WOLFGANG, Aaron, 1933-
LEARNING IN CONCEPT IDENTIFICATION AS A FUNCTION OF SOCIAL CUES AND COMPLEXITY IN A FREE SOCIAL INTERACTION SETTING.

The University of Oklahoma, Ph.D., 1965
Psychology, experimental

THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

LEARNING IN CONCEPT IDENTIFICATION AS A FUNCTION OF SOCIAL CUES AND COMPLEXITY IN A FREE SOCIAL INTERACTION SETTING

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirement for the

degree of

DOCTOR OF PHILOSOPHY

BY

AARON WOLFGANG

Norman, Oklahoma

1965

LEARNING IN CONCEPT IDENTIFICATION AS A FUNCTION OF SOCIAL CUES AND COMPLEXITY IN A FREE SOCIAL INTERACTION SETTING

APPROVED BY

DISSERTATION COMMITTEE

ACKNOWLEDGMENTS

I wish to express my deep gratitude to my major professor, Dr. Vladimir Pishkin, for his valuable assistance, encouragement, and continued support. Sincere appreciation is expressed to Dr. Alfred F. Glixman, Dr. Oscar A. Parsons, Dr. Carl R. Oldroyd, and Dr. Roger E. Nebergall for their valuable suggestions. And last, but not least, heartfelt appreciation is expressed to my dear wife Joan for her patience, empathy, and the many hours spent in typing this dissertation.

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LEARNING IN CONCEPT IDENTIFICATION AS A FUNCTION OF SOCIAL CUES AND COMPLEXITY IN A FREE SOCIAL INTERACTION SETTING

CHAPTER I

INTRODUCTION AND PROBLEM

Learning occurs most frequently in group situations where individuals exchange information, yet the most influential learning theories (e. g., Guthrie, 1959; Hull, 1951; Skinner, 1953; Spence, 1958; Tolman, 1949, 1959) including the more recent mathematical model theories, such as those presented by Estes (1950, 1963), Bourne and Restle (1959), and Restle (1955), have postulates based solely on the behavior of the individual working alone. Learning theoreticians of the past and present have tended not to give serious attention to social influences and their effects upon learning. The present study was designed primarily to accomplish three purposes: (a) to assess the effects of social cues on learning rates in concept learning within the framework of the extended mathematical theory of concept identification, (b) to compare the effectiveness of two-person groups free to interact and exchange information with one another with that of individuals working alone in solving concept identification problems of varying degrees of task complexity, (c) to explore the relationship between patterns of social interaction and decision-making behavior in a situation where two persons must reach common decisions in their attempt to solve a two-choice concept identification task.

Nature of Research in Concept Identification

The vast majority of studies dealing with concept identification has been concerned with a variety of experimental variables. Brown and Archer (1956) investigated distribution of practice; Pishkin (1961), misinformation feedback distribution; Bourne and Bunderson (1963), delay of information feedback and length of postfeedback interval; Trabasso and Bower (1964), memory; Pishkin and Blanchard (1964), auditory stimuli; Pishkin, Wolfgang, and Bradshaw (1963), drugs (hydroxyzine) and induced stress; and lastly, Pishkin and Wolfgang (1965), availability and type of past information feedback.

The variable that has received the most attention in concept identification experiments is task complexity. Previous investigators of concept learning had no direct method of measuring task complexity systematically or independently of the subject's response. Complexity of the concept was assayed by measuring the ease with which it was acquired. Qualitative differences in performance were compared in terms of subjects' responses being more or less abstract or concrete or whether concepts were easier to solve when they involved concrete objects, spatial forms, color or numerical quantities.

Heidbreder (1946a; 1946b; 1948; 1949) and her associates, (Heidbreder, Bensley, & Ivy, 1948; Heidbreder & Overstreet, 1948) exemplifying this method of ascertaining the relative difficulty of concepts, used in her early series of experiments (Heidbreder, 1946a; 1946b; Heidbreder, Bensley, & Ivy, 1948; Heidbreder & Overstreet, 1948) an experimental procedure that was similar to the familiar memory situation. In fact, subjects were told that they were participating in a memory experiment. The stimulus materials were presented via memory drum and consisted of a series of drawings that could be classified into three categories such as concrete objects (e.g., faces), spatial forms, and numerical quantities (e.g., drawings with two flowers, five spoons). The subjects were required to learn nonsense syllable names (e.g., Relk for faces) for the various categories of stimuli by the anticipation method. The findings indicated that concepts involving concrete objects were least difficult to attain, with spatial forms next, and numerical concepts most difficult.

In a later series of experiments Heidbreder (1948; 1949), in attempting to reduce the role of memory and increase the role of perception, used a card sorting format where subjects could manually sort the drawings into their respective piles. All materials were perceptually accessible for inspection throughout the experiment. The evidence indicated that under these "more perceptual" conditions, concepts were attained far more rapidly and far more easily in comparison to the modified memory procedure. On the whole, Heidbreder found that sorting for number, as in the modified memory experiments, was most difficult, whereas sorting for concrete objects was easiest.

Grant and his associates (1949; 1951; 1952), like Heidbreder (1946a; 1946b; 1948; 1949) and her associates (Heidbreder, Bensley, & Ivy, 1948; Heidbreder & Overstreet, 1948), were interested in assaying the relative difficulty of classifying number, form, and color concepts. In Grant's approach the Wisconsin Card Sorting Task was used, which consisted of a pack of 64 cards with geometrical designs that could be sorted for color, number, and form. Subjects were told simply whether their classifications were "right" or "wrong." In contrast to Heidbreder, Grant, Jones, and Tallantis (1949) found it was easier for subjects to sort for number than color and form. However, in subsequent experiments when Grant (1951) and Grant and Curran (1952) removed the constant configurational aspects of the number concept, the number concept became more difficult to classify, but not more difficult than the concept of form.

In 1949, when Underwood analyzed the experimental literature in concept learning, he pointed out some of the desired goals for the development of the area: (a) That more researchers concentrate on the theoretical aspects of conceptual behavior. (b) That tasks of various levels of complexity be developed and standardized to facilitate inter-laboratory communication.

In 1955, Archer, (Underwood's student), Bourne, and

Brown described a method based on information theory that would permit the experimenter to directly measure the amount of information contained in a concept, independently of the subject's response. The advantage of such a method is that the stimulus itself can be quantitatively assessed and functionally related to conceptual behavior. Archer, Bourne, and Brown (1955) and subsequently a number of other independent investigators (Battig & Bourne, 1961; Bourne, 1957; Bourne & Haygood, 1959; Bourne & Pendleton, 1958; Pishkin, 1960; Pishkin & Wolfgang, 1964; Wargo, 1960; Wolfgang, Pishkin, & Lundy, 1962) have varied task complexity quantitatively by systematically increasing the amount of irrelevant information along different binary stimulus dimensions (e.g., color: red and blue; form: squares and triangles). The basic unit of measurable relevant and irrelevant information in information theory is a bit, which is defined as $\log_2 x$, where x is the number of equally probable stimulus events. The general rule is that every time the number of alternatives is increased by a factor of two, one bit of information is added (Miller, 1953; Miller, 1956; Shannon & Weaver, 1949). The above experimenters clearly established that systematic increases in the amounts (bits) of irrelevant information made the task progressively more complex and resulted in a predictable linear increase in the total number of errors. These consistent findings stem from studies that were not mere repetitions of each other; rather task complexity was often not the main variable, but an incidental one.

Research dealing with social dimensions and their influence upon rates of learning in concept identification has received little attention. Among the few who have investigated the social aspects of concept identification are Lydecker, Pishkin, and Martin (1961) and Pishkin (1963). These investigators studied the effects of social (experimenter delivered the feedback) versus mechanical feedback (lights were used to indicate the correctness of the response) upon chronic schizophrenics when solving concept identification problems. Lydecker, Pishkin, and Martin (1961) found that there was no difference in performance between subjects receiving social feedback (experimenter said, "Right" or "Wrong") and those receiving mechanical feedback. The explanation given for not finding any differences in the social and nonsocial conditions was that in the latter condition the experimenter continued to provide social cues. Although he was not in view of the subject, the experimenter remained in the room behind a partition while the subject was performing. When the above study was replicated by Pishkin (1963) and the experimenter was taken out of the experimental situation in the nonsocial condition, the subjects' (chronic schizophrenics) performance significantly improved over those operating in the social condition.

In a recent and more comprehensive study, Pishkin and Blanchard (1963) tested the effects of social cues on schizophrenic and normal (psychiatric aides) populations. They manipulated social cues by having stooges respond either with the correct answer 100% of the time or randomly, i.e., correct on

50% of the trials. The main findings were that, although chronic schizophrenics and normals showed a decrement in concept learning when the stooge responded randomly, the normal subjects showed a significantly greater decrement than schizophrenics. It seemed as though schizophrenics were better able to shut out the disruptive influence of the social cues provided by the stooge (a psychiatric aide dressed as a patient) than the normal subjects. In the condition where the stooge responded correctly on 100% of the trials and subjects could solve the concept identification problem either by imitating the stooge or by using the relevant stimulus cues, concept learning was facilitated for both populations. In all three of the above studies, the experimenter or the stooge delivered reinforcement from a program; any type of social interaction was strictly prohibited.

In the present study the social dimension was the unrestricted interaction of a two-person group where subjects were permitted to freely communicate with each other. In this situation the subjects received not only mechanical information, but also relevant and irrelevant cues from their partners. In the two-person interaction setting, subjects had to learn to classify information in accordance with a relevant dimension and to arrive at a single decision before proceeding to the next trial, although they may have had different hypotheses concerning the correct response.

Theoretical Approach to Concept Identification

In 1959, Bourne and Restle offered a comprehensive mathematical model of concept identification. According to these theoreticians,learning in concept identification involves two processes--conditioning to the relevant (rewarded) cues and adaptation to the irrelevant (unrewarded) cues. It was assumed that rate of learning depended on the proportion of relevant cues and the probability that a cue was present at the time of reinforcement. The model has been successful in making accurate predictions in terms of number of errors to solution for experimental variables. The most often verified prediction was that number of errors in concept identification would increase linearly with increases in the number of irrelevant dimensions from one to five. A possible source of influence in concept learning which had been completely bypassed by the model, was social cues arising from individuals interacting without restriction.

One of the major aims of the present experiment was to account for the effects of social cues on concept identification performance in two-person groups in terms of the Bourne and Restle (1959) mathematical theory of concept identification and its extensions which have recently been advanced by Pishkin and Blanchard (1963) to include social parameters. Thus far, Pishkin and Blanchard (1963) have established the value of social cues in a situation where a stooge provided the social cues from a program and no further interaction was permitted. In the present experiment, the value of the social cue was assessed in two situations. In one condition two subjects were free to exchange information about the relevant or irrelevant aspects of the concept, and in the control group any communication between subjects was prohibited beyond stating their individual classifications (A or B) of the stimulus materials.

The equations to follow were used to compare the closeness of fit of theoretical estimates of learning rates (θ) with actual obtained learning rates in terms of total number of errors made by individual subjects and two-person groups. In addition, values of social cues for subjects operating under social conditions were established.

Bourne and Restle (1959) proposed that the learning rate (θ) in solving concept identification (CI) problems is determined by αr, where r is the proportion of relevant cues and α is the proportion of trials on which a relevant cue is reinforced. In the present study relevant cues were reinforced 100% of the time. The following equation developed by Bourne and Restle (1959) was used to account for theoretical θ for the individual learner:

$$\theta = \frac{k\,R}{R + I + B} \quad (1)$$

In this equation, k is an unknown constant which determines the proportion of relevant cues utilized; R and I are the number of relevant and irrelevant dimensions which have been shown by Bourne and Restle (1959) to contribute equal amounts of cues. B is an unknown constant which is the amount of residual or background irrelevant stimulation from apparatus, surround, and internal cues.

To establish values for parameters k and B, simultaneous equations were used. Two estimates of θ and its corresponding values were obtained from mean numbers of total errors produced by subjects solving concept identification problems with one and three irrelevant dimensions. These dimensions were chosen arbitrarily since any pair of dimensions (e.g., three and five irrelevant dimensions) could be used for estimating θ. The two θ values were estimated from the Restle (1955) and Bourne and Restle (1959) equation which follows:

$$\bar{E} = \frac{1/2 \log(\theta)}{(1-\theta)\log(1-\theta)} \qquad 2$$

$\bar{E}$ is the mean number of errors made to criterion as a function of the proportion of relevant cues and is obtained from the actual data in the experiment. Since equation 2 is not easily solved for θ, Bourne and Restle (1959) have provided a nomograph (p. 283) of the function where the two θ values could be obtained from the total number of errors. Because Bourne and Restle's (1959) nomograph provides only estimations of θ, equation 2 was solved and exact θ values were obtained. After k and B parameters were evaluated from the two obtained values of θ by use of simultaneous equations, then equation 1 was used to predict total number of errors to solution of the remaining problem which contained five irrelevant dimensions.

In order to obtain predictions for subjects in conditions II and III where social parameters were involved, the equation developed by Pishkin and Blanchard (1963) within the Bourne and Restle (1959) framework was used. When both social and stimulus cues are available and relevant, along with irrelevant concept identification stimulus cues, then:

$$\theta_{St+Soc} = \frac{kR + lS}{R + I + B + S} \qquad 3$$

In this equation all parameters are described as those in equation 1, except for the additions of l and S to account for the value of social parameters in concept identification performance. The l is the proportion of social cues utilized and S is an unknown constant and represents the overall value of the social cue, i.e., the one other person. The same procedure used to obtain θ values for equation 1 were used in solving equation 3. Simultaneous equations were used to solve for the constants, social values, l and S. In looking at equations 1 and 3 it can be noted that the numerators represent that portion of the cues which are relevant and the denominators represent the total amount of cues available to the subjects when solving concept identification problems.

Since theoreticians and experimenters have treated concept learning mainly as a solitary activity, it was necessary to refer to the area of group problem solving for information on how group interaction might effect concept learning.

Individual versus Group Problem Solving

The reviews of research on problem solving in social situations (Collins & Guetzkow, 1964, pp. 13-55; Kelly & Thibaut, 1954, pp. 735-785; Lorge, Fox, Davitz, & Brenner, 1958; Roseborough, 1953) indicate that over the past three decades the literature has been extensive. The common finding was that groups (i.e., an interacting face-to-face group where discussion was permitted) outperformed individuals working alone on such tasks as jigsaw puzzles, mathematical puzzles, word puzzles, anagrams, limerick completion, mazes, riddles, and syllogisms (Barnlund, 1959; Davis & Restle, 1963; Faust, 1959; Gurnee, 1939; Hoppe, 1962; Husband, 1940; Lorge & Solomon, 1955; Marquart, 1955; Perlmutter & DeMontmollin, 1952; Restle & Davis, 1962; Shaw, 1952; Sperow, 1961; Taylor & Faust, 1952; Thorndike, 1938). In addition to the many studies analyzing the comparative abilities of groups and individuals in problem solving there have been several investigations dealing with the question of whether there are any differences between group memory and individual memory. The results of several studies (Hoppe, 1962; Perlmutter & DeMontmollin, 1952; Yuker, 1955) were consistent in their finding that groups were superior to individuals in their ability to recall or remember information accurately.

The experimental literature concerning problem solving in interpersonal situations where groups were compared to individuals indicated certain trends: (a) There have been practically no attempts made to systematically evaluate the relative complexity of the problems introduced or to study problem solving performance of groups versus individuals under varying degrees of task complexity. (b) Performance on a problem was commonly summarized by the median or mean time to solution or by the proportion of subjects who successfully reached solution. (c) Subjects were usually not given any feedback on their progress toward solution. (d) Little attention was given to the process of group interaction and its possible effects on problem solution. In the present experiment the complexity of the problem was quantified by systematically varying the amount of irrelevant information, and feedback was given on each trial informing the subjects on the correctness or incorrectness of their responses.

In view of the results of the previously mentioned literature on group problem solving (e. g., Barnlund, 1959; Davis & Restle, 1963; Faust, 1959; Hoppe, 1962; Lorge, Fox, Davitz, & Brenner, 1958; Restle & Davis, 1962; Shaw, 1952; Sperow, 1961; Taylor & Faust, 1952) where groups of various sizes (2 to 4 subjects) have, in the large majority of instances, outperformed individuals working alone in solving puzzle tasks predominantly, it appears that more relevant cues were being produced in the social setting where subjects could have the benefit of testing out with each other their hypotheses or ideas before making a decision about the correct solution. It was expected in the present study that social cues that arose when two subjects were free to discuss and exchange information about the relevant and irrelevant aspects of the concept, as well as to share two memories stored with past and present information, would produce an additional supply of relevant information and result in groups making fewer errors when solving concept identification problems of different levels of complexity than individuals who had only the benefit of mechanical stimulus cues.

The last major consideration of the present experiment was to evaluate the possible effects of the social interaction process on concept attainment which has been bypassed in concept learning and group problem solving studies. Thus, in addition to measuring subjects' performance in the traditional way, i.e., the number of errors to criterion and time to solution, measures of latency of response, initiator of conversation, talk time, exchanges of conversation (sequential utterances), and whose decision was initiated and finally adopted were obtained and evaluated in their relationship to concept identification performance. Similar measures of social interaction proved to be useful when evaluating the conditioning of decision-making behavior of a two-person group in a free social interaction setting as a function of positive and negative reinforcement (Wolfgang, Banta, & Pishkin, 1964). Overall, one of the most significant findings was that although subjects on negative reinforcement were the least successful in getting their decisions adopted, they consistently talked longer, initiated conversation on each trial more frequently and responded with the shortest latencies of speech across all blocks of trials when compared to subjects on positive reinforcement. Due to the limited backlog of information the relationship between concept identification performance and social interaction measures could be only exploratory at this time.

<u>Summary</u>. Learning theorists and learning researchers, including those in concept identification, treat human and animal learning as though it were a solitary activity,

although, much of learning occurs in a group situation where information is shared and discussed. Research on the social aspects of concept learning where individuals are free to communicate and exchange information with each other has been practically nonexistent. It was the overall purpose of the present study to investigate the effects of social cues in a free social interaction setting on rates of learning concept identification problems of varied degrees of complexity and to compare these rates with those of the single learner and with those of groups (controls) where social interaction was restricted.

The findings of a large number of investigators in the area of group problem solving suggest that on problem solving tasks (e.g., mathematical puzzles, word puzzles, riddles, and syllogisms) groups of two to four subjects were superior to individuals working alone. There was also evidence that suggests that groups more accurately recall and retain information than the individual learner. On the basis of these findings it was proposed that two-man groups, free to exchange information in a free social interaction setting and having two memories to process past and present information feedback would produce more relevant cues and result in groups making fewer errors when solving concept identification problems of different levels of complexity than individuals working alone and two-man groups where communication was restricted.

The relationship between concept identification performance and social interaction measures was an exploratory undertaking since the literature in concept identification was barren in this subject. In addition to measuring subjects' performance in the traditional manner, i.e., number of errors and time to solution, a quantitative analysis was made of the social interaction process. Measures of sequential utterances (exchanges of conversation), latency of speech, talk time, initiator of conversation, and whose decision was initiated and finally adopted were obtained and evaluated for their relationship to concept identification performance. Such an analysis of social interaction was bypassed in concept learning and problem solving studies.

One of the major aims of this research was to account for the effects of social cues on learning rates within the framework of the mathematical model of concept identification developed by Bourne and Restle (1959) and extended by Pishkin and Blanchard (1963) to include social parameters. In the present experiment the theoretical values of social cues were established in a free social interaction setting and in a setting where interaction was restricted. Theoretical prediction of learning rates for two-man groups as well as for individuals were compared with the empirically obtained learning rates. It was anticipated that learning rates would be slower for individuals working alone than for two-man groups free to communicate with each other and exchange ideas and information.

CHAPTER II

METHOD

Subjects

The subjects were 120 male volunteer students in elementary psychology courses, who were randomly divided into nine treatment groups that were replicated eight times. Subjects in the two-man groups who acknowledged that they were friends were excluded from participating with each other.

Design

A 3 x 3 factorial design was used, which included three levels of complexity (1, 3, or 5 irrelevant dimensions) over 192 trials and three interaction levels with one or two subjects operating in one of three conditions. In Condition I subjects performed alone; in Condition II subjects in two-person groups were free to interact socially and exchange information in their attempts to identify the relevant dimensions in the concept; and lastly, Condition III was a control group composed of two persons, where any kind of social interaction was prohibited beyond the subjects simply verbally stating their individual responses, i.e., A or B, in classifying the stimulus patterns. The dependent variables in each of the three conditions is depicted in Table 1.

Table 1

Dependent Variables for Each Condition

Condition I Individual	Condition II Free Social Interaction	Condition III Restricted Interaction
Number of Errors	Number of Errors	Number of Errors
Time to Solution	Time to Solution	Time to Solution
	Latency of Speech Utterances	Latency of Speech Utterances
	Whose Decision Is Initiated and Finally Adopted	Who Initiates Decisions
	Initiator of Discussion	
	Talk Time	
	Sequential Utterances	

Task and Apparatus

The subject's task was to categorize a series of geometric patterns flashed on the screen in accordance with a relevant dimension. For example, if color was the relevant dimension, the solution was to press key A when the pattern was red and key B when the pattern was green.

The patterns were projected on a 12-in. x 8-in. milk glass screen by a Dunning Animatic strip film projector. The screen, stationed at the subject's eye level, was surrounded by a solid black wooden border which allowed the subject to view only the geometric patterns on the screen. Just below the screen there was a panel with two response keys positioned horizontally and two amber feedback lights just above the response keys. The two response keys were identified by the letters A and B located above the left and right feedback lights, respectively.

The experimenter's panel board was electronically connected to the subject's panel and contained in an identical manner two response keys identified by the letters A and B and two feedback lights, but the panel boards differed in function. When the subject pressed a key the experimenter's panel light indicated the subject's choice of response; then the experimenter, using a planned program of information feedback coordinated with the filmstrip programming, depressed a key which lit up one of the feedback lights on the subject's panel for approximately one second, indicating to the subject the correctness of his response. The Esterline Angus 20-pen operations recorder was electronically connected to both the experimenter's and subject's panel board to record the subject's response and the experimenter's feedback.

The Esterline Angus recorder was also connected to two microphones (one for each subject in the two-person group) in conjunction with two voice operated relays which, when activated, automatically recorded each subject's frequency and duration of speech. In order to channel the subject's speech utterances so that he activated only his own voice-operated relay the microphone was embedded in a conical soundproof shield which extended upward just beyond the subject's mouth. The experimenter's panel board contained, in addition to the two response keys identified by letters A and B and two feedback lights, two buttons representing subject 1 and subject 2, and when appropriately depressed they indicated on the Esterline Angus whose decision was initiated and finally adopted.

An electronic timer was set to automatically advance the filmstrip (stimulus pattern) to a blank frame, then to the next geometric pattern within 4 seconds after the onset of the experimenter's feedback, allowing the subject to start another trial after his last response.

To reduce background noise from the apparatus and surround, a wooden cubicle lined with soundproof tiles was constructed. The three paneled cubicle with a top and two sides was 63" high, 36" from front to back, and 48" in width. It was roomy enough so that one or two subjects could be comfortably seated inside. The cubicle was arranged so that the subjects could clearly view only the screen and their panel board directly in front of them.

Procedure

At the start of each session, the subjects in the social conditions were seated inside the soundproof cubicle in front of the screen, each having access to the response keys. Then the subjects' chest microphones were adjusted so that they were directly in front of the subjects' mouths. The subjects were instructed to try to speak into the microphone and avoid talking in either a very loud or a very soft voice. The subjects were told about the nature of the task, the significance of the response keys and feedback lights, as well as how to manipulate the controls. The instructions for individuals and subjects in two-person groups were essentially the same (see Appendix A) except that the subjects in the free interaction group (Condition II) were told that they were to arrive at a single decision and only one decision could be registered per trial, whereas the subjects in the noninteracting control group (Condition III) were told to simply state their individual decisions verbally and register them by depressing one of the two response keys on each trial.

In solving the two-choice discrimination problem, the subject was to match a relevant dimension with one or the other of the two response keys. The relevant dimensions of the two problem types were form and number. The relevant dimension is that property of the pattern, which, when identified by the subject, enabled him to press the appropriate key or state the appropriate hypothesis for a correct solution. Each problem type was elaborated into three levels of complexity (1, 3, or 5 irrelevant dimensions). An irrelevant dimension had a zero correlation with the correct response. For instance, where the relevant dimension was form, the subject would press the key A in response to a square, and key B in response to a triangle and be correct. If, however, the subject responded to the irrelevant dimensions such as color (red or green), or to the position (middle or bottom of the screen), or orientation (the upright or tilted figure), then his responses were correct only at chance level. When a dimension was held constant throughout the sequence of stimulus patterns, it was considered neither relevant nor irrelevant.

The criterion of concept solution was 16 consecutive correct responses. However, if criterion was not reached, then subjects were given a total of 192 trials. In the group condition when subjects concluded their performance they were instructed to individually write the solution to the problem on a slip of paper so that the experimenter could determine whether both subjects arrived at solution.

CHAPTER III

RESULTS

Upon inspection of the data, it was noted that variance differences between subjects in the free interaction (FI) condition and those in the restricted interaction (RI) and individual (I) conditions were quite large for both error and time scores. Cochran's test of homogeneity (Winer, 1962, p.94) revealed that for time ($\underline{C}$ = .44, $\underline{df}$ = 7, $\underline{p}$ < .01) and error scores ($\underline{C}$ = .42, $\underline{df}$ = 7, $\underline{p}$ < .01) there was significant heterogeneity. A number of psychologists and statisticians (Boneau, 1960; Box, 1953; Box, 1954; Edwards, 1962, p. 132; Lindquist, 1956, p. 86; Norton, 1956, pp. 78-88; Winer, 1962, p. 33) have generally concluded, in view of considerable evidence, that the $\underline{t}$ and $\underline{F}$ tests of analysis of variance are robust tests, insensitive to nonnormality and to heterogeneity of variance (when $\underline{N}$'s are equal). For example, Lindquist concluded, "In general, unless heterogeneity of either form or variance is so extreme as to be readily apparent upon inspection of the data, the effect upon the $\underline{F}$ distribution will probably be negligible" (1956, p. 86). Due to the marked heterogeneity (the difference between the largest and smallest variance was over 100), a log transformation upon error and time scores was performed.

The log transformation resulted in homogeneity of variance for both the error (C = .26, df = 7, p >.01) and time scores (C = .24, df = 7, p >.01).

Analysis of Error Scores

To determine whether subjects in the FI condition would be superior to subjects in the I and RI conditions in learning to solve concept identification (CI) problems a series of analyses were performed.

An analysis of variance on error scores disclosed that the main effects of interaction levels and complexity were significant.

Table 2

Analysis of Variance of Log Errors

Source	df	MS	F
Interaction Levels (IL)	2	4.4479	27.12*
Complexity (C)	2	1.7053	10.40*
Linear	1	3.2784	19.99*
Quadratic	1	.1321	.80
IL x C	4	.2116	1.29
Within	63	.1640	

*Significant at .001 level.

Figure 1 shows that the greatest mean number of errors was produced in the RI condition (29.75); the lowest, in the FI condition (2.29). Subjects' performance in the I condition (13.50) fell in between. Duncan's (1955) new multiple range test revealed, as expected, that the subjects' performance in the FI condition was superior to the learner in the I condition (*df* = 63, $p < .005$) and to those in the RI condition (*df* = 63, $p < .001$). And subjects in the I condition made significantly fewer errors than those in the RI condition (*df* = 63, $p < .001$). The learning curves for subjects in each interaction level under each level of complexity are presented in Figures 2, 3, and 4. These figures reveal that subjects in the FI condition consistently outperformed subjects in the I condition and the RI condition across all blocks of trials and under all levels of complexity. As the problem became more complex, subjects' performance in the I and RI condition grew progressively worse; whereas performance in the FI condition showed only a slight change. It appeared that the subjects in the FI condition could have solved CI problems which contained a greater amount of irrelevant information.

To determine whether pairs of subjects in the FI condition outperformed pairs of subjects in the RI condition and single learners on CI problems of different levels of complexity, a series of *t* tests were performed (Table 3). A graphic representation of mean errors between interaction levels within each level of complexity is shown in Figure 5.

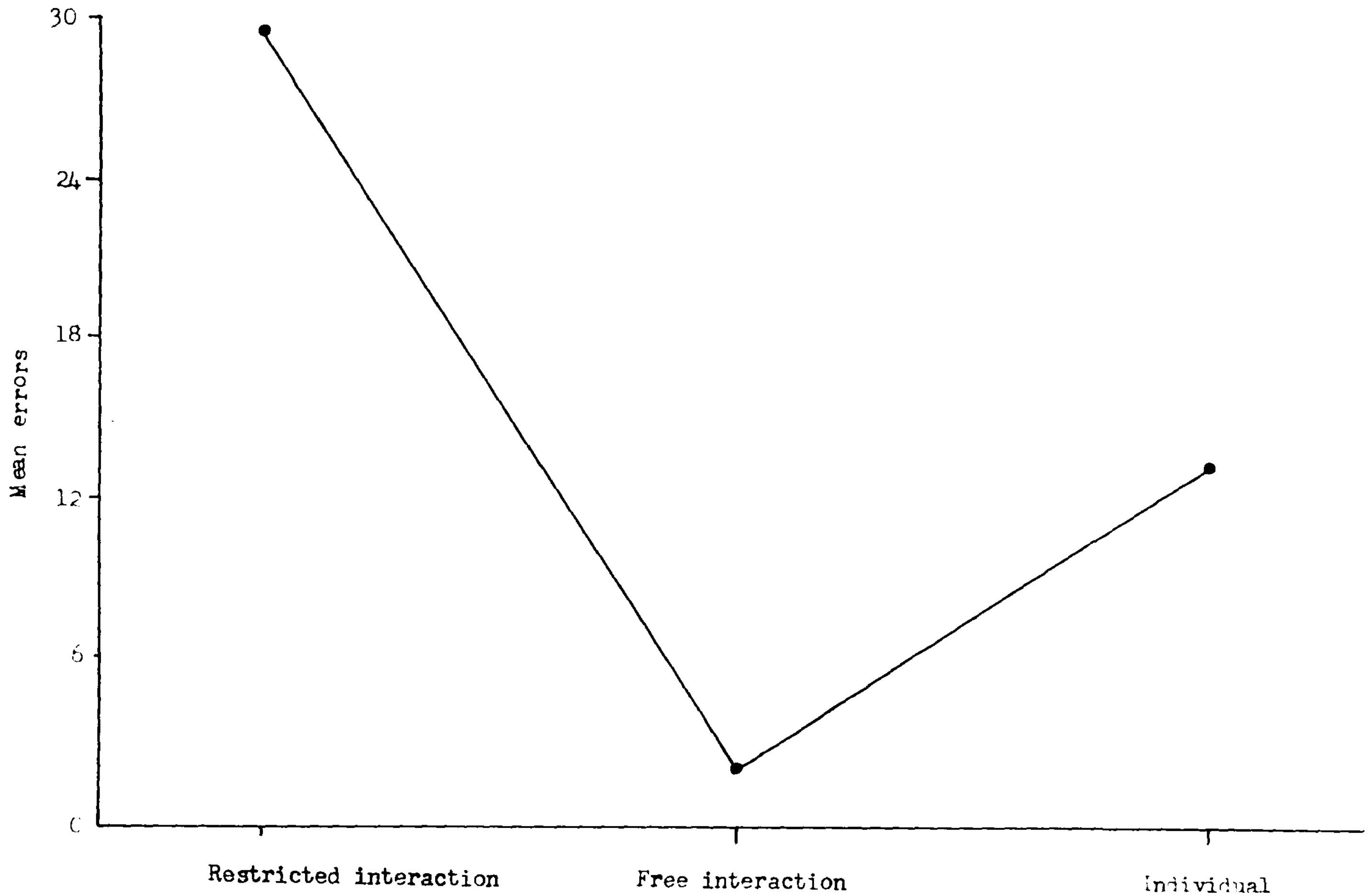

Fig.1. Mean errors as a function of interaction levels. (Each point represents an N of 24.)

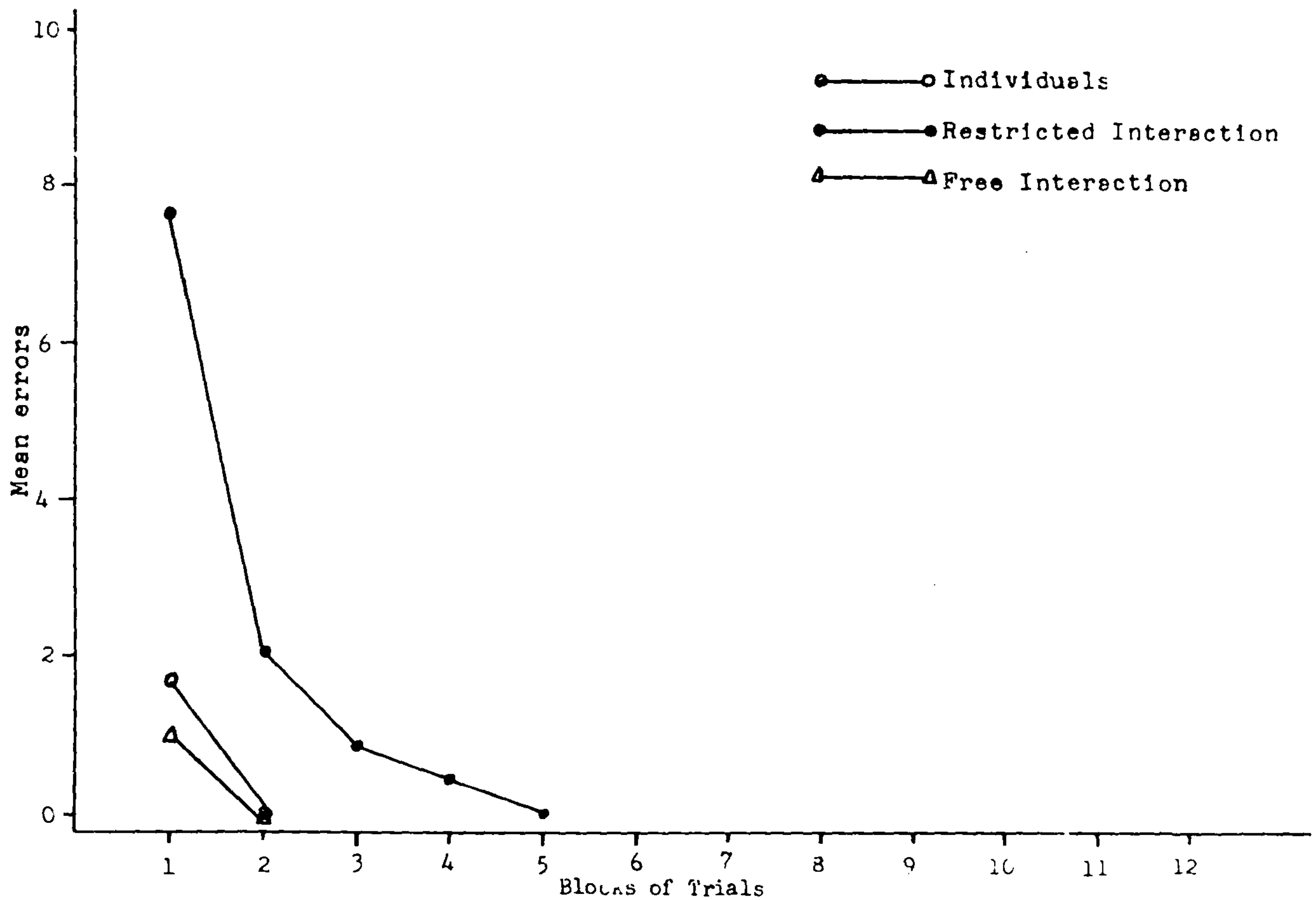

Fig. 2. Mean errors per block of 16 patterns as a function of interaction levels with one bit of irrelevant information. (Each point represents a mean based on an N of 8.)

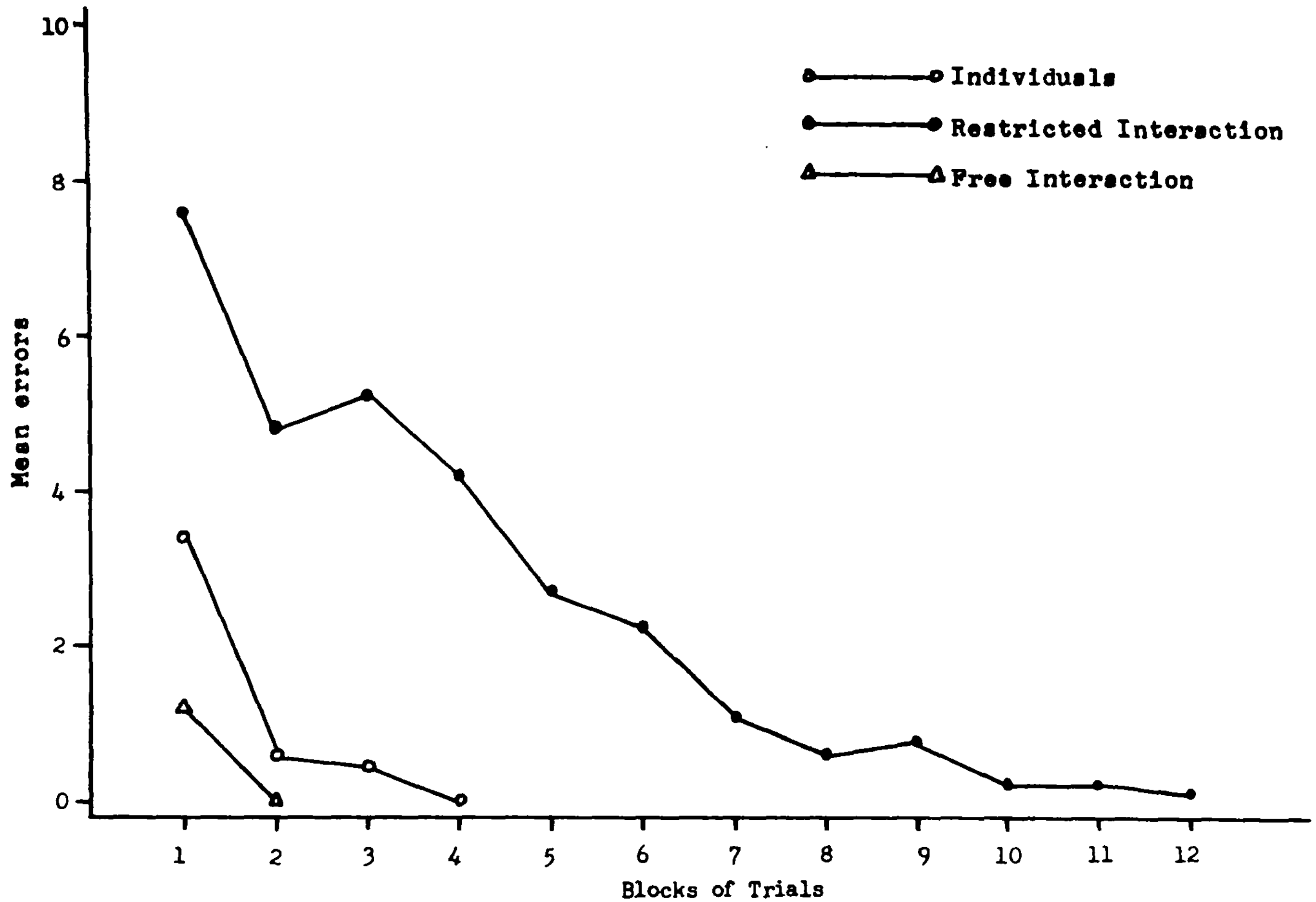

Fig. 3. Mean errors per block of 16 patterns as a function of interaction levels with three bits of irrelevant information. (Each point represents a mean based on an *N* of 8.)

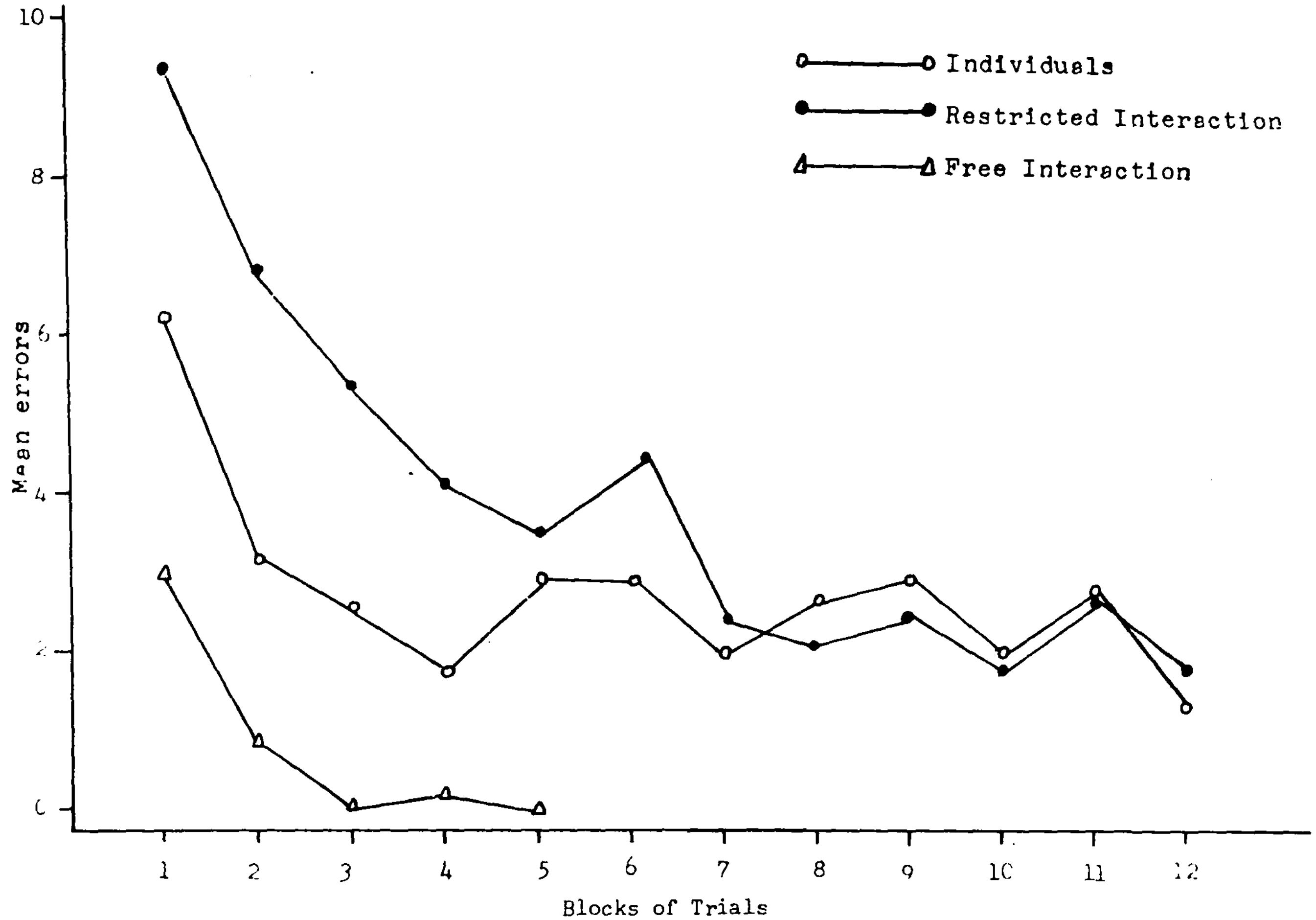

Fig. 4. Mean errors per block of 16 patterns as a function of interaction levels with five irrelevant bits of information. (Each point represents a mean based on an N of 8.)

Table 3

Summary of t Tests between Each Interaction Level at Each Level of Complexity (1, 3, and 5 Irrelevant Bits Of Information) for Transformed Error Scores

Interaction[a] Levels	Complexity	t Values (63 df)	p	
FI vs. I	1	.48		One-tailed Tests
	3	1.56		
	5	3.70	.001	
I vs. RI	1	2.85	.01	Two-tailed Tests
	3	3.44	.01	
	5	.92		
FI vs. RI	1	3.33	.01	One-tailed Tests
	3	4.90	.001	
	5	4.62	.001	

[a]FI = Free Interaction, RI = Restricted Interaction, I = Individuals

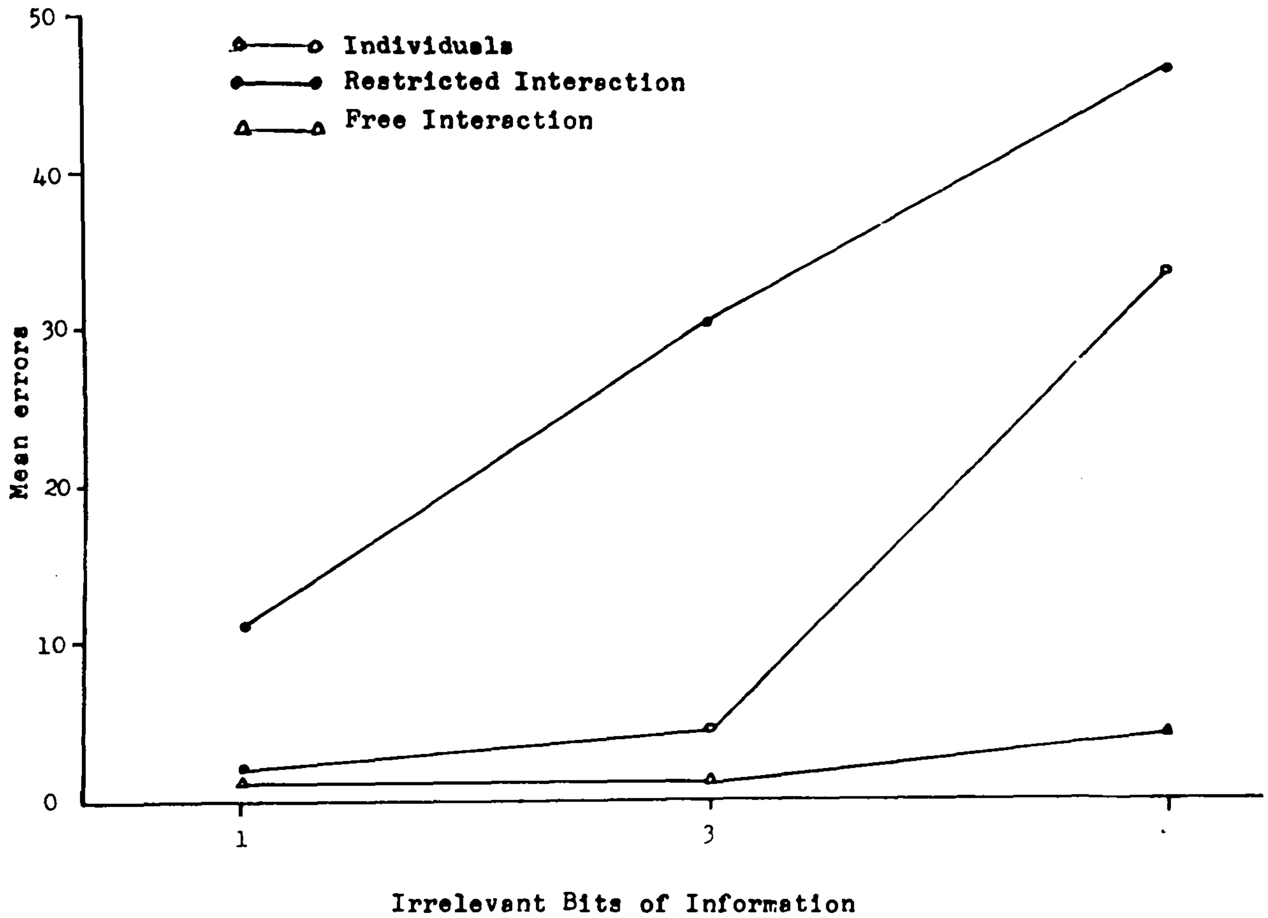

Fig. 5. Mean errors as a function of irrelevant bits of information. The parameter is interaction levels. (Each point represents an N of 8.)

Although subjects in the FI condition produced fewer errors than those in the I condition along all levels of complexity, Table 3 discloses that significance was reached only at the highest level of complexity ($p < .001$). In contrast, subjects in the FI condition showed superior performance to those in the RI condition along all levels of complexity (Table 3). When subjects in the I condition were compared to those in the RI condition, results indicated that individual performers made significantly fewer errors along two levels of task complexity (1 and 3 irrelevant bits), but not at the highest level (5 irrelevant bits). Thus the data indicate that pairs of subjects freely interacting outperformed subjects whose interaction was restricted along all levels of complexity, and FI subjects showed clear superiority to the single learner on CI problems with the highest level of complexity.

The significance of the main effect of complexity showed, as does Figure 6, that as the amount of irrelevant information increased, mean errors progressively increased. The mean number of errors for concepts containing 1, 3, or 5 irrelevant bits of information were 4.75, 12.12, and 28.66 respectively. An orthogonal polynomial analysis was performed for complexity (Table 2) and only the linear component reached significance ($p < .001$). The significance of complexity was consistent with the results obtained by several previous CI investigators (e.g., Archer, Bourne, & Brown, 1955; Bourne, 1957; Pishkin, 1960; Pishkin & Wolfgang, 1964; Wolfgang, Pishkin, & Lundy, 1962). Subsequent analysis with Duncan's (1955) test

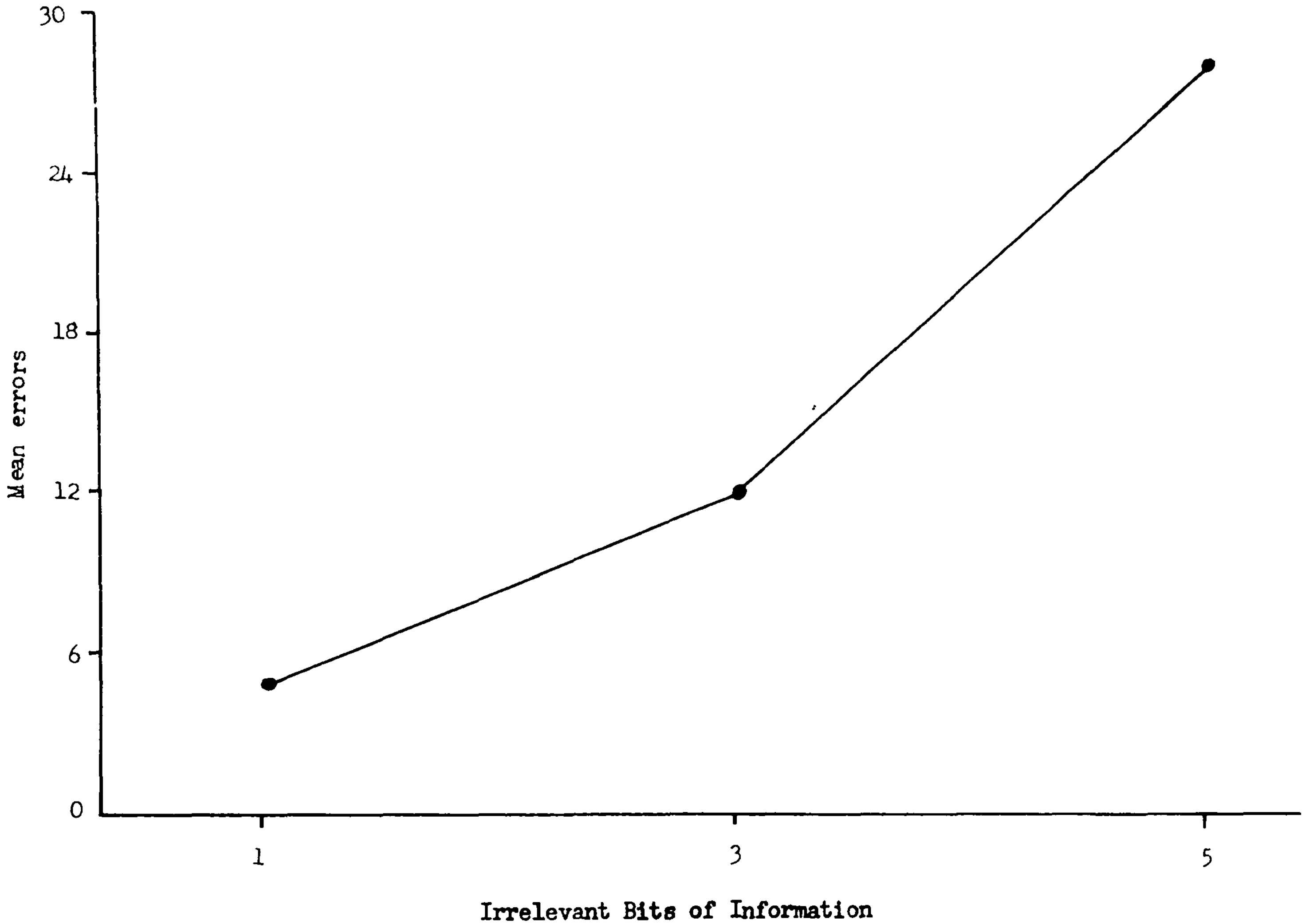

Fig. 6. Mean errors as a function of number of irrelevant bits of information. (Each point represents an N of 24.)

revealed that there were significant differences in mean errors between complexity levels 1 and 5 (df = 63, $p < .001$), 3 and 5 (df = 63, $p < .01$), but not between 1 and 3 (df = 63, $p > .05$).

To analyze the subjects' performance on problems with increasing levels of complexity within each interaction level, a series of t tests were performed (Table 4). Changes in mean errors with increasing levels of complexity within each interaction level is illustrated in Figure 5. The t tests in Table 4 disclosed that subjects in the FI condition showed no significant difference in performance between problems containing 1 and 3, 1 and 5, and 3 and 5 irrelevant bits of information ($p > .05$). In the RI condition there was a significant difference in errors between problems containing 1 and 5 irrelevant bits of information ($p < .01$), but subjects showed no significant difference in performance between problems with 1 and 3, and with 3 and 5 irrelevant bits ($p > .05$). Lastly, in the I condition subjects showed a significant difference in performance between problems with 1 and 5 ($p < .001$) and with 3 and 5 bits of irrelevant information ($p < .01$) but found problems containing 1 and 3 irrelevant bits of information to be of similar difficulty ($p > .05$).

Since the two subjects in the RI condition responded separately and registered independent decisions, it was possible to assess not only the group score, but also each subject's performance. The finding, using t tests (<u>direct-difference method</u>), was that subjects first to reach solution

Table 4

Summary of *t* Tests between Levels of Complexity Within Each Interaction Level for Log Errors

Interaction Levels	Complexity	*t* Values (63 *df*) One-tailed Test	*p*
Free Interaction	1 vs. 3	.03	
	1 vs. 5	1.23	
	3 vs. 5	1.26	
Restricted Interaction	1 vs. 3	1.54	
	1 vs. 5	2.51	.01
	3 vs. 5	.97	
Individuals	1 vs. 3	1.05	
	1 vs. 5	4.44	.001
	3 vs. 5	3.40	.01

(fast learners) made significantly fewer errors than their partners (slow learners) (t = 3.59, df = 23, $p < .01$). Thus two types of learners could be differentiated in the RI condition and will hereafter be referred to as fast and slow learners. Overall mean errors for fast learners were 11.20, and 24.54 for for slow learners. Fast learners made fewer mean errors over all levels of task complexity than slow learners. Mean errors for fast learners' solving problems with 1, 3, and 5 bits of irrelevant information were 5.75, 12.00, and 15.87 respectively; and for slow learners 8.50, 25.00, and 40.12. The *t* tests between fast and slow learners' performance indicated that there were significant differences on problems containing 3 ($t = 2.88$, $df = 7$, $p < .05$) and 5 ($t = 2.67$, $df = 7$, $p < .05$) irrelevant bits of information. Significance was not reached on problems containing 1 irrelevant bit ($t = .89$, $df = 7$, $p > .05$).

In addition to error scores, measures of decisions initiated and latency of speech in seconds were obtained. The number of times the fast or slow learner was the initiator of decisions (*A* or *B*) was totalled. The results showed that fast learners initiated significantly more decisions toward the correct solution than slow learners ($t = 2.10$, $df = 7$, $p < .05$). Overall mean number of decisions initiated was 57.62 for fast learners and 27.17 for slow learners. Comparisons were made between fast and slow learners for mean number of decisions initiated at each level of complexity; there was no significant difference in mean number of decisions initiated for problems containing 1 ($t = .39$, $df = 7$, $p > .05$) and 5 ($t = .99$, $df = 7$, $p > .05$) bits of irrelevant information, but significance was reached for problems containing 3 irrelevant bits ($t = 2.89$, $df = 7$, $p < .05$).

For both fast and slow learners measures of latency of speech were obtained. Latency was defined as the time in seconds that elapsed between the end of the trial, when the experimenter gave the feedback, and the pronouncement of each subject's decision, A or B. For problems with 3 (t = 2.37, df = 7, $p < .05$) and 5 (t = 2.69, df = 7, $p < .05$) irrelevant bits, speech latency was shorter for slow learners than for fast learners; on problems with 1 irrelevant bit no differences were found (t = 1.08, df = 7, $p > .05$).

Checks were made to ascertain to what extent solutions were independently arrived at, (i.e., did the slower learner mimic the answers of the faster learner to achieve solution?) The experimenter required that each subject independently write his solution to the problem after criterion was reached (i.e., when both subjects had made 16 consecutive correct responses). In four instances or 16% of the time slow learners were unable to state the solution to the problem, indicating that a proportion of the relevant social cues provided by the fast learner were being utilized by the slow learner.

To compare the fast learners' performance in the RI condition with that of the subjects in the FI condition, t tests were performed. Subjects free to interact made significantly fewer errors than fast learners in the RI condition (t = 3.27, df = 46, $p < .01$). Overall mean errors were 2.29 for subjects free to interact and 11.20 for fast learners in the RI condition, a ratio of about 5 to 1 in favor of subjects in the FI condition. Further analysis with t tests indicated that subjects in the FI condition made significantly fewer errors than fast learners on problems containing 1 (t = 2.16, df = 14, $p < .05$) and 3 (t = 2.21, df = 14, $p < .05$) bits of irrelevant information, but on problems containing 5 irrelevant bits significance was approached but not reached (*t* = 1.89, *df* = 14, *p* = .10). Mean errors for problems with 1, 3, and 5 irrelevant bits were for fast learners 5.75, 12.00, and 15.87 respectively and for subjects in the FI condition, 1.25, 1.25, and 4.37.

To determine whether fast learners in the RI condition were superior to individuals working alone, a series of *t* tests were performed. Results indicated that there was no difference in errors between fast learners and individual learners (*t* = .39, *df* = 46, *p* >.05). Overall mean errors for fast learners were 11.50, for subjects in the I condition, 13.50. Also, *t* tests revealed no significant differences in performance between fast learners in the RI condition and subjects in the I condition on problems with 1 (*t* = 1.82, *df* = 14, *p* = .10), 3(*t* = 1.43, *df* = 14, *p* >.05), and 5 (*t* = 1.25, *df* = 14, *p* >.05) irrelevant bits. Mean errors produced were 5.75, 12.00, and 15.87 respectively for fast learners on problems with 1, 3, and 5 irrelevant bits, and 1.87, 4.62, and 34.00 for subjects in the I condition.

To check out the possibility of subjects' seating positions (i.e., subjects seated on the left were closer to the left button and subjects on the right were closer to the right button) influencing errors made on the left and right buttons in the RI condition, a series of *t* tests were performed (Table 5). There were no significant differences in errors made by subjects seated on the left, on the right and left buttons along all levels of complexity (*p* >.05). Subjects seated on the right showed no significant differences in errors on the left

Table 5

Summary of t Tests for Errors on the Left vs. Right Response Button as a Function of Seating Position In the RI Condition

Position	Irrelevant Information in Bits	t Values (df = 7)
Subjects on the Left	1	1.36
	3	0.00
	5	1.66
Subjects on the Right	1	2.42*
	3	.54
	5	.40

*Significant at .05 level.

or right button for problems containing 3 and 5 irrelevant bits of information ($p > .05$), but made significantly more errors on the right button when the problem contained one irrelevant bit ($t = 2.54$, $df = 7$, $p < .05$). In comparing overall errors made by subjects seated on the left and right a t test revealed that there was no significant difference in performance as a function of seating position ($t = .66$, $df = 23$, $p > .05$). Thus, the data indicate that subjects' seating position in the RI condition had a negligible effect on CI performance.

Analysis of Time Scores

An analysis of variance of mean log time to solution, presented in Table 6, revealed significant main effects for interaction levels and complexity. Subsequent analysis of inter-

Table 6

Analysis of Variance of Transformed Time Scores

Source	df	MS	F
Interaction Levels (IL)	2	1.2017	18.54*
Complexity (C)	2	.9796	15.12*
Linear	1	1.9510	30.11*
Quadratic	1	.0083	.13
IL x C	4	.0898	1.38
Within	63	.0648	

*Significant at .001 level.

action levels with Duncan's test (1955) indicated, as does Fig. 7, that there were insignificant differences in time to solution between subjects in the FI and I conditions ($df = 63$, $p > .05$). However, there were significant differences in performance between subjects in the FI and RI condition ($df = 63$, $p < .001$) and between subjects in the I and RI condition ($df = 63$, $p < .001$), with the subjects in the RI condition taking longer to reach solution. Mean times to solution in minutes for subjects in the FI, RI, and I conditions were 6.42, 17.50, and 8.16 respectively.

To assess the differences in time to solution between interlevels under each level of complexity, a series of *t* tests were

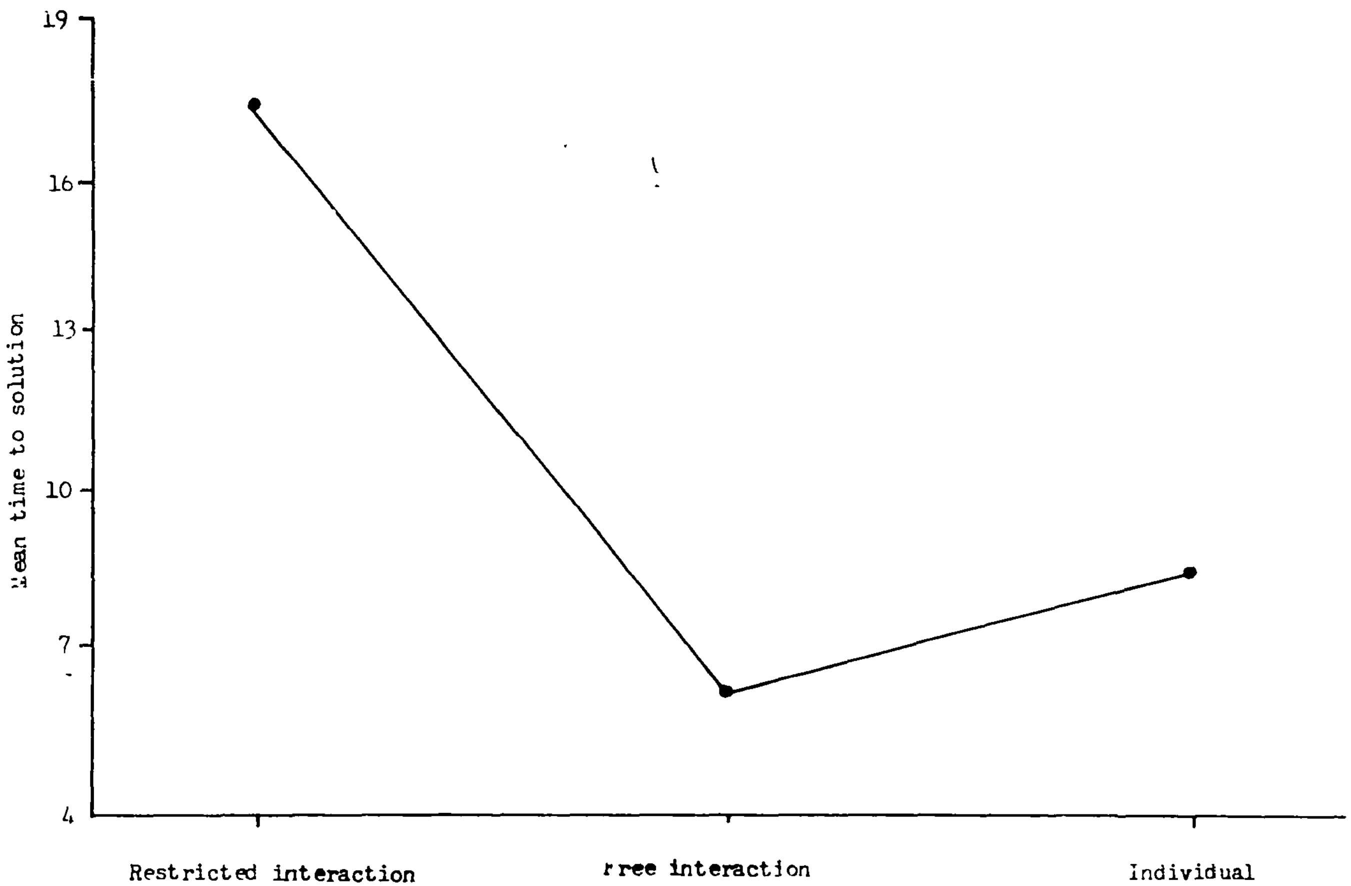

Fig. 7. Mean time to solution as a function of interaction levels. (Each point represents an N of 24.)

performed (Table 7).

Table 7

Summary of t Tests between Each Interaction Level Within Each Level of Complexity For Transformed Time Scores

Interaction Levels[a]	Complexity (Bits of Irrelevant Information)	t Values (63 df) Two-tailed Tests	p
FI vs. I	1	1.15	
	3	.05	
	5	1.40	
RI vs. I	1	3.23	.01
	3	4.08	.001
	5	1.68	
RI vs. FI	1	2.08	.05
	3	4.14	.001
	5	3.08	.01

[a]FI = Free Interaction, RI = Restricted Interaction, I = Individuals.

The results showed, as does Fig. 8, that subjects in the RI condition take longer to reach solution than subjects in the FI condition on problems containing 1 ($p < .05$), 3 ($p < .001$), and 5 ($p < .01$) bits of irrelevant information. In contrast,

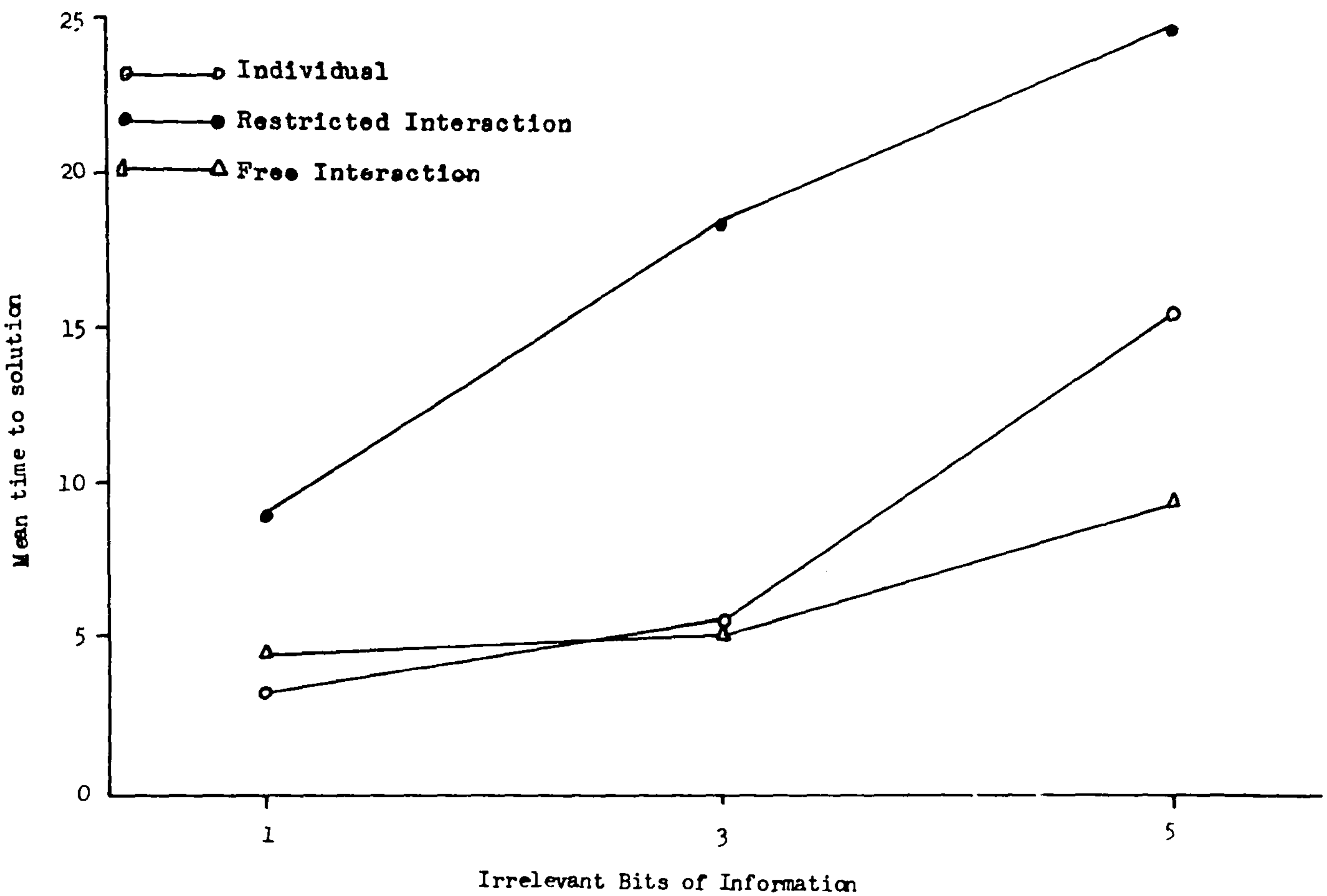

Fig. 8. Mean time to solution in minutes as a function of irrelevant bits of information. The parameter is interaction levels. (Each point represents an N of 8.)

insignificant differences in time were found between subjects in the FI and I condition along all levels of task complexity ($p > .05$). Subjects in the RI condition, when compared with those in the I condition, took significantly longer to reach solution on problems containing 1 ($p < .01$), 3 ($p < .001$) irrelevant bits of information, but significance was only approached on problems containing 5 irrelevant bits ($p = .10$).

The significant main effect of complexity (Table 6) indicated that differences among mean times to solution were a function of the amount of irrelevant information. As Fig. 9 shows, time to solution increased as the amount of irrelevant information increased from one to five irrelevant bits. The results of an orthogonal polynomial analysis of complexity revealed that only the linear component was significant ($p < .001$). Thus, increases were found for both time and error scores as a function of increases in irrelevant information. Pearson's product-moment correlations between errors and time to solution showed a significant positive correlation for problems with 1 ($r = .82$, $df = 22$, $p < .005$), 3 ($r = .86$, $df = 22$, $p < .005$), and 5 irrelevant bits of information ($r = .93$, $df = 22$, $p < .005$). These findings are consistent with the results of Archer, Bourne, and Brown (1955) and Bourne (1957).

Subsequent analyses of complexity with Duncan's test (1955) indicated, when comparisons were made between performances on problems with 1 and 5 ($df = 63$, $p < .001$) and 3 and 5 ($df = 63$, $p < .005$) bits of irrelevant information, that subjects took significantly longer to reach solution on the most

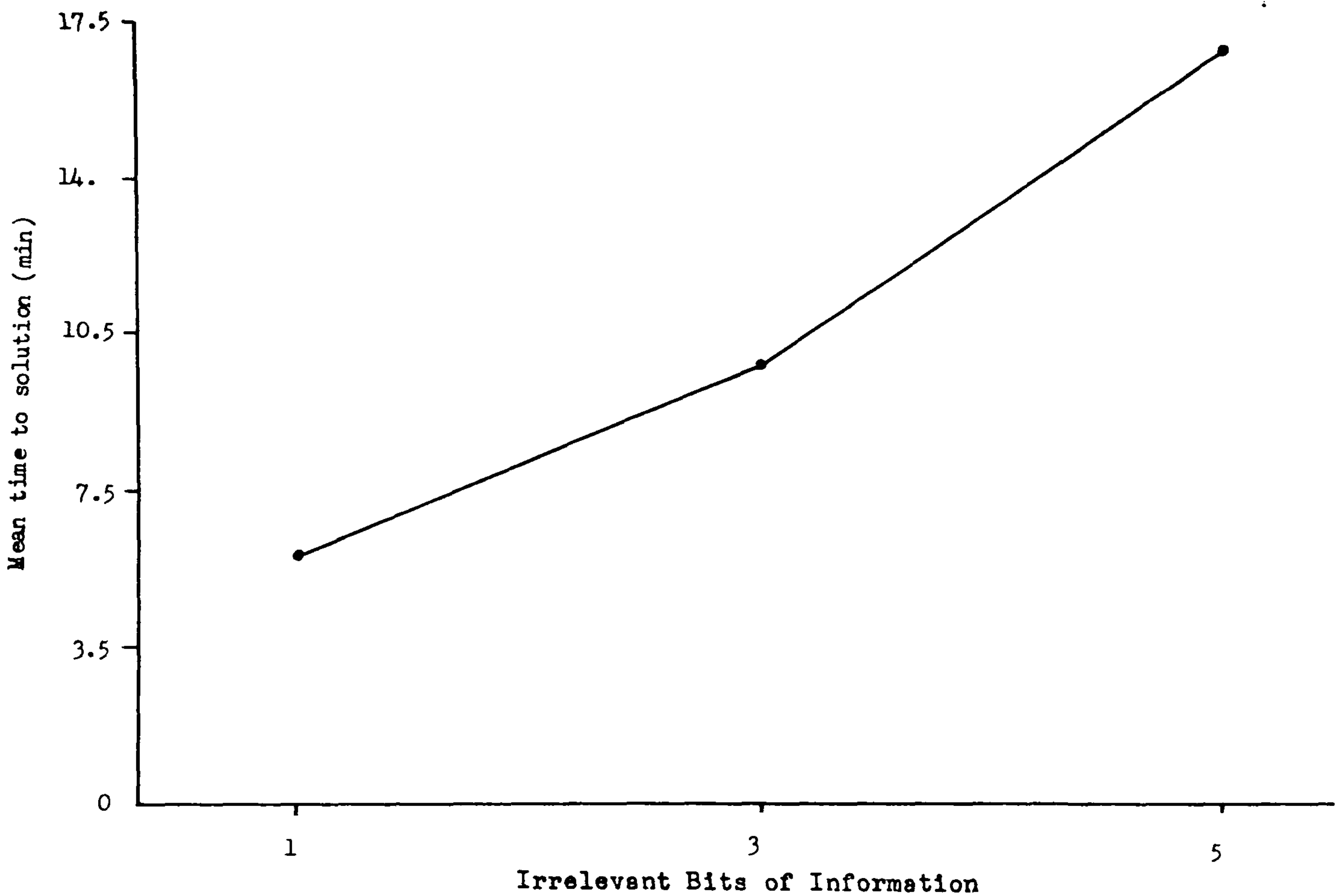

Fig. 9. Mean time to solution in minutes as a function of irrelevant bits of information. (Each point represents an N of 24.)

complex problems (5 irrelevant bits). No differences in time were found between problems with 1 and 3 irrelevant bits (*df* = 63, $p > .05$). Mean times to solution in minutes for problems with 1, 3, and 5 bits of irrelevant information were 5.58, 9.75, and 16.79 respectively.

To assess differences in solution time for problems of increasing levels of complexity within each interaction level, *t* tests were performed (Table 8). In the FI condition there was no difference in time to solution between problems with 1 and 3 ($p > .05$) bits of irrelevant information. Between problems with 1 and 5 ($p < .05$) and 3 and 5 irrelevant bits ($p < .05$), subjects took significantly longer to reach solution with 5 irrelevant bits.

In the RI condition an analysis of time to solution was performed between fast and slow learners. Overall, fast learners solved CI problems quicker than slow learners ($t = 4.09$, $df = 23$, $p < .001$). For fast learners overall mean time to solution was 9.75, and for slow learners, 17.45. Across all levels of task complexity, 1 ($t = 2.64$, $df = 7$, $p < .05$); 3 ($t = 3.05$, $df = 7$, $p < .02$); and 5 ($t = 3.03$, $df = 7$, $p < .02$) irrelevant bits, fast learners solved CI problems quicker than slow learners. Mean times to solution in minutes for problems with 1, 3, and 5 bits of irrelevant information were 6.62, 11.12, and 11.50 respectively for fast learners and 9.00, 18.37, and 25.00 for slow learners.

In comparing fast learners in the RI condition with subjects in the FI condition, the overall mean time to solution

Table 8

Summary of t Tests between Each Level of Complexity Within Each Interaction Level for Transformed Time Scores

Interaction Levels	Complexity (Bits of Irrelevant Information)	t Values (63 df) One- tailed Tests	p
Free Interaction	1 vs. 3	.32	
	1 vs. 5	1.98	.05
	3 vs. 5	1.67	.05
Restricted Interaction	1 vs. 3	2.38	.05
	1 vs. 5	2.99	.01
	3 vs. 5	.61	
Individuals	1 vs. 3	1.53	
	1 vs. 5	4.54	.001
	3 vs. 5	3.01	.01

in minutes for the former was 9.75 and for the latter, 6.42. A significant difference in solution time was approached but not reached (t = 1.97, df = 46, p = .06). When fast learners were compared to subjects in the FI condition across all levels of task complexity, no significant differences in time to solution were found for problems with 1 (t = 1.75, df = 14, p >.05) and 5 (t = .56, df = 14, p >.05) irrelevant bits. For problems containing 3 irrelevant bits, significance was approached (t = 2.11, df = 14, p = .06). Mean times to solution for problems containing 1, 3, and 5 irrelevant bits of information for subjects in the FI condition were 4.62, 5.12, and 9.50 respectively.

Lastly, when fast learners were compared to subjects in the I condition in time to solution, no significant differences were found (t = .71, df = 46, p >.05). Subjects in the I condition had an overall mean time to solution of 8.16; the fast learners' time was 9.75.

Analysis of Verbal Interaction Measures In the FI Condition

In addition to time and error scores, measures of verbal interaction (talk time, sequential utterances, latency of speech, decisions initiated and adopted, and initiator of discussion) were analyzed for the FI condition. In this condition subjects were free to discuss their hypotheses about the correct response before coming to a common decision on each trial. In view of the insignificant differences found between partners in talk time and latency of speech (see Appendix C), their scores were combined for the analyses to follow.

To determine whether there were significant differences in verbal activity between levels of task complexity, an analysis of variance was performed on sequential utterances (Table 9), talk time (Table 10), and latency of speech (Table 11). The number of sequential utterances, amount of talk

Table 9

Analysis of Variance for Sequential Utterances

Source	*df*	*MS*	*F*
Complexity	2	27,950.37	1.48
Within	21	18,857.14	

Table 10

Analysis of Variance for Talk Time (Secs.)

Source	*df*	*MS*	*F*
Complexity	2	25,800.79	1.55
Within	21	16,660.68	

Table 11

Analysis of Variance for Latency of Speech (Secs.)

Source	*df*	*MS*	*F*
Complexity	2	24,069.12	2.45
Within	21	9,810.18	

time, and speech latency of each pair of subjects were analyzed. A sequential utterance is an exchange of conversation, i.e., one subject's utterance followed by his partner's constituted two sequential utterances. Tables 9, 10, and 11 show insignificant main effects for complexity ($p > .05$).

Subsequent analysis with Duncan's test revealed that subjects' talk time, number of sequential utterances, and latency of speech did not show any significant changes between problems with 1 and 3 ($df = 21$, $p > .05$), 1 and 5 ($df = 21$, $p > .05$), and 3 and 5 bits of irrelevant information ($df = 21$, $p > .05$). Table 12 contains means for talk time, latency of speech, sequential utterances, and errors for each level of complexity. Note in Table 12 that changes in verbal activity are similar to changes in errors along each level of complexity. Pearson r's showed significant positive correlations between errors and talk time ($r = .93$, $df = 22$, $p < .005$), errors and latency ($r = .88$, $df = 22$, $p < .005$), and errors and sequential utterances ($r = .94$, $df = 22$, $p < .005$). Thus, in the FI condition verbal activity was positively related to errors in concept identification performance but not to task complexity.

Unexpectedly, subjects who initiated a decision got it adopted 99.5% of the time, indicating that disagreements about the correct response were at a minimum.

Tables with mean scores for all dependent variables in their respective treatment conditions are located in Appendix B, with the exception of the verbal interaction scores (Table 12).

Table 12

Means of Errors, Sequential Utterances, Talk Time
And Latency of Speech in the
Free Interaction Condition

	Bits of Irrelevant Information		
	1	3	5
Mean errors	1.25	1.25	4.37
Sequential utterances	69.25	68.25	171.12
Talk time in seconds	68.25	78.00	171.12
Latency of speech in seconds	185.37	196.25	285.50

Note.-Each mean is based on 8 two-person groups.

Extended Mathematical Theory of Concept Identification

A summary of the obtained and predicted learning rates (θ), obtained and predicted errors for each level of task complexity, and the values of the constants for subjects in the I, FI, and RI conditions is presented in Table 13. Subjects in the FI condition consistently obtained higher θ values (computed from equation 2), indicating faster rates of concept learning than subjects in the RI and I conditions at all levels of complexity. When comparing obtained mean errors of the subjects in the FI condition with those in the I condition on the simplest CI problems (1 irrelevant bit), error scores were similar, but as the complexity of the concept increased, differences became more pronounced. Individuals made $3\frac{1}{2}$ times as many errors on concepts with 3 irrelevant bits and about 8 times as many errors on the most complex conceptual problems (5 irrelevant bits). The differences in obtained errors in CI between subjects in the FI condition and those in the RI are more pronounced, particularly with slow learners.

One of the main predictions of the CI model is that as the amount of irrelevant information increases, learning rate (θ) should decrease. This prediction was verified in the I and RI conditions, but in the FI condition the prediction was not confirmed. Table 13 shows that the obtained θ's and errors for problems with 1 and 3 irrelevant bits were identical in the FI condition. Thus, the basic assumption of the model that increasing the number of irrelevant cues would retard learning did not hold up in a setting where two subjects

Table 13

Summary of Values of Constants, Obtained and Predicted θs and Mean Errors
As a Function of Interaction Levels and Number
Of Irrelevant Bits of Information

Interaction[a] Levels	Bits of Irrelevant Information	Predicted θ	Obtained θ	Predicted Errors	Obtained Errors	Constants
	1	....	.440	.....	1.25	K= .881
FI	3	.279	.440	2.71	1.25	B= .516
	5	....	.205	.....	4.37	S= .974
						1= .671
RI	1	....	.132	.....	8.50	K= .881
Slow	3	....	.059	.....	25.00	B= .516
Learners	5	.038	.041	43.93	40.12	S= -.904
						1= .739
RI	1	....	.170	.....	5.75	K= .881
Fast	3	....	.101	.....	12.00	B= .516
Learners	5	.072	.082	18.90	15.87	S= .406
						1= -.946
I	1	....	.350	.....	1.87	K= .881
	3	....	.195	.....	4.62	B= .516
	5	.135	.046	7.90	34.00	

[a]FI = Free Interaction, RI = Restricted Interaction, I = Individuals

were free to exchange information. Even with the extended model identical θ values could not be used to solve equation 3. Since the expressions for the unknowns were identical in both equations, it was not possible to eliminate one of the unknowns by addition or subtraction or by substitution of the other; instead θ values for 1 and 5 irrelevant bits of information were used and equation 3 was then solvable.

Table 13 discloses that the predicted errors for subjects in the FI condition and for fast and slow learners in the RI condition were quite close when compared to the actual errors obtained on the conceptual task. In the FI condition the extended model came within 1.46 errors of making a perfect prediction, while for fast learners in the RI condition the model was off by 3.03 errors, and 3.81 errors for slow learners. In the I condition the original model's (Bourne & Restle, 1959) error predictions were inaccurate by 24.1. Thus the model came much closer in predicting performance in the social condition than in the I condition. It was noted that the original model was capable of making error predictions with the same accuracy as the extended model (Pishkin & Blanchard, 1963) in the social conditions. The disadvantage of using the original model was that the values of the social cues could not be established, for they became absorbed by $\underline{k}$ and $\underline{B}$.

In addition to testing the accuracy of the predictions of of the model, a major aim of this research was to account for the effects of social cues on learning rates within the framework of the extended model and to establish the values of social cues in situations where two individuals were free to interact and situations where interaction was restricted.

To reiterate, in the Pishkin and Blanchard (1963) extended social model, the numerator of equation 3 represents that portion of the cues which is relevant; the denominator, the total set of available cues that would interfere with CI performance. The proportion of relevant stimulus cues utilized is symbolized by the constant *k*; *B*, a constant, represents the amount of background irrelevant stimulation from the apparatus,

$$\theta_{st+soc} = \frac{kR + lS}{R + I + B + S} \qquad 3$$

surround, and internal cues. The proportion of social cues utilized is *l*; and *S* stands for the overall value of the social cue, i.e., the other person. The values of *k* and *B* were constant for all conditions so that the facilitative and inhibitive effects of social cues in the FI and RI conditions could be attributed to *l* and *S*. That is, if new values were estimated for *k* and *B* in the social conditions, *k* and *B* would absorb all the value from *l* and *S*, leaving *l* and *S* zero.

In the FI condition the values of social cues were positive, facilitating concept learning (Table 13). The high value of *l* indicated that a large proportion of the social cues were being utilized. The positive value of social cues in the numerator along with the low value of *B* in the denominator increased the proportion of relevant to irrelevant cues which theoretically accounts for the faster learning rates. The value of *B* (.516) was much lower than the value obtained by

Bourne and Restle (1959), B = 3.40; by Pishkin (1961), B = 2.64; and by Pishkin and Blanchard (1963), B = 3.13. The introduction in the present experiment of a cubicle with soundproofing tile, in which the subjects were housed, apparently helped reduce the effects of background irrelevant stimulation from the apparatus and surround.

In contrast to the above findings, social cues in the RI condition interfered with CI performance for both fast and slow learners (Table 13). For slow learners the value of the social cue was negative, interfering with performance. The high value of I indicated that slow learners were using a high proportion of the relevant social cues provided by their partners. Although both fast and slow learners reached criterion to solution, slow learners in four instances were unable to state the solution, indicating that they were copying their partners. When considering that fast learners initiated more decisions, reached solution faster, and made less errors, the opportunity was present for the slow learners to rely on the relevant social cues provided by their partners. In view of the comparatively poor performance of the slow learners and the negative value of S, it seems reasonable to hypothesize that fast learners had a disruptive influence on performance and that slow learners did not make efficient use of the relevant social cues.

For fast learners the negative value of I, and the low positive value of the social cue (slow learners) indicated that utilizing relevant cues of the slow learner interfered with performance. That fast learners' performance was overall not significantly different from individuals showed that the value of S (slow learner) was negligible.

The predictions of learning rates for individuals did not fit the data accurately. This discrepancy may be attributed to the low value of B. That is, reduction of irrelevant background cues by having subjects perform in a cubicle resulted in faster learning rates on the simpler problems (1 and 3 irrelevant bits) in comparison with the most complex. The difference in errors between problems with 1 and 3 irrelevant bits was only 1.75, but between 1 and 5 irrelevant bits the error difference was 32.13, and between 3 and 5 irrelevant bits it was 29.38. Thus, it appears that reduction of the size of background irrelevant cues has a differential effect on conceptual performance in that differences in performance are reduced between simpler tasks, but not between the simpler and most complex conceptual tasks. Unfortunately there have been no direct studies to test out the Bourne and Restle (1959) prediction that reduction of background cues should improve performance. The evidence from the present study suggests that reduction of background cues would improve performance on simpler CI problems but not for the most complex problems.

CHAPTER IV

DISCUSSION

The common finding that groups are superior to individuals in problem solving must be re-evaluated in terms of task complexity and the group interaction condition. In the present study free interacting groups significantly outperformed individuals across all blocks of trials and at all levels of complexity. The learning curves (Figs. 2, 3, and 4) revealed that error differences between free interacting groups and individuals became more pronounced as the complexity of the concept was increased. That FI groups were superior in CI to the individual learner was in general agreement with the common finding of superiority of groups by investigators in the area of group problem solving (e.g., Barnlund, 1959; Faust, 1959; Goldman, 1965; Gurnee, 1939; Hoppe, 1959; Husband, 1940; Perlmutter & DeMontmollin, 1952; Shaw, 1952; Sperow, 1961; Restle & Davis, 1962; Thorndike, 1938). None of the above investigators made any attempts, however, to quantify or systematically evaluate the variable of task complexity when they made comparisons between individuals and group problem solving.

In the present study the variable of task complexity proved to be important in adding clarification to the generality that groups are superior to individuals. When comparisons were made between free interacting groups and individuals at each level of task complexity, free interacting groups significantly outperformed individuals only on the most complex concepts (5 irrelevant bits). Factors that might account for FI groups being superior on the most complex concepts where the information load and number of alternative hypotheses are greatest would be that groups through discussion would have the advantage of drawing on two memories for recalling which hypotheses were correct or incorrect. Also, the chances of perseverating on an incorrect hypothesis would be reduced, since a subject would have to offer his partner a justification for his persistently incorrect responses. To illustrate the last point, in the individual condition two subjects pursued incorrect hypotheses throughout problems containing 5 irrelevant bits and performed almost at the chance level; whereas perseveration on incorrect hypotheses was at a minimum on the simpler concepts in the FI and I conditions. On the simpler conceptual tasks where the information load, number of alternative hypotheses, and memory requirements were greatly reduced, the advantage of the group disappeared.

On the time dimension (minutes to solution) the superiority of FI groups over individuals vanished. There were no statistical differences in time to solution between individuals and free interacting groups along all levels of task complexity. When compared to individuals, the advantage of the FI group was that it was able to reduce errors, but it was unable to reduce the amount of solution time to less than that of individuals because of the time spent in discussion. Thus, on the time dimension, there was no difference in efficiency between individuals and FI groups in solving CI problems.

The second group interaction condition that could be used to contrast with individuals was the RI group where pairs of subjects independently stated and registered their responses in full view of each other but could not discuss their answers. In the previously cited studies concerning group versus individual problem solving, the type of group on which the results were based was an interacting, face-to-face group. The results of the present study showed that individuals made significantly fewer errors in CI than pairs of subjects in the RI group and reached solution faster (8.16 min. for I, 17.50 min. for RI). These results indicate that it is necessary to consider the type of group interaction being compared to individuals before any generalizations can legitimately be made about group superiority.

Judging from the relatively poor performance of the RI group it is plausible to reason that more irrelevant, distracting cues were operating in the situation. The CI task can be described as one that requires sustained attention, concentration, and reliance on memory of past and present information feedback. Subjects in the RI situation might have had difficulty in fully concentrating on their own hypotheses and feedback when almost at the same time additional information was offered by their partners who were voicing and registering similar or contrasting responses perhaps for different reasons.

In comparing the two interaction groups it was found that the FI group was superior to the RI group by making less errors across all blocks of trials and all levels of complexity and by reaching solution faster. In addition, there is some evidence to suggest that the nature of the interaction between the subjects in the FI group was one of cooperation. When a subject initiated a decision, usually after some discussion, the probability of its being adopted by his partner was .99, indicating that disagreements were at a minimum. This finding was consistent with the study of Bales and Borgatta (1955) who found when using the Bales interaction profile that certain unique aspects of two-person discussion groups were the low rates of showing disagreement and antagonism and the high rates of showing tension, asking for information and opinions. On the whole, the FI group may be described as being cooperative in their attempts to reach the common goal of solving CI problems. In contrast, the subjects of the RI group could be described as having high tension, having little opportunity to establish a relationship with their partners, as being unable to reconcile differences through discussion while working toward independent goals.

In the RI group the fast learners were characterized as making fewer errors, attaining solution to the problem faster, initiating more decisions, and giving their answers quicker overall than the slow learners. However, when fast learners were compared to individuals, there were no differences in time to solution and errors, but when compared to the FI group fast learners made more errors (5 times as many) while taking significantly longer to reach solution. Assuming there is equality in the initial ability among subjects to perform a CI task, then it could be reasoned that the relatively poor performance of the slow learners was due to social factors. Since fast learners in the RI group performed like individuals working alone, it is plausible that social influences were less detrimental for them. In the FI group there was no clear way of differentiating fast and slow learners since the overall error scores were so small ($\bar{x}$ = 2.29) and in 11 instances errors were equally divided between the two subjects. Perhaps with problems of greater complexity fast and slow learners could be more clearly differentiated in the FI group.

In the evaluation of task complexity, it was found that mean errors in CI increased with increases in the amount of irrelevant information contained in the concept. These findings are in agreement with the results obtained by a number of investigators (e.g., Archer, Bourne, & Brown, 1955; Bourne, 1957; Pishkin, 1960; Pishkin & Wolfgang, 1964; Wargo, 1960; Wolfgang, Pishkin, & Lundy, 1962). An analysis of error differences between each level of task complexity revealed that there were significant differences in errors between complexity levels 1 and 5, and 3 and 5, but not between 1 and 3. This finding is not surprising when considering that the total number of stimuli associated with each level of complexity does not increase in equal increments. In the present experiment there was always one bit of relevant information accompanied by 1, 3, or 5 irrelevant bits. With each additional bit of information the number of possible stimuli doubled. Thus for problems with 1 irrelevant bit, there were four stimuli to categorize; with 3 irrelevant bits, 16 possible stimuli; and with 5 irrelevant bits there were 64 stimuli from which to make a choice. Consequently, the increase in the total number of stimuli to be categorized from 1 to 3 irrelevant bits was much smaller than from 1 to 5, or 3 to 5 irrelevant bits.

The effects of task complexity on time to solution were similar to those obtained with mean errors; that is, it took progressively longer to reach solution with increases in the amount of irrelevant information. Correlations between time and errors were positive at all levels of task complexity. These results are consistent with those of Archer, Bourne, and Brown (1955), and Bourne (1957).

The performance of the subjects in the FI, RI, and I conditions was assessed on problems with increasing complexity. Subjects in the I and RI conditions made an increasingly greater number of errors with increases in the complexity of the concept, whereas in the FI condition there was only a slight change in performance. In view of the slight nonsignificant deterioration in performance by subjects in the FI condition, it seems reasonable to expect that they would be able to solve concepts of greater complexity. At the present time the maximum number of irrelevant bits of information that has been introduced into two-choice problems for individuals has been five. A logical follow-up study would be to test and compare the limits of the capacity of individuals, free interacting groups, and restricted interaction groups for solving CI problems of greater complexities.

An analysis of verbal activity for the FI groups revealed that there were insignificant increases in talk time, number of sequential utterances, and speech latency as a function of increases in task complexity. There were also insignificant changes in the FI group in mean errors and mean time to solution with increases in task complexity. Thus measures of verbal activity as well as measures for CI performance (errors and time) did not reflect the typical linear curve. Significant positive correlations obtained between errors and talk time, errors and number of sequential utterances, and errors and latency of speech indicated that verbal activity was positively related to errors in CI and not directly to task complexity.

The extended mathematical model of CI was tested for its accuracy in predicting learning rates for two group conditions; in one, pairs of subjects were free to interact and exchange information, and in the other, social interaction between pairs of subjects was restricted to simply stating individual responses. The predicted and obtained learning rates in both group conditions were in close agreement. Since the extended model has been shown to be effective in predicting learning rates in social situations ranging from highly restrictive, where programmed stooges were used (Pishkin & Blanchard, 1963), to situations where pairs of subjects were free to engage in discussion indicates that the model is quite powerful. Whether or not the model would be powerful enough to make successful predictions with larger-sized groups, varied populations, and in more natural settings awaits further research.

One of the basic postulates of the model is that the learning rate should decrease with increases in irrelevant information. However, that assumption was not confirmed in the FI condition where subjects showed no change in learning rate on problems with 1 and 3 irrelevant bits. Thus the model which bases its assumption, that increasing the number of irrelevant cues retards learning, on the performance of the individual needs to be revised or qualified for pairs of learners freely exchanging information.

In establishing values of social cues for the two interaction conditions and assessing their effects on rates of learning in CI, it was found that social cues facilitated learning in the FI groups, but interfered with subjects' performance in the RI groups. Subjects in the FI condition consistently obtained higher θ values for all levels of complexity than subjects in the I and RI conditions, indicating that subjects in the FI group learned to identify the relevant cues faster. The positive values of both $\underline{S}$ and $\underline{1}$ reflected their fast learning rate. It seemed as though subjects in the FI group made better use of their resources than those in the RI group by cooperating with one another and using, in addition to the relevant stimulus cues, a high proportion of the relevant social cues.

In contrast, the value of social cues for the slow learners in the RI condition was negative, indicating interference with learning, while for the fast learners the value of the social cue was negligible--only half the value obtained by the FI group. Since the fast learners performed at the same level as individuals working alone, it may be assumed that social cues had a negligible effect on their performance. The value of _1_ for fast learners was negative, and for slow learners was positive, suggesting that slow learners attempted to use more of the relevant social cues provided by their partners. Studies by Lydecker, Pishkin, and Martin (1961), Pishkin and Blanchard (1963), and Wolfgang, Pishkin, and Lundy (1962) suggest that intelligence was not related to CI performance within the subject populations used (chronic schizophrenics and psychiatric aides with varying degrees of education). In view of the findings on intelligence, it is likely that the differences between fast and slow learners would be due to other factors.

Perhaps, in addition to social factors, personality (e.g., dominance, independence), and strategies used by the subject may have contributed in different degrees to the differences in performance between the fast and slow learners. Pishkin (1961) found that individual differences in subjects' approach to CI problems was an important variable. He discovered that individuals using a systematic approach were more efficient in discarding irrelevant cues (as reflected in the higher k value) than subjects who did not start out with a systematic approach to a task. Since k could not be estimated in the social conditions because it contributed to deflating the values of social cues to zero, there was no direct way to independently assess the values of k for fast and slow learners. For future research one way of obtaining independent estimates of k for fast and slow learners would be to have them perform alone.

The mathematical model was not successful in predicting accurately the errors for the individual learner. The discrepancy could be explained in terms of the reduction of background irrelevant cues having a differential effect on performance with problems of different levels of complexity. In the present experiment the value B was much lower than that obtained by other experimenters using a similar apparatus and procedure (e.g., Bourne & Restle, 1959). However, unlike Bourne and Restle's (1959) study, the subjects were placed in a semi-soundproof cubicle where only the screen and the panel board were in direct view. In the present experimental setting where background cues were reduced, error differences between the simpler concepts were small, but not between the simple and the most complex tasks. The Bourne and Restle (1959) model predicts that reduction in background irrelevant stimulation should facilitate concept learning; however, the present findings suggest that this prediction would hold true on simpler CI tasks, but not necessarily for the most complex concepts. At present there have not been any studies reported that have systematically varied background cues in CI.

CHAPTER V

SUMMARY AND CONCLUSIONS

The primary aims of the present experiment were first to evaluate the effects of social cues on learning rates in concept identification (CI) within the framework of the extended Bourne and Restle (1959) mathematical model of concept identification (Pishkin & Blanchard, 1963) and to establish theoretical values of social cues in both a free and restricted social interaction setting; second, to investigate the effectiveness of two-person groups, free to interact, in comparison with restricted interaction two-person groups and individuals working alone in learning CI problems of different levels of complexity. On the basis of the findings in the area of group problem solving, it was predicted that freely interacting groups would be superior to their controls, the restricted interaction groups, and to individuals. The last aim was exploratory, i.e., to investigate the relationship of a series of social interaction measures in the free interaction (FI) and restricted interaction (RI) groups to concept identification performance.

Subjects were 120 male volunteer students in elementary psychology courses, who were randomly divided into nine treatment groups. Students assigned to two-man groups, who acknowledged they were friends were randomly reassigned to other conditions. A 3 x 3 factorial design was used, which included 3 levels of complexity (1, 3, and 5 irrelevant bits of information) and three interaction levels with one or two subjects operating in one of three conditions. In Condition I, subjects performed alone; in Condition II, subjects in two-man groups were free to interact; and in Condition III, interaction between two subjects was restricted to each subject's simply stating and registering his individual responses. Subject's task was to learn to correctly categorize a series of geometric patterns flashed on the screen in accordance with the relevant dimension. Criterion of solution was 16 consecutive correct responses.

In terms of the extended mathematical model, the results indicated that its predictions of errors for subjects in the FI and RI groups were in close agreement with the data. However, for individuals the predictions were not accurate. The basic assumption of the model that learning rates decrease with increases in the amount of irrelevant information in the problem was not confirmed in the free interaction condition. Learning rates were highest in the FI condition, lowest in the RI condition, with the individual performance falling in between, indicating that subjects in the FI condition were the most efficient in identifying relevant information. Values of social cues were established; in the FI group, social cues facilitated learning, but in the RI group they retarded it.

The usual finding that groups are superior to individuals in problem solving needs to be reassessed in terms of task complexity and the group interaction condition. Error differences between individuals and FI groups became more pronounced as the complexity of the concept increased. Subjects in the FI group significantly outperformed individuals only on the most complex concepts (5 irrelevant bits). On the time dimension (minutes to solution) there was no statistical difference in efficiency between individuals and FI groups in solving CI problems.

The restricted interaction group was found to be one group that was not superior to individuals or the FI group, for both individuals and FI groups outperformed subjects in the RI group by making less errors and reaching solution to the problem faster. In the RI condition fast learners were characterized as making fewer errors, as being generally faster in giving answers, as reaching solution faster, and as initiating more decisions than the slow learners.

In investigating the variable of task complexity, analysis revealed that mean errors and mean time to solution increased with increases in the number of irrelevant bits of information contained in the concept. Correlations between time and errors were positive at all levels of task complexity. In contrast to subjects in the RI and I conditions, subjects in the FI condition showed only a slight change in performance on concepts with increasing complexity, indicating that they could cope with concepts of greater complexity.

An analysis of verbal activity in the FI group revealed that there were insignificant increases in talk time, number of sequential utterances, and speech latency as a function of increases in task complexity. However, significant positive correlations were obtained between errors and number of sequential utterances, errors and talk time, and errors and latency of speech, indicating that verbal activity was positively related to errors and not directly to increases in task complexity.

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APPENDIX A

INSTRUCTIONS

Instructions for Individual and Free Interaction Conditions

After the experimenter placed the chest microphone on the subject(s), he delivered the following instructions:

Try to speak into the cone where the microphone is located and try to avoid speaking in a very loud or very soft voice. Your conversational voice would be fine.

I want to see how well you can do on this problem. There will be a series of geometric patterns appearing on this screen. Your job is to classify these patterns into two categories, A or B. After each pattern appears, I want you to guess which one of the two buttons you should press, A or B. For example, if it was the position of the pattern that made the difference in your choice of buttons, you would push button A whenever the pattern was on top of the screen and push button B whenever the pattern was on the bottom. If you pushed the right button and the right light above it lit up you would know that you were right. If you pushed the right button and the left light lit up, you would know that your choice of buttons was wrong. (Demonstrate with two cards, one with a circle on the top and one with a circle on the bottom.) In this example your choice of buttons, A or B, was determined by the position of the patterns only. You may take as much time as you wish in making your decision as to which button to press. Any questions?

<u>Additional instructions for subjects in the free interacting group</u>. Since you can register only one decision at a time, the two of you may discuss your answers for as long as you wish before the two of you agree upon a single answer. When you have decided upon a single answer you may register it by pressing one of the two buttons. Any questions?

<u>Instructions for Restricted Interaction Condition</u>

After the experimenter placed the chest microphone on the subjects, he delivered the following instructions: Try to speak into the cone where the microphone is located and try to avoid speaking in a very loud or very soft voice. Your conversational voice would be fine.

I want to see how well you can do on this problem. There will be a series of geometric patterns appearing on this screen. Your job is to classify these patterns into two categories, <u>A</u> or <u>B</u>. After each pattern appears, I want each of you to respond separately by saying <u>A</u> or <u>B</u> only, and then press button <u>A</u> or button <u>B</u>, so that your decision will be recorded. No further communication is permitted between you. For example, if it was the position of the pattern that made the difference in your saying <u>A</u> or <u>B</u>, then you would say <u>A</u> and depress button <u>A</u> whenever the pattern was on <u>top</u> and say <u>B</u> and press button <u>B</u> whenever the pattern was on the <u>bottom</u>. If you said <u>A</u> and pressed <u>A</u> and the light above button <u>A</u> lit up, that meant that you were right; but if you said <u>A</u> and pressed <u>A</u>, and the light lit up above the <u>B</u> button, you would know that your choice was wrong. (Demonstrate with two cards, one with a circle on the top and one with a circle on the bottom.) In this example your choice of saying and pressing button A or B was determined by the position of the patterns only. You may take as much time as you wish in making your decision to respond by saying A or B and then pressing button A or B. Remember, no communication is allowed between you beyond saying A or B. Any questions?

APPENDIX B

TABLES OF MEAN SCORES FOR ALL DEPENDENT VARIABLES

Table 14

Mean Errors for Main Effects of Complexity
And Interaction Levels

Complexity (Irrelevant Information in Bits)	Mean Errors	Interaction Levels	Mean Errors
1	4.75	FI	2.29
3	12.12	RI	29.75
5	28.66	I	13.50

Table 15

Mean Errors as a Function of Interaction Levels
And Amount of Irrelevant Information

Irrelevant Information in Bits	Free Interaction	Restricted Interaction	Individuals
1	1.25	11.12	1.87
3	1.25	30.50	4.62
5	4.37	47.62	34.00

Table 16

Mean Time to Solution for Main Effects Of Complexity and Interaction Levels

Complexity (Irrelevant Information in Bits)	Mean Time to Solution in Minutes	Interaction Levels	Mean Time to Solution in Minutes
1	5.58	FI	6.42
3	9.75	RI	17.50
5	16.79	I	8.16

Table 17

Mean Time to Solution in Minutes as a Function of Interaction Levels and Amount of Irrelevant Information

Irrelevant Information in Bits	Free Interaction	Restricted Interaction	Individuals
1	4.62	9.00	3.12
3	5.12	18.50	5.50
5	9.50	25.00	15.87

Table 18

Means of Errors, Decisions Initiated, Solution Time And Speech Latency for Fast and Slow Learners In the Restricted Interaction Condition

	Bits of Irrelevant Information					
	1		3		5	
	Fast	Slow	Fast	Slow	Fast	Slow
Mean errors	5.75	8.50	12.00	25.00	15.87	40.12
Time to solution in minutes	6.62	9.00	11.12	18.37	11.50	25.00
Mean no. decisions initiated	23.00	18.00	71.00	22.37	78.87	41.12
Latency of speech utterances in seconds	165.00	201.25	257.87	374.50	434.37	563.87

APPENDIX C

ANALYSIS OF POSITION EFFECTS

Analysis of Seating Position and Verbal Interaction

An exploratory analysis was made to evaluate the relationship between seating position and verbal interaction. The number of times subjects seated on the left and right initiated discussion was totalled. No significant differences in initiation of conversation were found on problems with 1 (t = 1.06, df = 7, $p > .05$), 3 (t = .88, df = 7, $p > .05$), and 5 (t = 1.55, df = 7, $p > .05$) irrelevant bits as a function of seating position.

Similar results were obtained concerning the relationship of seating position to latency of speech for concepts with 1 (t = .20, df = 7, $p > .05$), 3 (t = .11, df = 7, $p > .05$), and 5 (t = .49, df = 7, $p > .05$) irrelevant bits. Latency of speech was defined as the time that had elapsed in seconds after the experimenter's feedback and the first speech utterance of each subject.

Lastly, no significant differences in talk time were found between subjects solving concepts with 1 (t = .40, df = 7, $p > .05$), 3 (t = 1.78, df = 7, $p > .05$), and 5 (t = 2.19, df = 7, $p > .05$) irrelevant bits as a function of seating position. Thus the results indicate that verbal activity was not significantly influenced by seating position. These findings are consistent with those in the RI condition where no differences were found in errors between subjects who seated themselves more to the left or right portion of the screen.

Table 19

Mean Errors on the Right and Left Response Buttons As a Function of Seating Position in the Restricted Interaction Condition

Position	Irrelevant Information in Bits	Right Button	Left Button
Subjects on the left	1	4.62	3.12
	3	8.75	8.75
	5	12.87	11.12
Subjects on the right	1	4.75	1.62
	3	10.62	9.50
	5	15.12	16.37

Note.-Each mean is based on an N of 8.