clearly Ss in the High IC groups
were using a focusing strategy a lot by the middle of the study—68%—
but by the last 4 trials it was being used by virtually every S on
every problem.

The differences between the best and worst Ss in the Medium IC
group was larger than that of the High IC group. While every S in the
Medium IC group exhibited the focusing strategy by the 7th trial,
they never developed the consistent use of it that the High IC group
did. The focusing strategy was used by the 10 Ss in the Medium IC
group on problems 12, 13, 14 and 15 only 18 of 40 times. While on
problems 7, 8, 9 and 10 it was used 18 of 40 times as well. There
is no net gain in the use of a focusing strategy from the middle to
the end problems of the Medium IC group.

The graph of the variance for the Low IC group shows massive
differences in the responding of the worst and the best S; there is
no relation between the 2 curves at all. The worst S in the Low IC
group never showed a focusing strategy, and was unable to even solve
6 of the problems. The best S used focusing 8 times, more than half
the problems. And the worst was by no means atypical, Ss 1, 2, 3, 7

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Comparison between the S who took the most total trials in his group to solve all the problems and the S who took the least number of total trials to solve all the problems. Data are presented for all three groups (— = most trials; —— = least trials.)
and 8 did almost as poorly. Like the Medium IC group, the Low IF group showed no systematic increase in the use of focusing. On problems 12, 13, 14 and 15 the 10 Ss in the Low IC group used focusing on 23 of 40 problems. On problems 7, 8, 9 and 10 they used it on 19 of 40 problems.

Clearly as the amount of IC decreases the effect is less systematic; both in the sense that individual S scores vary more, and in the sense that Ss do not improve as much over trials. This second point is reinforced by the data in Fig. 6. Fig. 6.1 shows the average trial on which Ss in the High IF group solved each problem. The curve shows a steady decrease in the average number of trials to solution over problems. The average number of trials to criterion over the first 3 problems for the High IC group was 8.2, and the average over the last three problems was 5.3. The Medium IC groups aggregate data of average number of trials to solution, in Fig. 6.2, shows no systematic decline in the average number of trials to criterion. The average number of trials to criteria over the first 3 problems for the Medium IC group was 11.6, and the average over the last 3 problems was 9.4 trials, a slight decrease. The Low IC group showed more of an improvement over problems than did the Medium IC group (Fig. 6.3), even though they did not use a focusing strategy progressively over problems. The average number of trials to criterion over the first 3 problems for the Low IC group was 13, and the average over the last 3 problems was 9.6.

Figs. 6.1, 6.2, and 6.3 cannot be directly compared because the amounts of IC for each group differ. But trials on which Ss did not
FIGURE 6 - TRIALS TO CRITERION

HIGH IC

LOW IC

MED IC
use focusing can be compared since Ss in higher IC groups are not using the extra IC anyway. Fig. 6.4 shows the curves of all three groups when only non-optimal strategies are used. Although we would expect them to be similar, it is clear that the Ss in the Low IC group required many more trials on the average to solve the problems, even though they were using the same strategies as the other two groups. The Low IC group averaged a lower number of trials to criteria than one of the other two groups on only 3 of 15 problems when all three groups were using non-optimal strategies.
CHAPTER IV

DISCUSSION

The present results demonstrate differences in the strategic behavior of Ss who are exposed to varying quantities of information in a concept formation paradigm. Ss in the High IC group developed the optimal strategy quickly, faltered in the middle problems, but were very consistent in their use of focusing on the last quarter of the problems. Ss in the Medium IC group developed the optimal strategy by the 5th problem, but never showed a consistent tendency to use it on later problems: they did not show an increase of focusing over problems. Ss in the Low IC group did not develop the optimal strategy until almost half way through the experiment—problem 7 on average—and also did not show a tendency to increase the use of focusing over problems. The Low IC Ss did improve slightly in trials to criterion over problems however, because their non-optimal strategies improved in efficiency on the last few problems. The effects of the treatments were more uniform over Ss as IC increased. This could be seen in the differences between the best and worst S in each group. All the Ss in the High IC group developed the optimal strategy and used it almost exclusively on the last 4 problems. Conversely, some Ss in the Low IC group managed to develop and use the optimal strategy on more than half the problems, while other Ss did not use the optimal strategy more than once.
An interesting discrepancy between the present research and other studies that looked at strategies in concept formation is in the amount of hypothesis checking reported. These studies (Philips & Levine, 1975; Mims & Gholson, 1978; Gholson & O'Connor) report between 8% and 40% of their Ss used hypothesis checking in various treatments. This is much more than the present research reports. Apart from methodological differences, this discrepancy may have to do with the fact that these other studies used mostly children as Ss, and that their concept formation paradigms used fewer dimensions. In any case, adults in the present research did not use hypothesis checking to solve complex concept formation problems.

There are several possible reasons for the fact that the Ss in the Low IC group did so much poorer than the Ss in the High IC group. The Ss in the Low IC group had to do more memorizing for much longer than did the High or Medium IC groups. A S in the Low IC group would possibly have to remember information gleaned from the first card for seven more trials before he/she finally knew the answer. Temporally, that means the S would have to remember some information up to (5 sec. x 8 cards) 40 seconds while constantly trying to remember other possibilities and engage in strategic behavior. The sheer amount of time required to solution was greater. Compounding that is the amount to be remembered. Ss in the Low IC group trying to remember the positions of "correct" or "incorrect" choices would have twice the number of locations to recall as the High IC group. These two additional requirements, in concert, could inhibit S performance when he/she is trying to use focusing. Ss did, in fact, show a great deal of forgetting when the number of trials to solution was high. On problems
where Ss needed eight or more trials to solve the problem, 73% showed forgetting by reselecting at least one solution that had already been directly disconfirmed by an "incorrect" when originally picked. Further research on memorization behavior could control for forgetting by marking the selections of the S, so that he/she does not have to remember which stimuli were selected, in order to test the role of memory in this type of research.

Another possible factor in the differences between IC groups is in the relative efficiency of using the optimal strategy for the various groups. For Low IC Ss both optimal and non-optimal strategies lead to the elimination of only one possibility at a time. The optimal strategy is a little more systematic, because it does not require a disconfirmation to eliminate a possibility, but that is its only advantage over the non-optimal strategies for Low IC Ss. But the optimal strategy is much more useful than non-optimal strategies for the High and Medium IC Ss. These Ss can always eliminate two or more possibilities per trial with focusing, while a non-optimal strategy can eliminate one possibility per trial at best. For Low IC Ss the optimal strategy offers little more efficiency than non-optimal strategies and requires more work—in comparison and analysis—that simple strategies don't require. The dubious value of focusing for Low IC Ss may simply make the work required in using it greater than the benefits.

Closely related to the above point is the effect that adventitious reinforcement may have had on Low IC Ss. For these Ss any guess occurring on or before the 8th trial—with say dimension checking—
would be at least as likely to be correct as one using the optimal strategy. For Low IC Ss guessing was more likely to pay off than for High IC Ss who would have to get the solution within four trials to make guessing as efficient as using focusing. Trials on which a guess would be reinforcing for the Low IC group would be inefficient for the High IC Ss, since they could have gotten the answer sooner by using focusing; the Low IC treatment reinforces guessing rather than using strategies.

While the Low IC treatment did not foster the use of the optimal strategy, the High IC treatment did. The subtle and complex behavior involved in using focusing was not instructed; it appeared because the High IC situation provided circumstances for its occurrence. In a situation with much change, and a great deal of information to be dealt with, it is economical to have strategies to sort out the possibilities, thus increasing the probability of finding the solution. When methodically given small amounts of information Ss only need to integrate the pieces as they come in, complex sorting and comparing is not required. More complex strategies that involve looking at, comparing, and contrasting possibilities are useful only when there is a great deal of information to respond to. Strategies for problem solving may generate and occur simply because of the problem solving contingencies, regardless of historical or instructional variables. However, the exact interplay between antecedent exposure to "instruction" and quantitative IC contingencies is in need of further study.
That exposure to the High IC treatment generated a general tendency to seek as much information as possible was alluded to in Fig. 6.4, which showed that Low IC Ss took more trials to criterion than the other two groups on problems where focusing was not used. This contention is further borne out by data from question #5 on the questionnaire. Answers to the question were rated by the E and an assistant (Reliability = 87%) on the number of face-up cards Ss reported looking at when solving problems. Each Ss response to the question was placed in one of four categories: 1) S did not make comparisons between cards; 2) S reports generally comparing two or more cards per trial; 3) S reports generally comparing all available cards per trial; or 4) Ss answer was irrelevant. In the High IC group, seven of the ten Ss reported perusing all the available cards, and the other three reported generally observing two or more cards per trial. There were four Medium IC Ss who reported perusing all the available cards while five reported looking at two or more, and one S who reported only looking at one card at a time. In the low IC condition only one S reported perusing all the cards available, while six reported perusing two or more cards per trial, and three Ss reported only observing one card per trial.

Clearly, Ss who received more information on the initial trials of the problems—High and Medium IC—reported tendencies to use more of the information made available on secondary trials. Specifically, on problems where focusing was not used, these Ss developed "proto-optimal" strategies: dimension checking where the selections are determined by comparisons of previous cards on which the S was told
"correct". A S using a proto-optimal strategy would select a feature as in dimension checking, and continue to pick it until told "incorrect". Instead of then randomly picking another feature that had not yet been eliminated the S would look over the cards that he/she had been told "correct" on, and see what feature(s) had been paired with the one they had been selecting. The S would then proceed to choose one of these features on the next trial. (Ss anecdotally reported using proto-optimal strategies, and mentioned using it on the questionnaire. Typical Ss wrote "I compared cards to determine after each 'correct' response what features the cards had in common", and "I'd pick a solution on the first card and keep that going until I was told it was 'incorrect', while watching the 'pattern' of the previous cards, thereby observing similarities of previous cards so when I got an 'incorrect', I'd have a high probability guess as to another solution based on what all my correct previous answers had in common". These rather concise descriptions are consistent with the data). The Ss in the High IC group attempted to extract as much information as possible more often than Ss in the Low IC group, even when both groups were using the same strategy with the same set of cards. The tendency to use all available information, that was reinforced on the initial cards in the High IC group, carried over on to trials where only non-optimal strategies could be used. Conversely, Ss in the Low IC group, who were not initially reinforced for using all available information, did not use as much of the extra information that could be obtained from the secondary cards, which were presented on later trials of the problems. (The secondary cards altered at least four
features on each successive card, potentially making each secondary card four times as informative as the eight initial cards in the Low IC group).

We may ask if Ss who "learn" not to use all available information would have trouble adjusting to High IC situations, by, for example, first exposing Ss to the Low IC treatment and then to the High IC treatment. Will these Ss do worse than Ss who are directly exposed to High IC? It is possible that a specifically engineered history of information deprivation may predispose people to act in less efficient ways even though other more useful alternatives are available. This is analogously seen in learned helplessness, where organisms who have no history of successful escape merely tolerate aversive stimulation when obvious paths of escape are made available. If this is so, then we must be careful not to expose vulnerable populations, such as the retarded and mentally ill, to environments where their already diminished capacities may be further channeled into simplicity. Unlucky "normal" persons will most likely be exposed to more complex environments which will counteract—eventually?—the effects of Low IC situations, but the mentally handicapped—who often are exposed to more complex environments only as they prove themselves capable—are not as mobile, and therefore more susceptible to such stigmatizations.

The question of how these findings generalize to other concept formation paradigms is another area for further research. In a study by Grover and Fowler (1979) children were taught juxtapositional concepts, involving the positioning of blocks in a pattern, by
matching a model. Ss who had an obstructed view of the model had to develop hypothesis about how and where blocks were to be placed. These Ss did better on generalization problems that presented only a photo of the stimulus complex, rather than an actual model, than the Ss who did not have to develop hypotheses; Ss who learned to compare and analyze in a concept situation were able to generalize the skills to another situation. Will this work with quantitative information paradigms?

A more global problem involves the extent to which this phenomenon generalizes to problem solving situations in general. Does the quantitative information effect extend to other "higher mental processes" like math, logic and language training? A similar design with other materials is required.

The present research has educational implications concerning the amount of material that should be presented at one time. If this phenomenon generalizes, at least within concept formation paradigms, it could be useful to increase the rate of exposure of information in some settings. The tendency to control flows of information so as to not overwhelm children—in, for example, DISTAR—may not produce the strategic behavior necessary to cope with large amounts of information; which surely children must face eventually anyway. When a problem is presented in its entire myriad of complexity, the learner is in a position to develop and use strategies for solving complex—High IC—problems. A quantitative approach to information flow would allow for the controlled exposure of information in greater amounts without resorting to extremes of either overwhelming
complexity or simplistic hand-holding characteristic of so much computer assisted instruction.

It is typical of many of the developmentalist educators to eschew the importance of environmental factors—such as information amounts—in favor of a static notion of developmental stages. Piaget (1969), who is a mentor to many with this view, expounded a notion which he termed "genetic epistemology", the gist of which is that it is virtually useless to try to teach something to a child until he/she has entered a preordained stage. The effect of this Platonic philosophy is to encourage researchers and educators to take a passive stance towards education rather than an active attempt to accelerate "development" through enriched environments. (Albeit, Piaget did not completely ignore the environment. He wrote, "Man tends to organize his behavior and thought and to adapt to the environment." But he immediately followed it with, "These tendencies result in a number of psychological structures which take different forms at different ages. The child progresses through a series of stages...before he attains adult intelligence"). Skinner (1976) accurately points out that:

If a child no longer behaves as he behaved a year before, it is not only because he has grown but because he has had the time to acquire a much bigger repertoire through exposure to new contingencies of reinforcement, and particularly because the contingencies affecting children at different ages are different. A child's world "develops," too (p. 75).

That these "new contingencies" should be complex, that we should expose learners to as much information as they can handle, is implicit in the present research.
## APPENDIX A

### DATA SHEET

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APPENDIX B

QUESTIONNAIRE

IF GROUP: ___________________ SS#: ________________ DATE: __________

1) EACH CARD ALLOWED YOU TO ELIMINATE SOME OF THE POSSIBLE SOLUTIONS BY TELLING YOU WHICH CONCEPTS MIGHT BE RIGHT OR WRONG. ON THE AVERAGE, DID EACH CARD LET YOU ELIMINATE A LOT, A FEW, OR ONLY ONE POSSIBLE SOLUTION?

2) WHAT IS THE MINIMAL NUMBER OF CARDS IT TAKES TO DISCOVER THE SOLUTION TO A GIVEN PROBLEM? HOW DID YOU DISCOVER THE MINIMAL AMOUNT IF YOU KNOW WHAT IT IS?

3) DID YOU USE ANY STRATEGIES TO SOLVE THE PROBLEMS, OR TO DISCOVER HOW TO SOLVE THEM? CAN YOU EXPLAIN THE STRATEGIES?
4) DID YOU TALK TO YOURSELF DURING THE EXPERIMENT? WHAT SORTS OF THINGS DID YOU SAY?

5) DID YOU COMPARE CARDS AS YOU DID THE PROBLEMS, OR JUST LOOK AT EACH CARD AS IT WAS PRESENTED? EXPLAIN?

6) WHAT DO YOU THINK THE PURPOSE OF THE STUDY WAS?

7) GENERAL COMMENTS?
BIBLIOGRAPHY


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