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A STUDY OF IDEA GENERATION OVER TIME

A THESIS

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Studies and Research

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Approved:

Thomas L. Sadosky, Chairman

Douglas C. Montgomery

Norman R. Baker

Date approved by Chairman: May 29, 1972

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## SUMMARY

The primary purpose of this research was to evaluate the rate at which ideas flow from creative problem solving groups of three different sizes utilizing six separate problem solving strategies. Three experiments were conducted in which 144 junior and senior industrial engineering and industrial management students participated in two of them for periods of 50 and 90 minutes. Twenty-four executives from an internationally known firm worked 50 minutes in the remaining one. A materials handling problem involving the storage and handling of sugar served as the vehicle for ideation by requiring the subjects to generate as many improvements as possible to the current operating procedures. To facilitate the flow of ideas, rules of brainstorming were employed and the number of ideas generated per five minute interval was recorded and evaluated by five judges.

Students formed two, four, and six-member groups while the sample of executives was sufficient for only two and four-member groups. Strategies are detailed in Chapter III, but may briefly be described as various combinations of individual and group effort utilized in differing orders.

Hypotheses formulated were:

1. Larger groups significantly outproduce smaller groups after 50 minutes of effort on the problem.
2. Larger groups significantly outproduce smaller groups when

the session is increased to 90 minutes.

3. No significant difference in problem solving strategy is present in any of the experiments.

4. Ideation rate does not vary with time for approximately the first 15 minutes, then decreases as time increases.

5. Average cleverness of group output per five minute interval remains constant over time for all groups.

Hypothesis 1 was supported using the student subjects, but not with the executive subjects. Hypothesis 2 was rejected while hypotheses 3 through 5 were supported. In conjunction with hypothesis 3, problem solving strategy only affects ideation rates when large groups work short periods. In this situation, it appears that it is better to have the members work alone rather than together. The larger the group and the shorter the session the more striking the superiority of this strategy over those involving collective effort.

The lack of support for the second hypothesis suggests the possibility that, for a particular problem and sample of subjects, a finite limit of possible solutions exists. Larger groups generate the set faster than smaller ones, but the latter will accomplish the same objective given sufficient time. The more rapid decrease in ideation rates of larger groups toward an apparent asymptotic limit over those of smaller ones lends credence to this explanation. This can be seen by inspecting the cumulative distribution functions shown in this experiment.

Average cleverness of group output per five minute interval was found to be constant over time in all experiments for all groups.

## CHAPTER I

### INTRODUCTION

The publication of Alex F. Osborn's (31) Applied Imagination (Scribners, 1953, revised edition 1957) marked the advent of a new era in the development of techniques designed to stimulate the imagination in the production of ideas. Haefele (17) presents detailed descriptions of some of the more popular techniques such as:

1. Gordon's Method. Designed by William J. Gordon of Arthur D. Little, Inc., the procedure requires the use of six-member groups organized such that only the leader knows the actual problem to be addressed during the meeting. He opens the session with an abstract statement designed to prevent early convergence on possible inferior solutions. For example, in wanting a new lawn mower, he might simply say, "The question today is separation." As the discussion proceeds, opportunities are sought to narrow and guide the group discussion, meanwhile developing a number of associated responses which can be directed to the specific problem when it is announced.

2. Collective Notebook Method. A group of individuals receive a notebook in the front of which is printed a problem of major scope. Each recipient records his thoughts and ideas on it from one to several times a day for a period of a month. At designated times they summarize their best ideas and submit them to a coordinator who in turn collates the material and prepares a detailed summary. This then serves as a vehicle

for final creative discussions held by the participants.

3. Phillips 66 Buzz Sessions. A problem is initially discussed by a large number of individuals who are later subdivided into smaller six-member groups designed to work together for short periods of time to generate as many solutions as possible. They then select their best ideas and present them for consideration to the initial body.

4. Brainstorming. Of all these procedures, brainstorming is probably the one most widely accepted, and Osborn's book on the subject is used as a text for most creative thinking courses. Simply stated, brainstorming sessions include five to twelve individuals who develop ideas concerning a problem for periods ranging from a few minutes to an hour while adhering to the following rules:

- a. Criticism is absolutely barred.
  - b. Modification or combinations of ideas with one another are encouraged.
  - c. Quantity of ideas is the primary objective.
  - d. Unusual, remote, or wild ideas are sought.
5. Brainstorming Variants.
- a. Waste-Not Method. The group is shown a plant discard such as a small packing box. Uses are then brainstormed.
  - b. And-Also Method. A suggestion is made which requires each member of the group to follow with an additional comment saying, in effect, "Yes, and also this would make it even more effective."
  - c. Tear-Down Technique. This has been called brainstorming in reverse. The objective is to think of all the possible limitations or failings of the specific product under consideration. The list of weak-

nesses is analyzed with a view to improvements and corrections.

If a technique such as brainstorming is used, so also is its accompanying requirements of five to twelve individuals per session working exclusively as a group for a period of time normally less than 60 minutes.

The three variables of total number of individuals, time limit, and strategy (working together the entire time as opposed to some other scheme such as working together half the time and alone the remainder, etc.) have been arbitrarily set by the originator of the technique without supporting experimental evidence as to the optimality of the value of these variables. If a manager decided, for example, to utilize Phillips 66 Buzz Sessions described above, then strategy is pre-determined. The procedure requires a large number of individuals to initially brainstorm the problem followed by continued effort through smaller six-member groups which provide input for a final brainstorming session to be conducted by the original body. Since smaller groups are set at six members each, manpower requirements have been partially defined.

Management can, and probably does, modify available techniques to suit particular needs, but how effective the technique is in the first place or how modifications attenuate or amplify it have been experimentally investigated for only the past 10 to 15 years. Studies considered classic in this area and referenced most often are described in Chapter II. They attempt to examine variables such as the effect of group size on the ideation rate, as well as the effects of varying the strategies employed by problem solving groups. Experimenters have analyzed the relationship between total output of ideas as a function of increasing group sizes, but results are limited in most of these works as allotted time per group and

problem solving strategy are normally fixed. Other experimenters fix the allotted time for the problem and group size at specific values and examine the effectiveness of different problem solving strategies on the total output of ideas. Typically, real interacting groups are compared with "statistical" or "nominal" groups representing individuals who brainstormed alone and had their non-overlapping ideas combined. This output is normally randomly distributed into groups of the size required for comparison purposes and represents the expected level of productivity if brainstorming neither facilitates nor inhibits creative thinking. Limitations in these findings are evident in that information is provided on a particular point in time for one group size employing two divergent strategies. Of the experiments designed to examine other problem solving strategies, further limitations in findings have resulted from a shifting of problems concomittant with a shift in strategies as well as from the utilization of experimental time limits of extremely short duration. Few experimenters have examined the ideation rate over time and those that have conducted experiments with individuals rather than groups. Therefore, a need exists for an experiment which analyzes the effects on group and individual ideation rates as a function of time when various sized groups employ several different problem solving strategies. These ideation rates can be obtained by providing a procedure in the experimental design which makes possible the determination of the time in which a particular idea was generated. This, in effect, permits analysis of group or individual output of ideas at several points in time within the limits of the experiment.

### Purpose of Experiment

The purpose of this experiment was to extend the findings of current research by evaluating the performance of three different group sizes employing six separate problem solving strategies as well as examine what effect these combinations have on the rate at which ideas are generated. Group sizes consisted of two, four, and six, and strategies are described in Chapter III. Cleverness of ideas as a function of time was also examined for various sized groups in order to determine the existence of possible trends in this attribute. Finally, in order to more easily justify the statement of general conclusions which might result from the findings, an industrial sample of executives as well as students participated in the experiment.

### Hypotheses

Based on extensive examination of the literature as well as an expectation of the findings that might result from the experiment, the following hypotheses were posed:

1. Quantitative and qualitative output of larger groups is significantly greater than that of the smaller ones when time allowed on the problem is limited to 50 minutes.
2. Quantitative and qualitative output of larger groups increases faster than that of smaller ones when time limit is extended to 90 minutes.
3. No significant difference exists between problem solving strategies at 50 or 90 minutes.
4. Ideation rate does not vary with time for approximately the

first 15 minutes, then begins decreasing as time is extended.

5. Average cleverness of group output per five minute interval remains constant over time for all group sizes and problem solving strategies.

## CHAPTER II

### REVIEW OF THE LITERATURE

There is an abundance of literature regarding the analysis of group versus individual effectiveness in creative problem solving. Many studies advocate the superiority of group problem solving over independent individual effort and support it with sophisticated experimental designs and complex statistical analysis. Others expound the superiority of combined independent individual effort and provide similar experimental support. This apparent anomaly can be partially resolved by the observation that group versus individual effectiveness in creative problem solving in large measure is a function of the problem presented for resolution. In experiments utilizing a task or problem requiring a single, or best solution, groups were reported to be superior to individuals in terms of quality of output. Studies supporting this comment are: South (40), Watson (45), Watson (46), Shaw (38), Thorndike (43), Husband (24), Carter, Haythorne, Lanzetta, and Mairowitz (5), Taylor and Faust (42), Kelly and Thibaut (25), Lorge and Solomon (26), Marquart (27), Tuckman and Lorge (44), Campbell (4), and Holloman and Hendrick (23). No study was found which contradicts these findings.

If the task presented is open ended, i.e., there is a large number of solutions, and the primary objective is to generate as many as possible, then experiments generally report that the combined efforts of individuals working independently are superior to those of real interacting groups,

even after duplicate solutions are eliminated. Experiments germane to this research, and described below, are those containing the latter type of problem.

Gibb (15) experimented with three groups each of size 1, 2, 3, 6, 24, 48, and 96 in order to determine the effects of size of group and induced reduction of threat upon productivity and creativity under two experimental conditions.

Under Condition A the groups contained an equal number of each sex seated alternately, were arranged in a standard seating pattern, were given comparable instructions with an attempt to avoid special induced motivations or inhibitions to the activity in question. Under Condition B the conditions were the same with the exception that the experimenter read a different set of instructions, which had been found in previous experiments to reduce the threat in the situation.

Scoring was a function of the absolute number of ideas generated, and these were then weighted by independently judged "goodness" of solution. Gibb found that "number of ideas produced increased in a negatively accelerating function of size of group in each of the two conditions." The number and quality of solutions under the second condition was significantly greater than under the first.

Taylor, Berry, and Block (41) examined the effectiveness of group problem solving using brainstorming techniques. Twelve real groups and 24 individuals, later randomly assigned to 12 nominal four-man groups, were tested on three separate tasks. Fifteen minutes per task was allowed and scoring was a function of both mean total number of responses and mean total number of unique responses. Additionally, judges rated feasibility, effectiveness, generality, probability, and significance of solutions on a scale of one to five. They reported that nominal groups were superior

on all measures used and that group brainstorming inhibits rather than stimulates creative thinking. They further speculated that increased training in brainstorming procedures, or enlarging the size of problem solving groups, would not significantly alter their findings. Similar results were shown by Sadosky and Long (37) for group sizes greater than two members producing solutions to an industrial engineering problem.

Weiskopf and Eliseo (47) analyzed the effectiveness of Osborn's rule, no critical comments during ideation, in reducing the inhibiting effect on members of problem solving groups reported by Taylor, Berry, and Block (41). Quantitative and qualitative output of six seven-member mixed groups of student men and women were required to function under this rule as well as a highly critical censorship condition which served as control. Tasks were to invent brand names appealing to students for cigars, deodorants, and automobiles. Each idea was rated 50 times by non-participating students on a five point scale of one to five. Results show that the mean quality score under the critical censorship condition was greater than the mean quality score under the no criticism allowed condition for all three products. The cumulative number of responses under the latter was found to be significantly greater than cumulative number of responses produced under the former.

Dunnette, Campbell, and Jaastad (9) essentially replicated Taylor's (41) experiment using two industrial samples rather than student ad hoc groups. Twelve four-member groups worked on four separate tasks in differing orders. Three groups brainstormed two tasks by working alone for the first half of the experiment, and then collectively during the second half. Three other groups followed the same pattern but worked on all

four tasks. The reverse order of collective then individual effort was also tested utilizing the remaining six groups on all four tasks. Fifteen minutes per task was allowed and the mean total number of solutions calculated. They reported that individual brainstorming produced significantly more solutions than did group brainstorming and was most effective when preceded by a collective session.

Rotter and Portugal (36) conducted similar experiments with four-member groups employing two separate tasks with the additional factor of homogeneity of groups with respect to sex. Problem solving orders similar to those of Dunnette, Campbell, and Jaastad (9) were used with the addition of a pattern involving collective group effort during the entire experiment. Nominal groups were formed by randomly combining the efforts of individuals working alone. Subjects were allowed 15 minutes per task, and the mean number of ideas per problem solving pattern was used as the measure of performance. Their results indicate that individual brainstorming is superior to patterns involving group effort and that males out-performed females for this experiment.

Collaros and Anderson (8) further examined the inhibiting effects of group brainstorming through an analysis of Kelly and Thibaut's (25) "self-weighting" effect. This effect essentially portrays members as participating only according to their "felt competency within the group." Subjects consisted of 120 males and 120 female undergraduate students working in groups of size four. Homogeneity of sex in groups was retained and members were subjected to three perceived conditions. The first, and also the control, was a "no-experts" condition in which subjects read instructions stating that no member of their group was an expert in problem

solving techniques. The "one expert" condition contained instructions designed to lead subjects into believing that one of their members was an expert, while the "all experts" condition was contrived to convince each participant that he was the only member not proficient in group problem solving techniques. Additionally, an "inhibition score" was determined for each subject by requiring them to record all ideas that came to mind during the group session but, for some reason, were not mentioned. These ideas were totaled and added to the original quantity of ideas produced by the group. This value, when divided into the number of ideas each individual generates after the session, results in the ratio with the acronym stated above. Subjects later rated ideas for originality, practicality, and creativity as well as replied to questions designed to determine such things as the sense of disapproval felt from other members when offering ideas that are "far out," even when no criticism was expressed.

Collaros and Anderson reported that replies on questionnaires, in conjunction with the above ratios, allowed them to announce that the "all experts" condition produced an inhibition in members which was always significantly higher than in the "no expert" condition. Members subjected to the "one expert" situation experienced a moderate amount of inhibition which fell between the two extremes but was not significantly higher than the control condition. They also reported that quality and quantity of ideas were significantly higher under the "no expert" condition than under the "one" or "all expert" conditions.

Bouchard and Hare (2) expanded the range of group sizes used in comparison of real and nominal groups over those used in previous studies.

Osborn recommends group sizes of five to twelve individuals in the conduct of a brainstorming session where, in fact, most investigators utilized groups of size four. Two groups each of five, seven, and nine, in addition to 84 subjects working alone, brainstormed a single task for 25 minutes, and the only measure of performance was the quantity of ideas generated. Bouchard found that the performance curves of real groups did not outperform those of the nominal groups, as he had originally predicted, and, in fact, discovered that they actually diverged, rather than converged, as group sizes were increased.

A scarcity of papers appears in the literature which focuses on the ideation process as a function of time, and those that do primarily concern themselves with individual rather than group ideation analysis. Three papers relevant to this research are discussed below.

Bousfield and Sedgewick (3) hypothesized that, for tasks involving simple recall rather than creative thought, the rate of occurrence of ideas, where a limit exists to the number of possible responses, varies directly with the number of those already recited and the available number yet to be recalled. The process may be mathematically expressed as

$$n = c(1 - e^{-mt})$$

where  $n$  = total responses

$c$  = limit of available responses

$m$  = a constant

$t$  = time devoted to producing ideas.

This exponential relationship was found to adequately describe the above process when subjects were required to recall or name all the United

States cities, quadrupeds, fellow students, birds, etc., as rapidly as possible within a given limit of 18 minutes per task.

Christensen, Guilford, and Wilson (6) extended Bousfield and Sedgewick's work to the analysis of the rate of production of ideas involving inventiveness rather than simple recall. They predicted that the rate of production would be relatively constant and that the more original responses would occur later in the session. Four tasks were utilized in which subjects were allowed 12 minutes per task for three of the four and 16 minutes for the last. Uncommonness, remoteness, and cleverness were the quality measures used where uncommonness was determined empirically through frequency of occurrence data transformed to a one to five scale. Remoteness was assigned weights of one, two, or three, depending on the degree of uncommonness and cleverness was rated by two judges on a scale of one to five. Principal findings were that the rate of ideation did not seem to vary with time within the limits of the experiment and that the more uncommon responses occurred later in the session. Also noted was that remote or indirect responses occurred later, while cleverness did not seem to vary with time.

Parnes (34) conducted two experiments designed to test the hypothesis that extended effort in ideation will lead to an increasing proportion of "good" ideas and increased output. The task was to find as many unique uses as possible for an ordinary coat hanger within the limits of five and fifteen minutes for experiments 1 and 2, respectively. The effects of subjects trained in the techniques of brainstorming versus those that were not trained was also evaluated. Quantity and quality of ideas

were measured with the latter subjectively rated on a three point scale utilizing attributes of uniqueness and value. A "good quality" idea was one achieving a value plus uniqueness score greater than or equal to five. In experiment number 1, the list of ideas was divided in half and analysis revealed that more "good" ideas occurred in the second rather than the first half of the list, as well as that a significant relationship existed between quantity and quality of ideas. The list generated from the second experiment was divided into thirds. The mean number of "good" ideas was significantly greater in the last third of the list than the first two thirds and significantly more ideas were generated during the first five minutes by trained subjects than untrained subjects. Finally, there was no significant difference in the mean number of "good" ideas generated between the first two thirds of the list.

Many other variables enter into an ideation analysis which were not addressed in this study but have been analyzed extensively by other experimenters. Some closely related variables and subsequent relevant studies are briefly mentioned below.

Homogeneous versus non-homogeneous composition of problem solving groups plays a significant role in the output of these groups as shown by investigators such as Hoffman (19,20), Cohen, Whitmyre, and Funk (7), and Fiedler and Neuwese (13).

Effects of leadership in problem solving groups have been extensively analyzed by Fiedler (10,14), Fiedler and Fiedler (11), and Anderson and Fiedler (1).

The influence of training in the techniques of group problem solv-

ing also has been shown to have a significant effect on the effectiveness of groups as indicated in studies conducted by Meadow and Parnes (28,29, 35) and Hall and Watson (16).

In summary, experimenters have found that setting the time per task and strategy of problem solving groups constant, while increasing their size, results in an "increase in the number of ideas produced as a negatively accelerating function of group size." Comparison of interacting four-member groups with nominal ones for periods of time usually less than 60 minutes has shown that nominal groups are superior in terms of number and quality of solutions produced. When criticism is allowed during a brainstorming session, the number of responses decreases in relation to the number generated under a no criticism allowed condition; however, the mean quality score of the solutions produced under the former condition is higher than the mean quality score of those produced under the latter. Experiments designed to analyze strategies other than group effort only, or individual effort only, have shown that combinations of group and individual effort are superior to that of group effort in terms of number and quality of ideas produced, but inferior to outputs of nominal groups. The results are based on four-member groups working under experimental limits of 16 minutes or less. In a recent analysis using group sizes greater than four, nominal groups continued outperforming real groups when allotted time per task was 25 minutes. Finally, idea generation over time has received little attention and has been examined only for periods up to 18 minutes with resultant curves found to be exponential in shape for tasks involving simple recall and linear when creative responses are required.

Since no studies were found which examined the ideation process for groups, one purpose of this work was to fill that void. The popular four-member group size as well as the strategies employed by Dunnette, et al. were included to provide a basis of comparison to the extent possible given the conditions of this experiment. Of primary importance, however, is the fact that the dependent variable in the ideation process, whether it is in terms of number or quality of ideas, is a function of more than one variable and as such should be examined in response to as many of these dimensions as possible. The experiment, as described in Chapter III, was designed with this objective in mind.

## CHAPTER III

### METHODS AND PROCEDURES

The purpose of this study was to determine the relationship between quantity and quality of ideas generated as a function of time for groups of three different sizes utilizing six separate problem solving patterns. Group sizes consisted of two, four, and six members and the six patterns are described below. Catalyst for this ideation analysis was a materials handling problem which required the subjects to suggest as many improvements as possible to the current operational procedures. Rules of brainstorming were employed to facilitate the flow of ideas and three separate experiments were conducted.

#### Hypotheses

In Chapter I, five hypotheses were formulated to predict the anticipated findings of this study. They are mentioned again for the primary purpose of refocusing attention on the research objectives of the experiment.

1. A significant group effect would result in an analysis of variance conducted on quantity and quality of output when 50 minutes is allowed on the problem.

2. A significant group effect would remain in an analysis of variance conducted on quality and quantity of output when time allotted is extended to 90 minutes.

3. No significant difference exists between problem solving strategies at 50 or 90 minutes.

4. Ideation rate does not vary with time for approximately the first 15 minutes, then begins decreasing as time is extended.

5. Average cleverness of group output per five minute interval remains constant over time for all group sizes and problem solving strategies.

#### Subjects

The subjects were 144 junior and senior industrial engineering and industrial management students attending the Georgia Institute of Technology of Atlanta, Georgia, and an industrial sample of 24 executives from an internationally known firm. Of the 144 students, 98 worked on the problem for a period of 50 minutes while the remaining 48 were given 90 minutes. The 24 executives worked for 50 minutes.

#### Problem

The problem was adapted from one in a book written by Gerald Nadler (30) and presented to the subjects as follows:

In a company bottling soft drinks, sugar is unloaded from trucks and stored in the basement. At the present time, three men are utilized in the operation and their work is done in the area depicted in Figure 1. The first two men are on the first floor and the third is in the basement. The procedure used is as follows: The first man is on the truck and moves an average of 15 feet to a bag of sugar, picks it up, and moves to the edge of the truck where he tosses it to the second man who in turn moves about four feet to a hand truck to place the bag down.

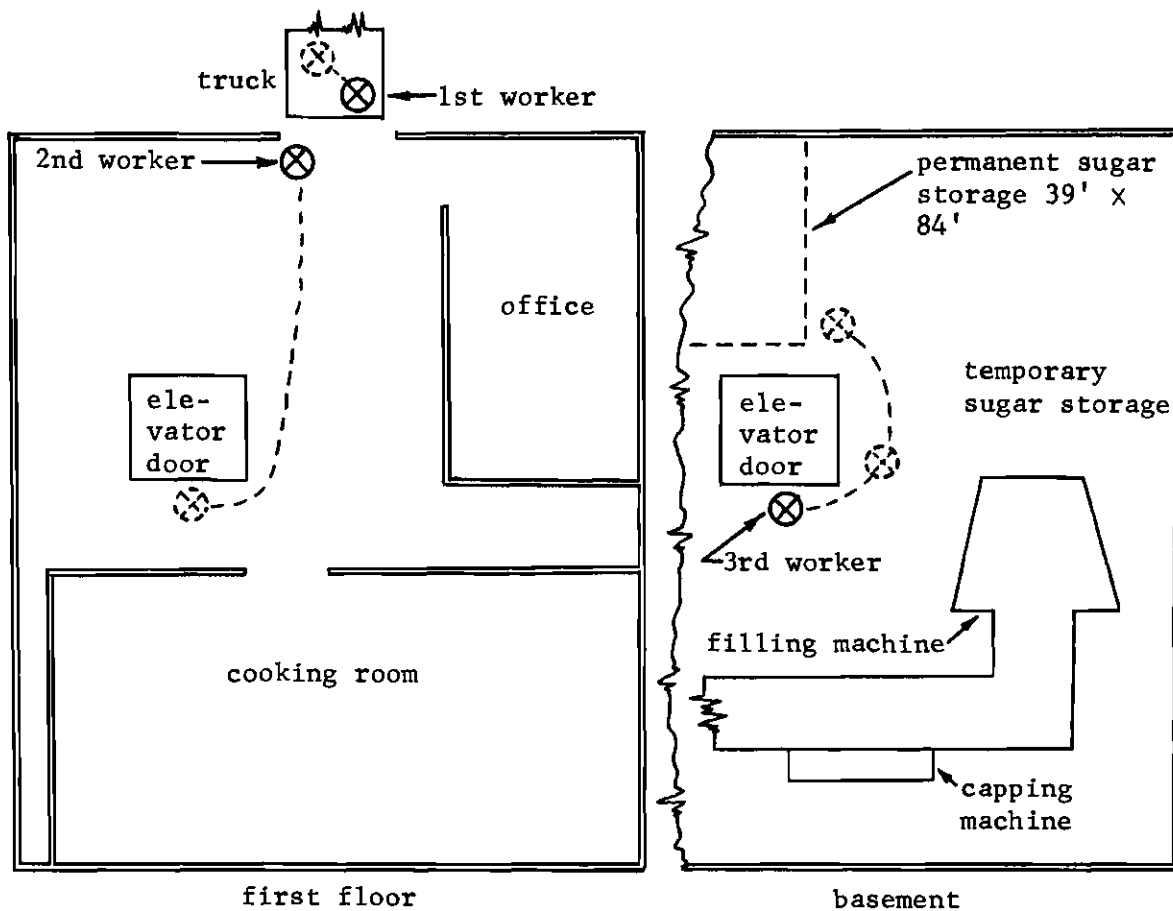


Figure 1. Diagram of Current Methods and Procedures for Sugar Handling and Storage Problem

When six bags are placed on the truck, the second man moves 21 feet to an elevator and unloads the six bags. The above cycle is repeated until 18 bags are placed on the elevator. After the 18<sup>th</sup> bag, the second man sends the elevator to the basement where the third man unloads the sugar and places it just to the right side of the elevator. If there is an excess amount of sugar, the third man moves the bags to a storage area behind the elevator at a later time. The objective at this time is to propose

as many methods as possible to the problem of sugar delivery and storage. Since the company operates several facilities of this type and is planning to construct many more, it is desired that you consider not only modifications of current methods, but also any alternatives for sugar delivery and storage. Remember, quantity is wanted. Write down everything regardless of how slight the modification of the present procedures or how radically different a new alternative is.

#### Experimental Design

Experiment 1 was a  $4 \times 3$  factorial design consisting of the two main factors of group size and problem solving pattern. Both factors were at fixed levels, and the 98 students participating were sufficient to obtain two data points per cell. The subjects were allowed 50 minutes to work on the problem. The design appears in Table 1.

Experiment 2 was a  $4 \times 2$  factorial again consisting of the two main factors of group size and problem solving pattern. Both factors were at fixed levels. The 24 executives participating were sufficient in number to permit the acquisition of one data point per cell. The subjects were all to work 50 minutes on the problem. The design appears in Table 2.

Experiment 3 was a  $4 \times 3$  factorial design consisting of the two main factors of group size and problem solving pattern. Both factors were at fixed levels. The 48 participating student subjects were given 90 minutes to work on the problem. One data point per cell was obtained, and the design is shown in Table 3.

Table 1. Experimental Design 1

Problem Solving Pattern	Group Sizes		
	2	4	6
A			
B			
C			
D			
<p>A - Work alone for 50 minutes - Individual conditions (I)            B - Work as a member of a problem solving group for 50 minutes - Group conditions (G)            C - Work as a member of a group for 30 minutes, then alone for the remaining 20 minutes - Group-Individual conditions (G-I)            D - Work alone for 30 minutes, then as a member of a problem solving group for the remaining 20 minutes - Individual-Group conditions (I-G)</p>			

Table 2. Experimental Design 2

Problem Solving Pattern	Group Sizes	
	2	4
A		
B		
C		
D		
<p>A - Work alone for 50 minutes - Individual conditions (I)            B - Work as a member of a problem solving group for 50 minutes - Group conditions (G)            C - Work as a member of a group for 30 minutes, then alone for the remaining 20 minutes - Group-Individual conditions (G-I)            D - Work alone for 30 minutes, then as a member of a problem solving group for the remaining 20 minutes - Individual-Group conditions (I-G)</p>		

Table 3. Experimental Design 3

Problem Solving Pattern	Group Sizes		
	2	4	6
A			
B			
C			
D			
<p>A - Work alone for 90 minutes - Individual conditions (I)</p> <p>B - Work as a member of a problem solving group for 90 minutes - Group conditions (G)</p> <p>C - Work for 30 minutes as a member of a problem solving group followed by 40 minutes of individual effort, concluding with 20 minutes of group effort - Group-Individual-Group conditions (G-I-G)</p> <p>D - Work alone for 30 minutes followed by 40 minutes of group effort, concluding with 30 minutes of individual effort - Individual-Group-Individual conditions (I-G-I)</p>			

#### Nominal Groups

Forty-two subjects participating in the experiment worked alone on the problem. A table of random numbers was employed to divide 24 of these subjects into two groups each of size two, four, and six for experiment 1. The same procedure was used to distribute the six executives into one group each of size two and four for experiment 2. The 12 remaining subjects worked on the problem alone for 90 minutes and were distributed in a similar fashion into one group each of size two, four, and six for experiment 3. These random, or nominal, groupings form the entries in the design matrix labeled "A" pattern. If any member of a nominal group recorded an idea, the group was regarded as having presented it. If two or more members of the group recorded the same idea, it was still regarded as one idea. Since the B, C, and D patterns involve real interacting groups, the A pattern serves ideally as control with its non-interacting groups.

### Real Groups

One hundred and twenty-six subjects were randomly assigned to real groups of size two, four, and six for experiments 1 and 3 and size two and four for experiment 2.

### Instructions to Subjects

Subjects retired to separate rooms with members of their assigned groups and were read instructions by monitors before proceeding with the experiment. These were similar to those utilized by Rotter (36), and are given below. On a few occasions a large number of groups had to be processed at the same time which required the assignment of more than one to the same room. In these instances, very large rooms were used and monitors situated the groups in opposite corners. They reported no occurrences of cross-talk and felt the probability of one group biasing the output of another to be very small. Later, analysis of the data seemed to support this contention.

### Individual Conditions

This is an experimental study in creative thinking using brainstorming as a technique. You have probably never worked on a problem in this way, so I will go over the procedure with you. The technique is a form of group interaction which is used to facilitate the flow of ideas. It is widely used in a large number of U.S. corporations generally when new, unique, original, and creative ideas are desired. It is not used to solve everyday problems. It is relatively straightforward and easy to comprehend. The following rules are for groups. You will be working alone. However, I would like you to apply these rules as best you can

while working on the problem.

1. Criticism is ruled out. Adverse judgment of ideas must be withheld. There is a time for judicial thinking later. The fact that no one should criticize anyone else's ideas is clear for a group, but for an individual it means don't criticize any ideas that come to mind.

2. Freewheeling is welcomed. The wilder the idea, the better. It is easier to tame down ideas than to think them up. Don't be afraid to write anything that comes to mind, the farther out the ideas the better. This will stimulate more and better ideas.

3. Quantity is wanted. The greater the quantity of ideas, the more likelihood of winners. Come up with as many as you can.

4. Combinations and improvements are sought. You should be willing to change suggestions you have written down. Don't be afraid to combine and improve on them. Let me repeat these rules. Now, the problem I would like you to consider has been distributed.

You will have approximately 50 minutes to work on it. Please record all ideas as they come to mind. At intervals of five minutes, I will ask you to draw a horizontal line below the last idea you have written, and then you are asked to continue with more ideas. In the event you have thought of nothing new since the previous signal, draw another line just the same.

Your efforts will be graded, and the results provided you and your instructor after the experiment is completed. Primary consideration in computation of scores will be the quantity of ideas generated, although quality will also be a factor.

You are asked not to discuss this experiment with anyone until you are furnished the results. All materials will be turned in to me at the end of the experiment.

Are there any questions before we begin?

#### Group Conditions

Instructions were similar to those read under individual conditions with the exception that rule 1 was written as follows:

Criticism is ruled out. Adverse judgment of ideas must be withheld. There is a time for judicial thinking later. Anyone who criticizes will cause a penalty to be incurred resulting in a reduction of the team score. Before you has been placed a list of "killer" phrases, so named because they are extremely effective in discouraging ideas. These are examples of the types of statements that will be counted against the team score if they are spoken.

Groups were also instructed to have one of their members record all ideas as they were originated.

#### Group Then Individual Conditions

Instructions were similar to those read to groups with the exception that subjects were told they would have 30 minutes to work on the problem as a member of a problem solving group followed by 20 minutes of individual effort.

#### Individual Then Group Conditions

Instructions were again similar to those read to groups with the exception that subjects were told they would have 30 minutes to work on

the problem individually followed by 20 minutes of collective effort as a member of a problem solving group.

These instructions were identical for experiment 1 and experiment 2 with the exception that the paragraph concerning grading of results was eliminated for the executives in experiment 2. The instructions for experiment 3 were also similar for the group and individual conditions except that the subjects were told they were allowed 90 rather than 50 minutes to work on the problem. Patterns C and D in this experiment were different, however, so the corresponding instructions were as follows:

#### Group Then Individual Then Group Conditions

Introductory comments and rules of brainstorming were the same as above; however, subjects were told that they would be working together for the first 30 minutes, then individually for the next 40 minutes, and again as a group for the remaining 20 minutes.

#### Individual Then Group Then Individual Conditions

These instructions differed only in that subjects were told that they would be working alone for the first 30 minutes, then as a member of a problem solving group for the next 40 minutes and finally complete the session with another 20 minutes of individual effort. A detailed set of these instructions appears in Appendix I.

#### Instructions to Monitors

Each group participating in the experiment was observed by monitors who in all cases were either members of the faculty of the Georgia Institute of Technology or graduate students. In order to insure that they

did not interact with problem solving groups, the following instructions were furnished:

1. Commence keeping a record of the time when the session begins.
2. Announce five-minute intervals.
3. Do not answer questions or participate in group discussions after the session is under way.
4. Listen for "killer" phrases and make note of them when they occur.
5. Insure that all materials are collected at the end of the period and that participants are asked not to discuss the experiment until final results are furnished.

#### "Killer" Phrases

Each subject was provided a list of phrases that are typical of the type considered effective in discouraging ideas. The list appears in Appendix II and is not to be considered exhaustive but is simply to serve as a sample.

## CHAPTER IV

## RESULTS

The dependent variable in this experiment is the number of different ideas generated by real and nominal groups. Refinement of an initial listing of 205 ideas generated from the data yielded a final list of 75 as shown in Appendix III. Illogical, absurd, or irrelevant responses, in addition to those recorded in terms too general to determine actual intent, were grouped under idea number 75.

Quality of ideas was evaluated by five judges rating the feasibility, effectiveness, and future effectiveness of each on a scale of one to five where:

- 5 = very highly feasible/effective
- 4 = highly feasible/effective
- 3 = some feasibility/effectiveness
- 2 = little feasibility/effectiveness
- 1 = very little feasibility/effectiveness

Three of the five judges were members of the faculty in the department of Industrial and Systems Engineering at the Georgia Institute of Technology while the remaining two were graduate students in attendance at the same institution. Descriptions of the above attributes are given in Appendix IV, and the ratings are given in Appendix V. The cleverness of each idea was also evaluated with the intention of measuring the creativity of individuals and groups rather than including it as a component of qual-

ity. Analysis of this attribute is therefore conducted independently of the others.

Inspection of the ratings indicated that judges evaluated effectiveness and future effectiveness essentially the same. Support for this observation was provided from a Friedman (39) two-way analysis of variance for ranked data conducted on each judge for the two attributes. The hypothesis tested was that no significant difference existed in the ratings of effectiveness and future effectiveness for the five judges. Ratings of three support the hypothesis at the ( $p = .05$ ) level of significance, while those of a fourth support it at the ( $p = .02$ ) level. Ratings of the last judge reject the hypothesis as shown in Appendix VI. In view of the findings, future effectiveness was deleted as a separate measure and considered a part of the effectiveness score.

Ratings over the remaining three attributes produced 225 (number of ideas times number of attributes per idea) row vectors containing five numbers. Analysis of the differences between the highest and lowest numbers in these vectors yielded the following:

	<u>Number of Vectors</u>	<u>% of Total Vectors</u>	<u>Cumulative %</u>
Difference = 0	22	9.80	9.80
Difference = 1	44	19.60	29.40
Difference = 2	132	58.60	88.00
Difference > 2	<u>27</u>	12.00	100.00
Total	225		

Twenty-two ideas comprised the 27 row vectors containing numbers with differences greater than two. These were returned to the judges for

reevaluation with the initial ratings arranged in ascending numerical order. No information was provided as to which number represented a particular judge's initial rating. Those components of ideas with two row vectors in Appendix V indicate the ones that were reevaluated. Initial ratings appear as the lower vector while the upper vector depicts the reevaluation. None of the reevaluated components contained numbers which differed by more than two; therefore, the feasibility, effectiveness, and cleverness of each idea was obtained by computing the mean of the vectors with the resultant value representing a consensus opinion of five judges as to the numerical values to be assigned these attributes. Compilation of these data allows for the conduct of quantitative and qualitative analyses of variance for experiments 1 through 3 as shown in the following tables and figures.

Table 4. Factorial Analysis of Variance of Number of Ideas in Experiment 1

Source	df	MS	F
Group Size (G)	2	118.54	6.13*
Problem Solving Pattern (P)	3	18.11	< 1
G × P	6	110.33	5.73**
Error	12	19.33	

\*  
p < .05  
\*\*  
p < .01

Table 4 shows that there was no significant difference between the problem solving patterns used in this experiment, while a significant

group and interaction effect did result. The  $F$  ratio less than unity for the main effect of problem solving pattern in Table 4 required further evaluation using Ostle's (32)  $F'$  test. No significant  $F'$  statistic was encountered for any of the quantitative or qualitative analyses of variance conducted.

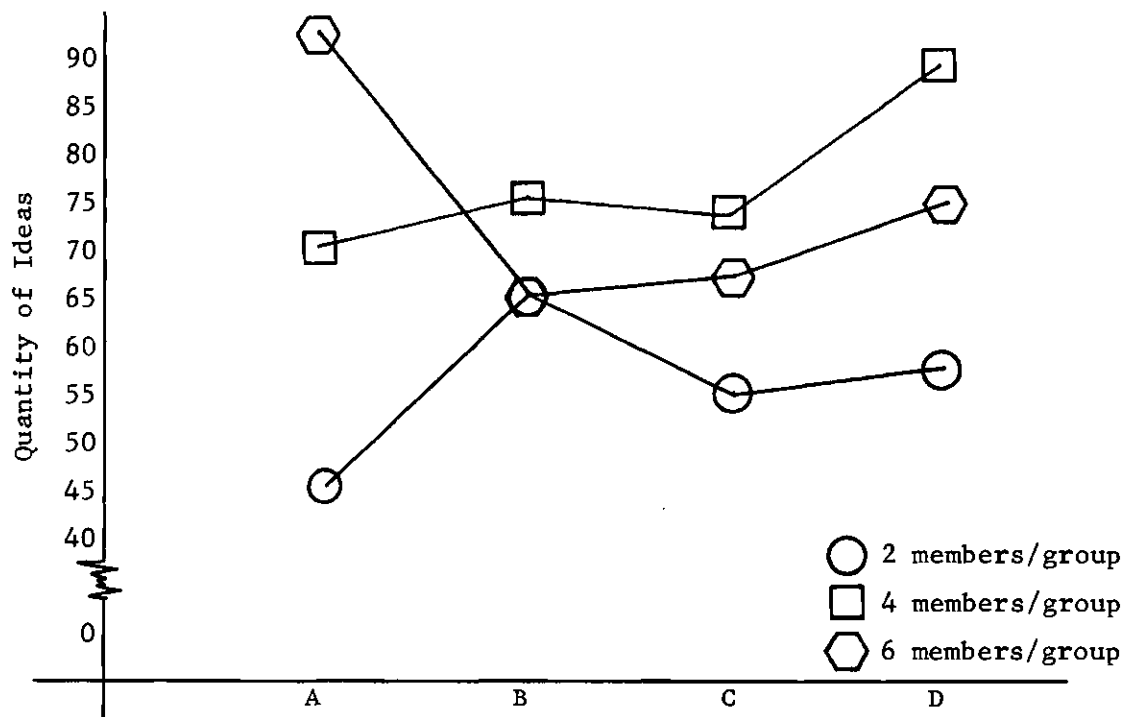


Figure 2. Total Number of Ideas Generated for Three Separate Group Sizes Under Four Problem Solving Patterns

Because of the occurrence of a significant interaction, it was necessary to perform a further analysis of the data depicted in Figure 2 using a Duncan Multiple Range test (18) on the means of the cell totals. Results indicated that, at the ( $p = .05$ ) level of significance, six-member groups utilizing problem solving pattern A were significantly superior to six-member groups operating under the B and C patterns. No significant

difference was detected between patterns for groups of size two and four. A possible explanation for the apparent inefficiency of six-member groups using B and C patterns might be the constraint of one recorder for the entire 50 minute session under the B pattern, and 30 minutes under the C pattern. The A and D patterns involved independent individual effort for 50 and 30 minutes, respectively, thereby employing the services of six recorders, rather than one, during those periods.

Tables 5 through 8 and Figures 3 through 6 display the results of the qualitative analysis of the data obtained in experiment 1. Feasibility and effectiveness were analyzed alone, followed by combinations of the two through an additive and multiplicative scheme. The additive scheme involved adding the feasibility and effectiveness scores for each idea and summing over the set generated by each group. Feasibility and effectiveness scores were multiplied together for each idea and again summed over all ideas generated by the group to form the total score under the multiplicative scheme. The objective of providing analysis as detailed as this was to determine if any of the qualitative measures would affect the results found in the quantitative analysis. If no significant changes were observed, it is academic as to which more accurately portrays the quality of an idea. Results clearly show that the main effect of problem solving pattern remained non-significant for all four analyses and that group effects continue to be significant. Group significance actually increased from the ( $p = .05$ ) level to the ( $p = .01$ ) level, while the significant interaction discovered in the quantitative analysis was present in the qualitative one involving effectiveness as a measure at the ( $p = .01$ ) level. Interaction was reduced to the ( $p = .05$ ) level for

Table 5. Factorial Analysis of Variance of Feasibility of Ideas in Experiment 1

Source	df	MS	F
Group Size (G)	2	2878.1	10.12*
Problem Solving Pattern (P)	3	360.8	1.27
G x P	6	772.5	2.72
Error	12	284.4	

\*p < .01

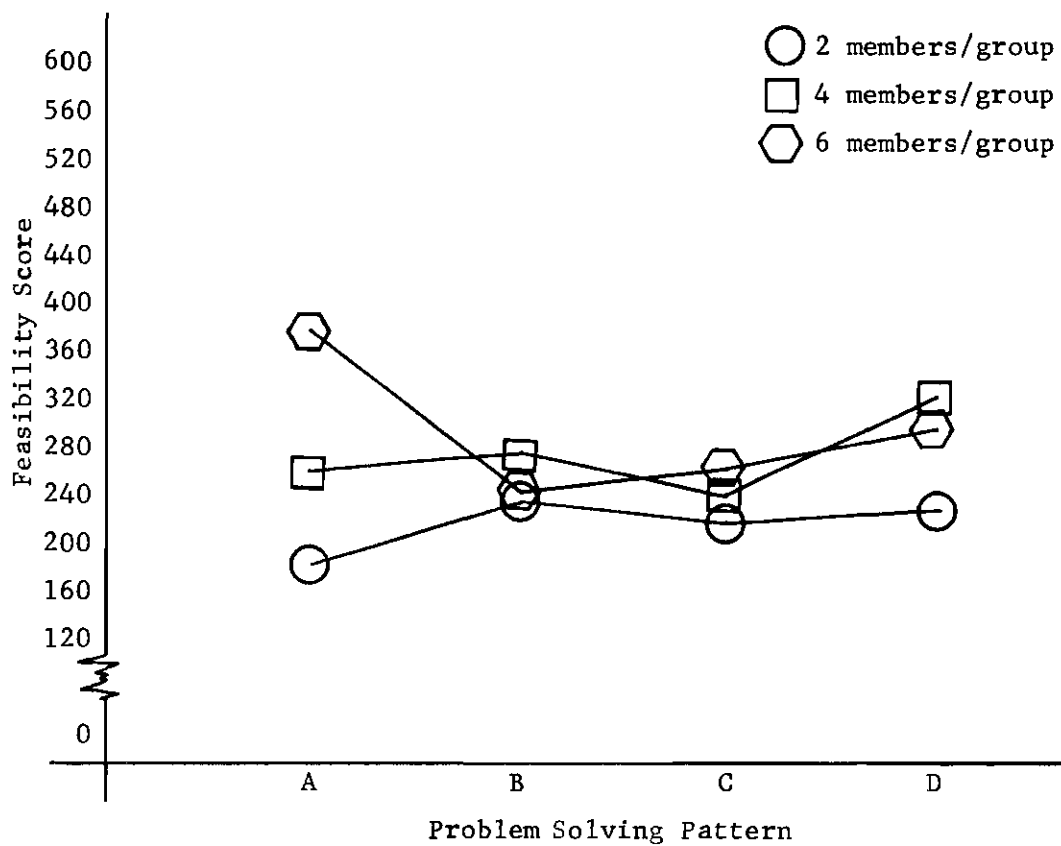


Figure 3. Total Feasibility of the Ideas Generated by Three Separate Group Sizes Under Four Problem Solving Patterns

Table 6. Factorial Analysis of Variance of Effectiveness of Ideas in Experiment 1

Source	df	MS	F
Group Size (G)	2	1493.14	19.21*
Problem Solving Pattern (P)	3	146.69	1.89
G X P	6	382.19	4.92*
Error		77.72	

\* p < .01

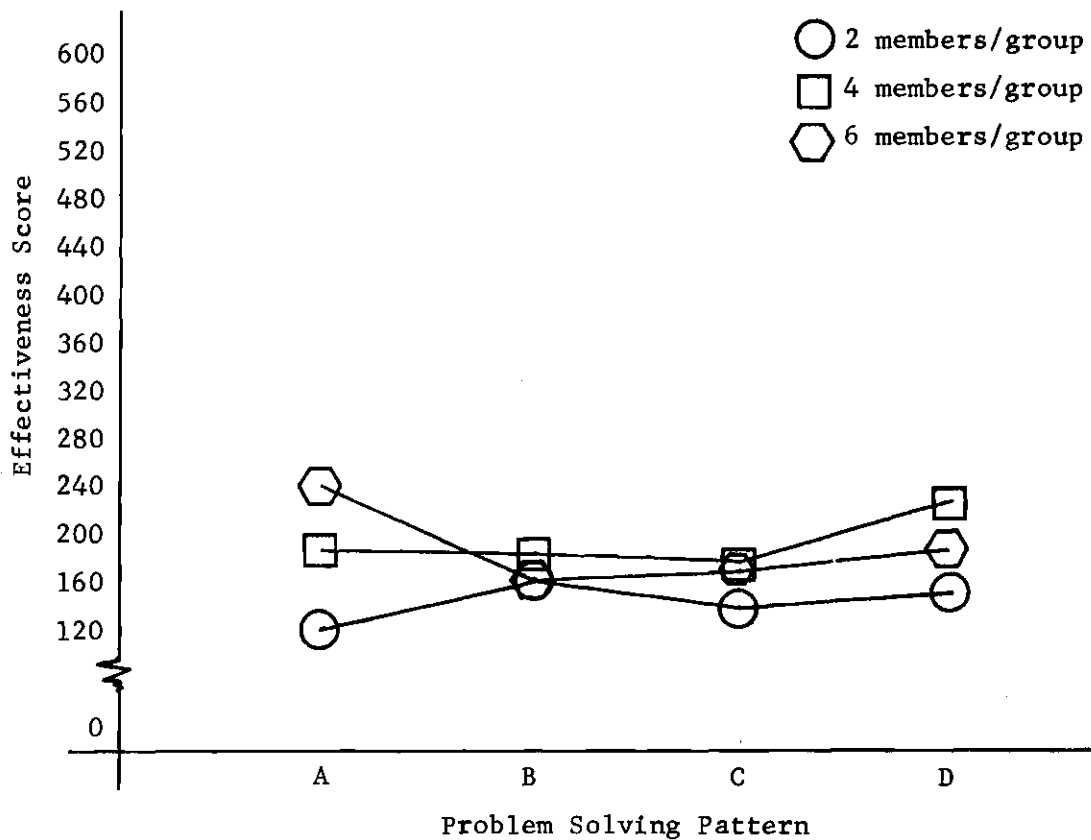


Figure 4. Total Effectiveness of Ideas Generated by Three Separate Group Sizes Under Four Problem Solving Patterns

Table 7. Factorial Analysis of Variance  
of Additive Scheme in Experiment 1

Source	df	MS	F
Group Size (G)	2	8413.92	13.32*
Problem Solving Pattern (P)	3	923.06	1.46
G x P	6	2216.23	3.51**
Error	12	631.73	

\*  
p < .01  
\*\*  
p < .05

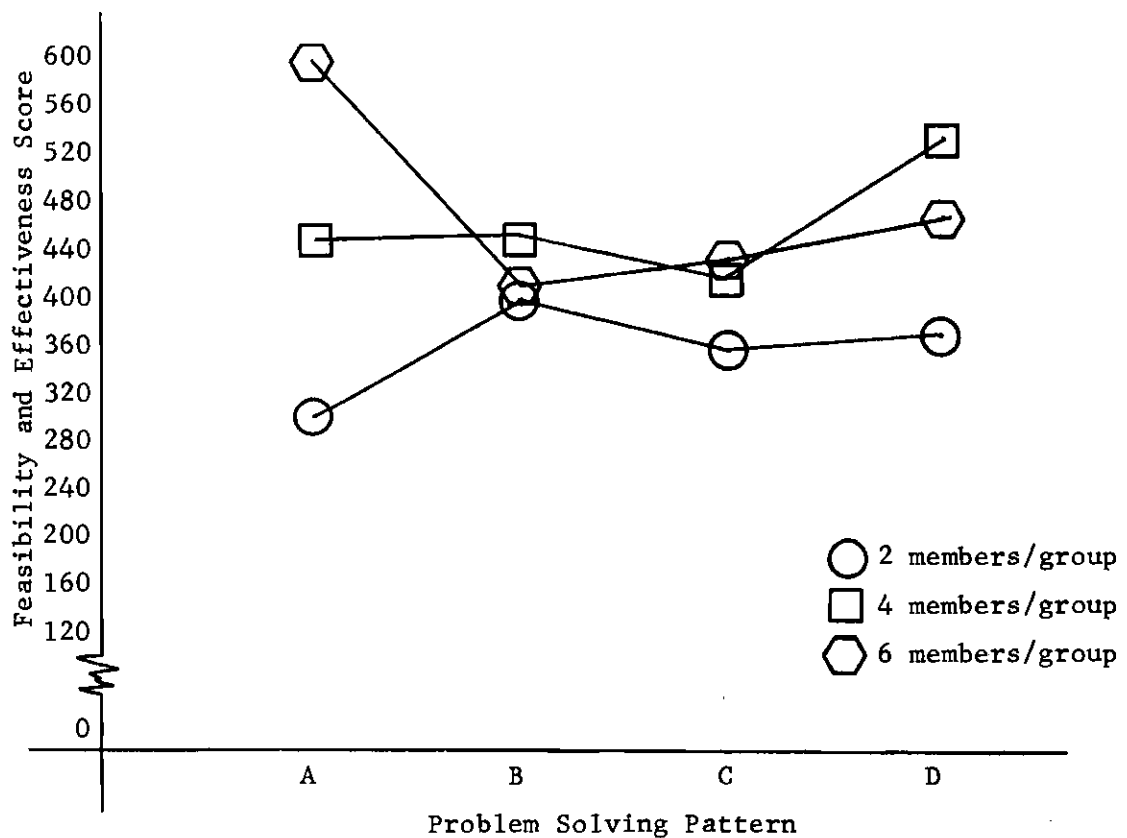


Figure 5. Total Additive Score of the Ideas Generated by Three Separate Group Sizes Under Four Problem Solving Patterns

Table 8. Factorial Analysis of Variance of  
Multiplicative Scheme in Experiment 1

Source	df	MS	F
Group Size (G)	2	18722.53	12.60*
Problem Solving Pattern (P)	3	2511.43	1.69
G × P	6	4934.26	3.32**
Error	12	1486.32	

\*  
p < .01

\*\*  
p < .05

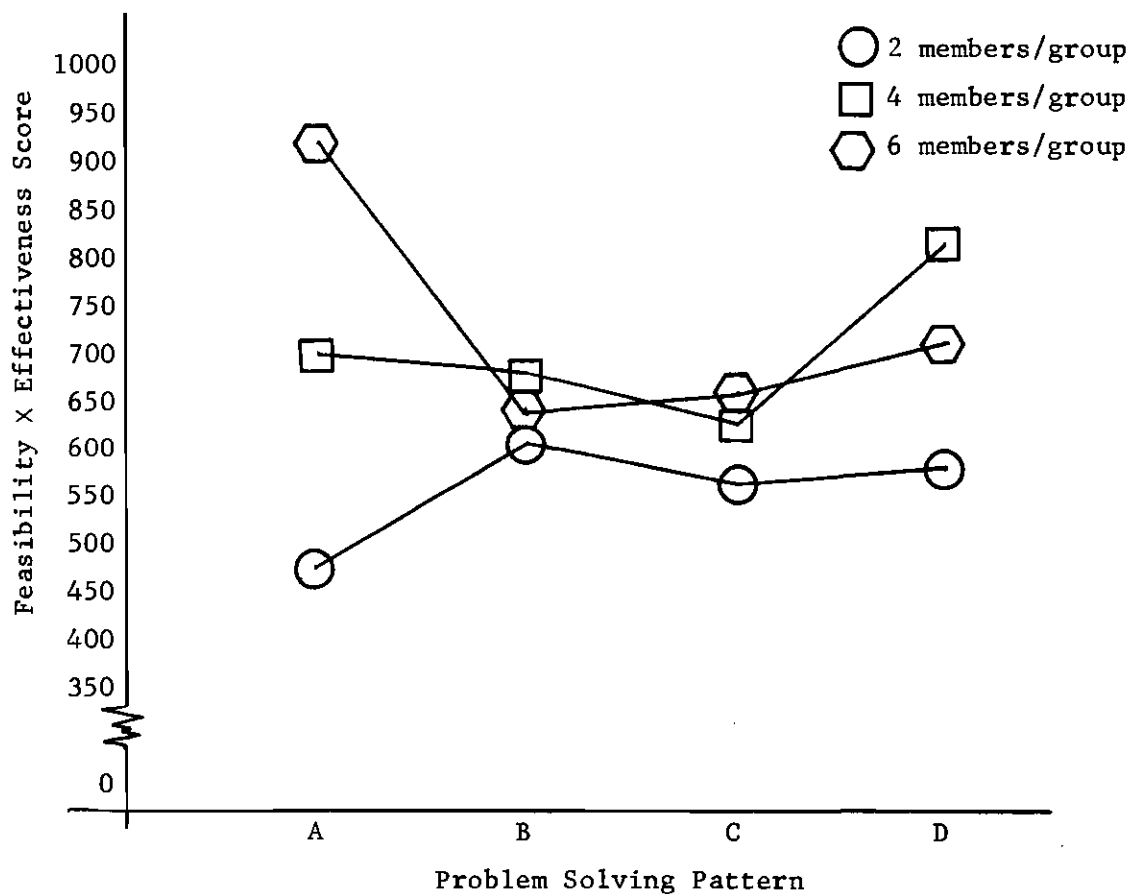


Figure 6. Total Multiplicative Score of the Ideas Generated by Three Separate Group Sizes Under Four Problem Solving Patterns

the additive and multiplicative scheme and was not significant when using feasibility as a single measure.

Duncan Multiple Range tests conducted on the qualitative results at the ( $p = .05$ ) level of significance revealed findings similar to those obtained in tests on the quantitative data. Utilizing feasibility as a single measure of quality provided exactly the same results. The remaining measures accentuated the superiority of the A pattern for six-member groups by showing it to be significantly superior to the D as well as the B and C patterns. No significant difference was found between patterns for groups of size four and two.

Table 9. Factorial Analysis of Variance of Number of Ideas in Experiment 2

Source	df	MS	F
Group Size (G)	1	55.12	4.29
Problem Solving Pattern (P)	3	15.74	1.23
Error and G $\times$ P	3	12.84	

Table 9 shows no significant difference between problem solving patterns in experiment 2 as well as no significant group effect. Interaction cannot be separated from the main effects as the experiment was not replicated.

The data depicted in Figure 7 were also analyzed using the Duncan Multiple Range test with resultant findings similar to those of experiment 1 in that no significant differences between patterns occurred for groups of size four and two.

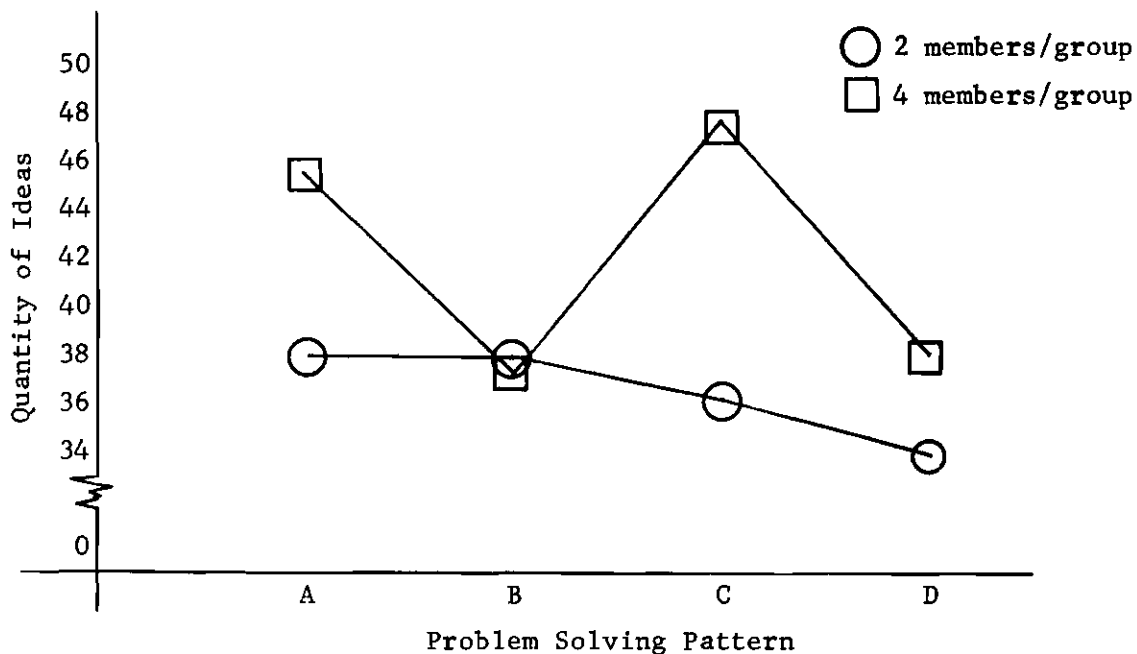


Figure 7. Total Number of Ideas Generated for Two Separate Group Sizes Under Four Problem Solving Patterns

The qualitative examination of data conducted in experiment 1 was repeated for experiment 2 with the results as shown in Tables 10 through 13 and Figures 8 through 11. Analysis of variance continued to show non-significant group and pattern effects for all qualitative measures while Duncan Multiple Range tests indicated no significant difference between problem solving patterns for groups of size two and four. Without replicating this small experiment, it is difficult to explain the lack of a group effect. The performance of the four-member group functioning under the B pattern was most likely a major factor as an F statistic of 15.36, significant at the ( $p = .05$ ) level, would have resulted for the group effect if just five more ideas had been generated by this group.

Table 10. Factorial Analysis of Variance of Feasibility of Ideas in Experiment 2

Score	df	MS	F
Group Size (G)	1	780.13	3.21
Problem Solving Pattern (P)	3	67.81	< 1
Error and G x P	3	242.99	

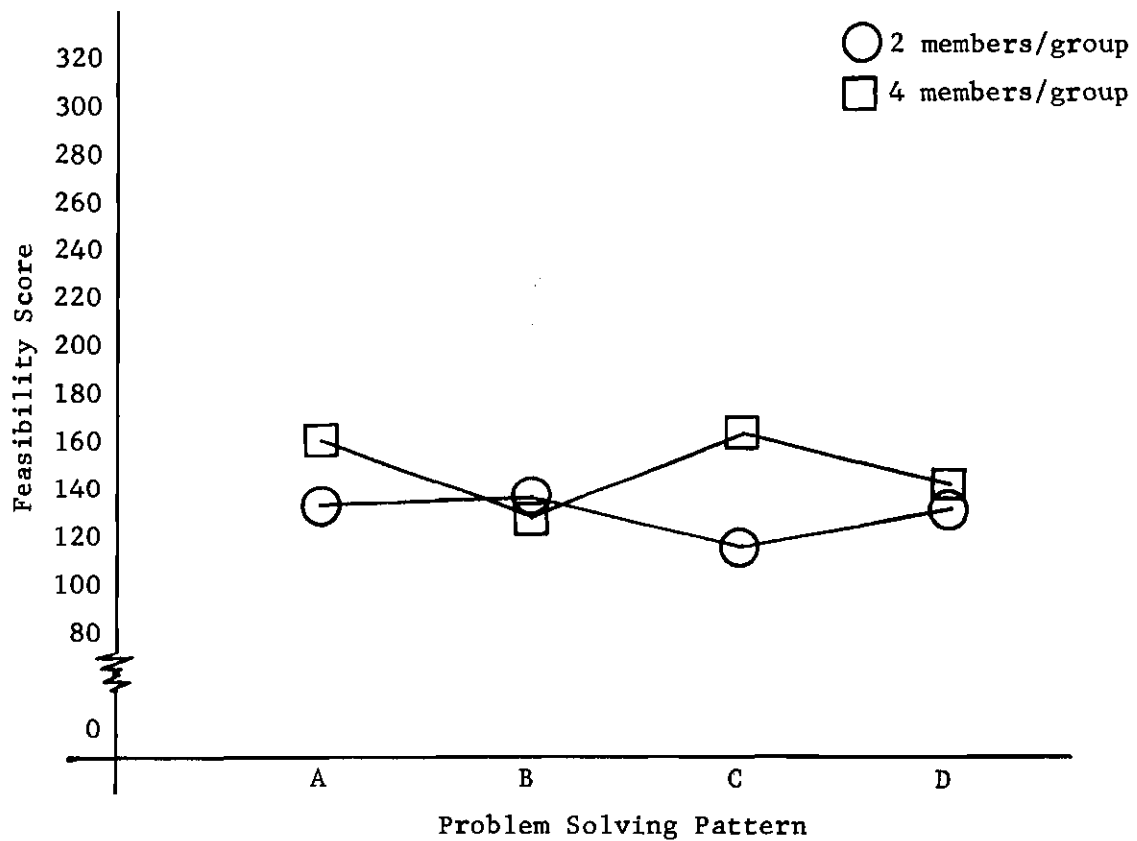


Figure 8. Total Feasibility of the Ideas Generated by Two Separate Group Sizes Under Four Problem Solving Patterns

Table 11. Factorial Analysis of Variance of Effectiveness of Ideas in Experiment 2

Source	df	MS	F
Group Size (G)	1	190.13	1.836
Problem Solving Pattern (P)	3	27.57	< 1
Error and G x P	3	103.57	

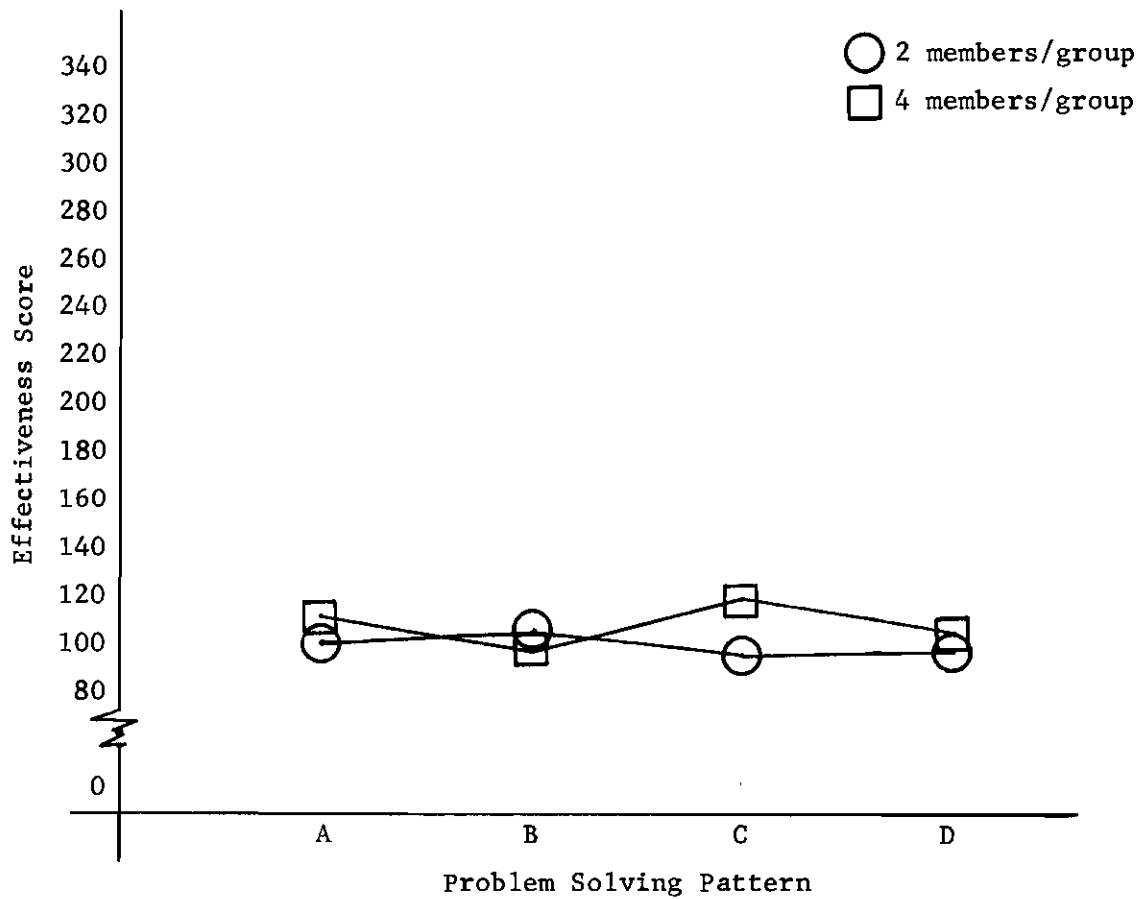


Figure 9. Total Effectiveness of the Ideas Generated by Two Separate Group Sizes Under Four Problem Solving Patterns

Table 12. Factorial Analysis of Variance  
of Additive Scheme in Experiment 2

Source	df	MS	F
Group Size (G)	1	1740.50	2.66
Problem Solving Pattern (P)	3	166.15	< 1
Error and G $\times$ P	3	655.15	

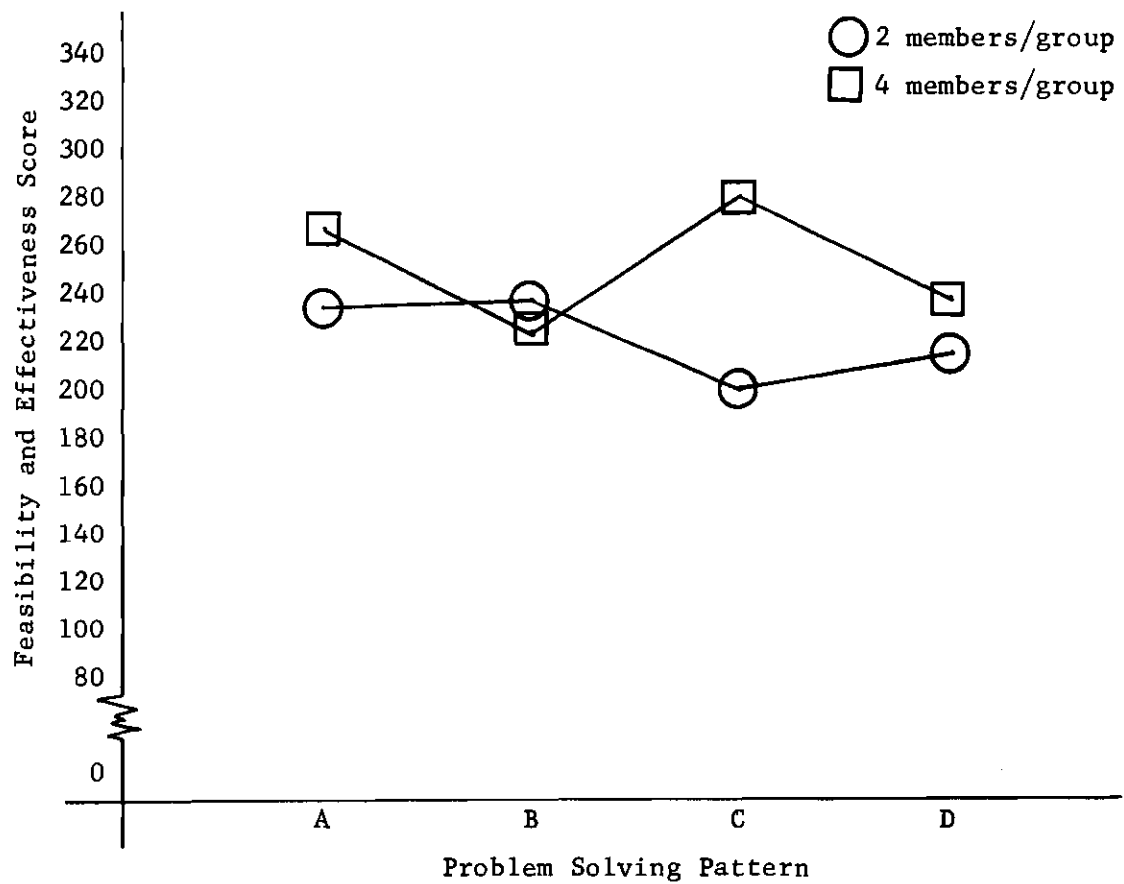


Figure 10. Total Additive Score of the Ideas Generated by Two Separate Group Sizes Under Four Problem Solving Patterns

Table 13. Factorial Analysis of Variance of Multiplicative Scheme in Experiment 2

Source	df	MS	F
Group Size (G)	1	3128.41	1.86
Problem Solving Pattern (P)	3	252.68	< 1
Error and G $\times$ P	3	1667.59	

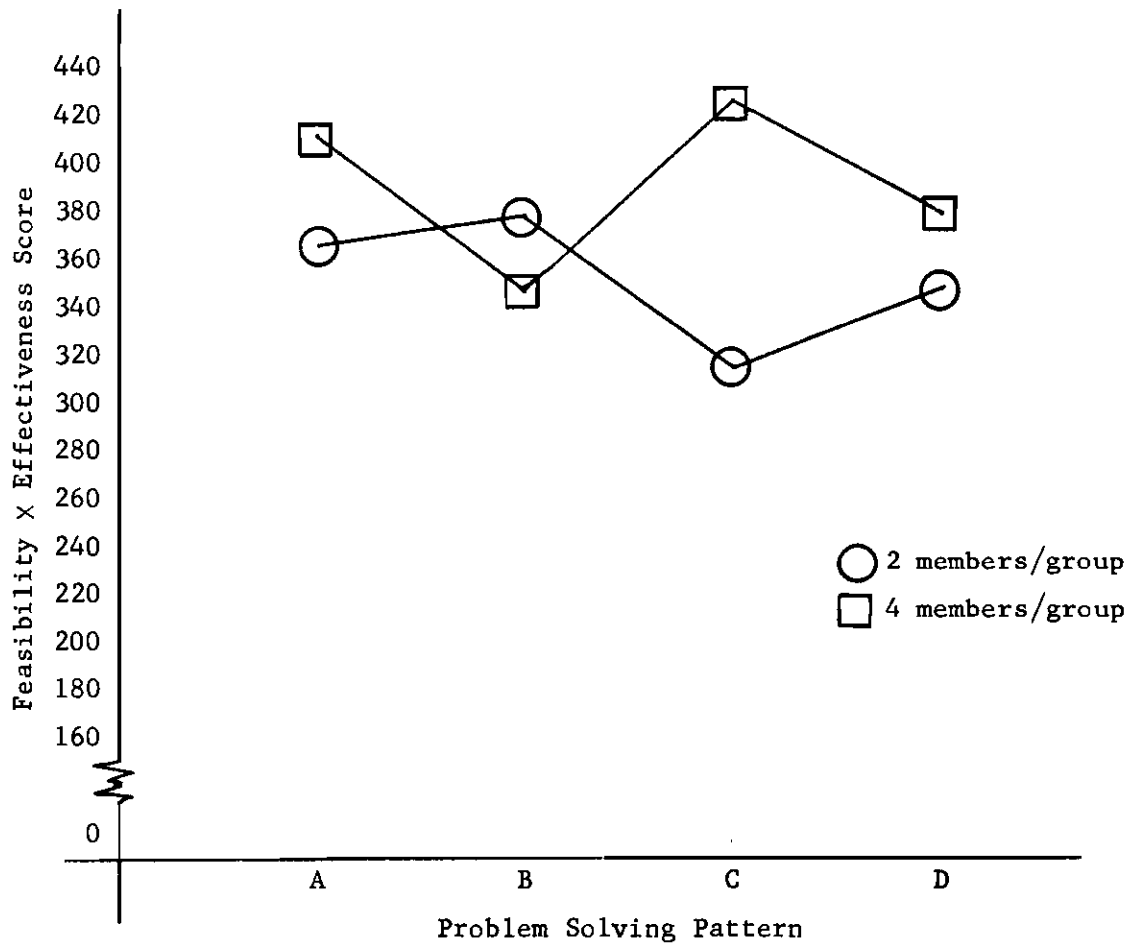


Figure 11. Total Multiplicative Score of the Ideas Generated by Two Separate Group Sizes Under Four Problem Solving Patterns

Table 14. Factorial Analysis of Variance of Number of Ideas for Students Versus Executives

Source	df	MS	F
Type of Subject (T)	1	159.39	18.55*
Group Size (G)	1	244.14	28.59*
T × G	1	26.26	3.08
Problem Solving Pattern (P)	3	1.33	< 1
T × P	3	35.76	4.19
G × P	3	15.02	1.76
Error and G × P × T	3	8.54	

\*  
p < .05

Table 14 shows that, at the ( $p = .05$ ) level, group effect was significant and executives were superior to students in terms of quantity of ideas generated. Problem solving pattern and all first order interactions were not significant. Qualitative analysis shown in Table 15 using the additive scheme as a measure produced essentially the same results with the exception that executive superiority diminished from the ( $p = .05$ ) to the ( $p = .10$ ) level. After the experiment, executives were questioned as to whether they had received training in brainstorming or other ideation techniques. Some had participated in brainstorming sessions, but none had received formal training on the techniques used in these sessions. The difference, then, between students and executives is conceivably a function of the experience and consistency of the latter, as the six subjects working alone in experiment 2 generated a mean of 23.83 ideas per subject with a standard deviation of 4.36, while 24 student subjects working independently produced a mean of 17.44 ideas per individual with a

standard deviation of 6.38

Table 15. Factorial Analysis of Variance of Quality of Ideas for Students Versus Executives

Source	df		
Type of Subject (T)	1	5119.41	9.21*
Group Size (G)	1	6938.89	12.48**
T × G	1	590.49	1.06
Problem Solving Pattern (P)	3	81.14	< 1
T × P	3	696.00	1.25
G × P	3	496.04	< 1
Error and G × P × T	3	556.12	

\*  
p < .10  
\*\*  
p < .05

Table 16 shows no significant difference between either group or problem solving pattern for this experiment, and interaction significance cannot be tested due to the lack of replication.

Table 16. Factorial Analysis of Variance of Number of Ideas in Experiment 3

Source	df	MS	F
Group Size (G)	2	165.08	4.68
Problem Solving Pattern (P)	3	44.83	1.27
Error and G × P	6	35.31	

A Duncan Multiple Range test conducted on the data shown in Figure 12 indicates that six-member groups functioning under the A pattern were no longer superior to those utilizing the B, C, and D patterns, and no

significant difference was detected between problem solving strategies for groups of size two and four.

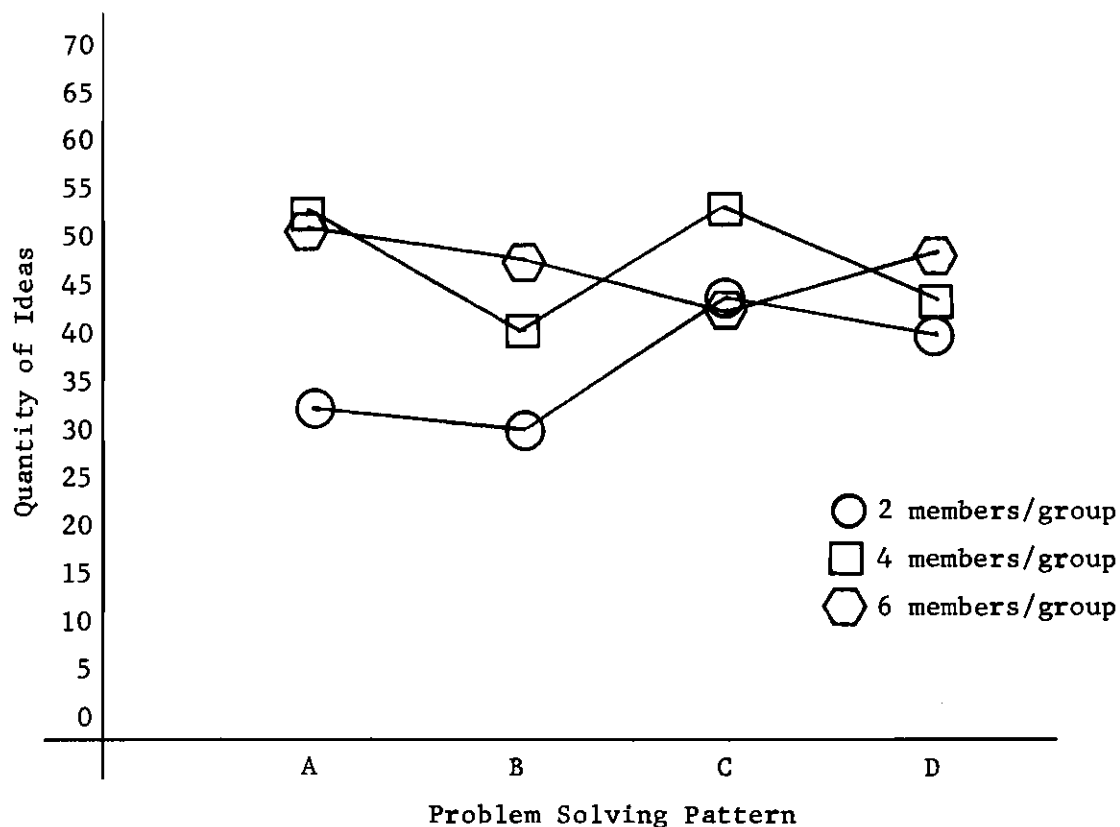


Figure 12. Total Number of Ideas Generated for Three Separate Group Sizes Under Four Problem Solving Patterns

Qualitative analysis of the data is shown in Tables 17 through 20 and Figures 13 through 16. Analysis of variance conducted on each measure of quality continued to show no significant difference between group or pattern effect and Duncan Multiple Range tests for each produced results identical to those found in the quantitative analysis.

Table 17. Factorial Analysis of Variance of Feasibility of Ideas in Experiment 3

Source	df	MS	F
Group Size (G)	2	2137.50	3.29
Problem Solving Patterns (P)	3	407.14	< 1
Error and G x P	6	630.80	

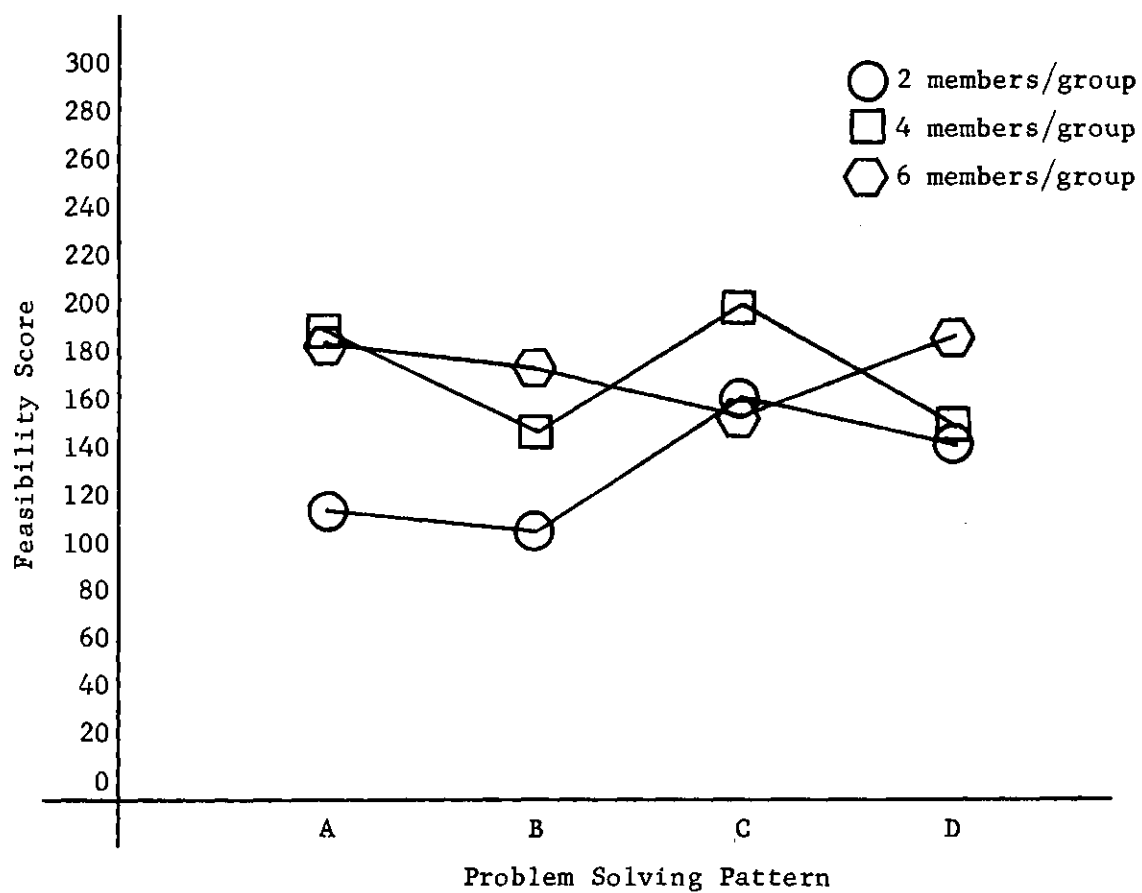


Figure 13. Total Feasibility of the Ideas Generated by Three Separate Group Sizes Under Four Problem Solving Patterns

Table 18. Factorial Analysis of Variance of Effectiveness of Ideas in Experiment 3

Source	df	MS	F
Group Size (G)	2	1009.13	4.172
Problem Solving Pattern (P)	3	247.91	1.025
Error and G x P	6	241.89	

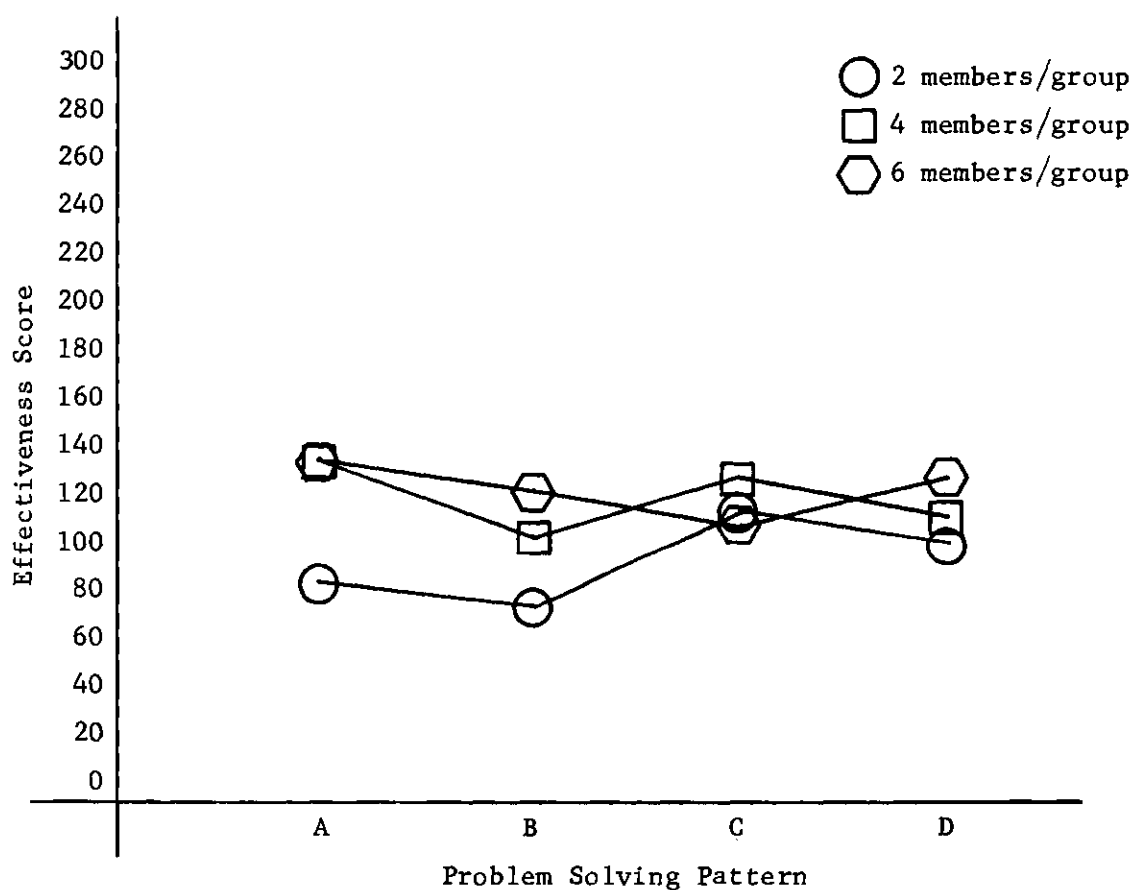


Figure 14. Total Effectiveness of the Ideas Generated by Three Separate Group Sizes Under Four Problem Solving Patterns

Table 19. Factorial Analysis of Variance of Additive Scheme in Experiment 3

Source	df	MS	F
Group Size (G)	2	9254.12	4.52
Problem Solving Pattern (P)	3	2526.16	1.22
Error and G $\times$ P	6	2047.39	

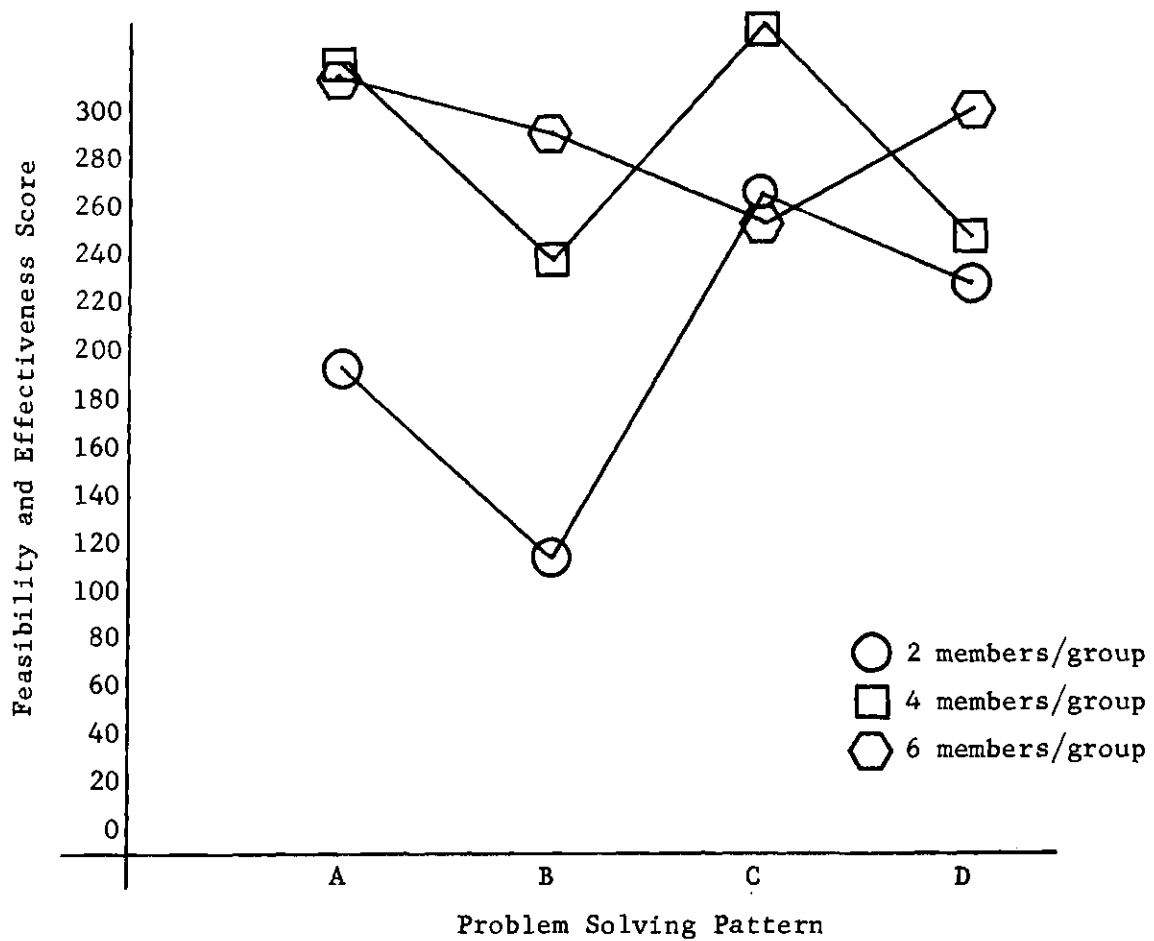


Figure 15. Total Additive Score of the Ideas Generated by Three Separate Group Sizes Under Four Problem Solving Patterns

Table 20. Factorial Analysis of Variance of Multiplicative Scheme in Experiment 3

Source	df	MS	F
Group Size (G)	2	15195.17	4.22
Problem Solving Pattern (P)	3	3677.25	1.02
Error and G x P	6	3603.59	

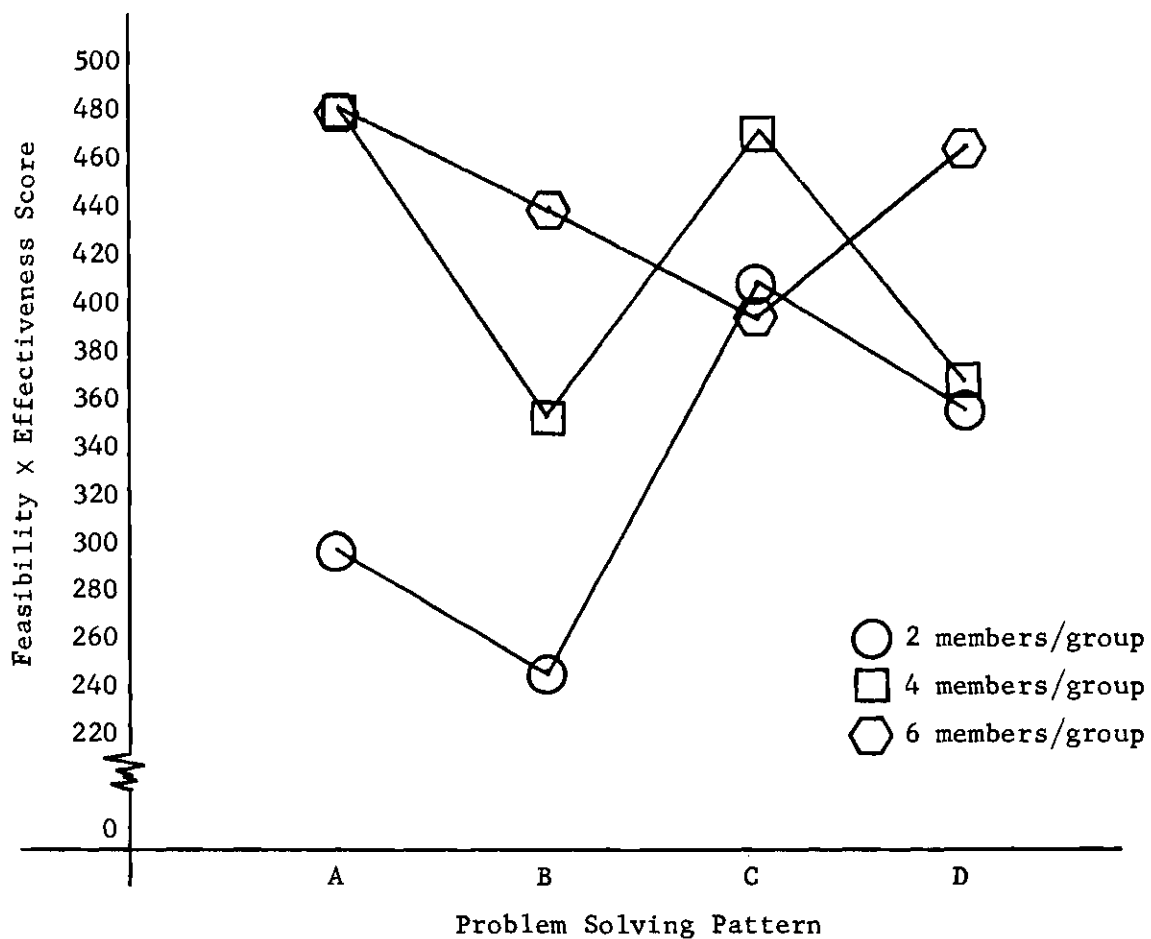


Figure 16. Total Multiplicative Score of the Ideas Generated by Three Separate Group Sizes Under Four Problem Solving Patterns

The data for the three experiments from which the analysis of variance and Duncan Multiple Range tests were conducted are recorded in Appendix VII.

#### Cumulative Distributions

Since there was no significant difference between problem solving patterns for all experiments, the number of ideas generated by all real groups of the same size was averaged and plotted in the form of cumulative distribution functions. They are depicted in Figures 17 through 19 for experiments 1 through 3, respectively. Nominal groups are shown separately in order to depict differences between them and real groups.

The linearity reported by Christensen, Guilford, et al. is clearly evident for all distribution functions during the first 15 minutes, but begins conforming to the functional relationship reported by Bousefield and Sedgewick as time increases. The superiority of nominal six-member groups over real interacting groups of the same size is readily apparent in Figure 17. The lack of a significant difference between patterns for the other sized groups is also obvious. Figure 19, on the other hand, indicates that nominal six-member groups are no longer superior to real groups of that size and that 90 minutes of ideation is sufficient for all curves to converge to the point where a significantly superior output as a function of increased group size no longer holds.

Further inspection of Figure 19 suggests an analysis of variance of the data at the 50 minute point to determine if a significant group effect and non-significant pattern effect result. Findings such as these would be consistent with those of experiment 1.

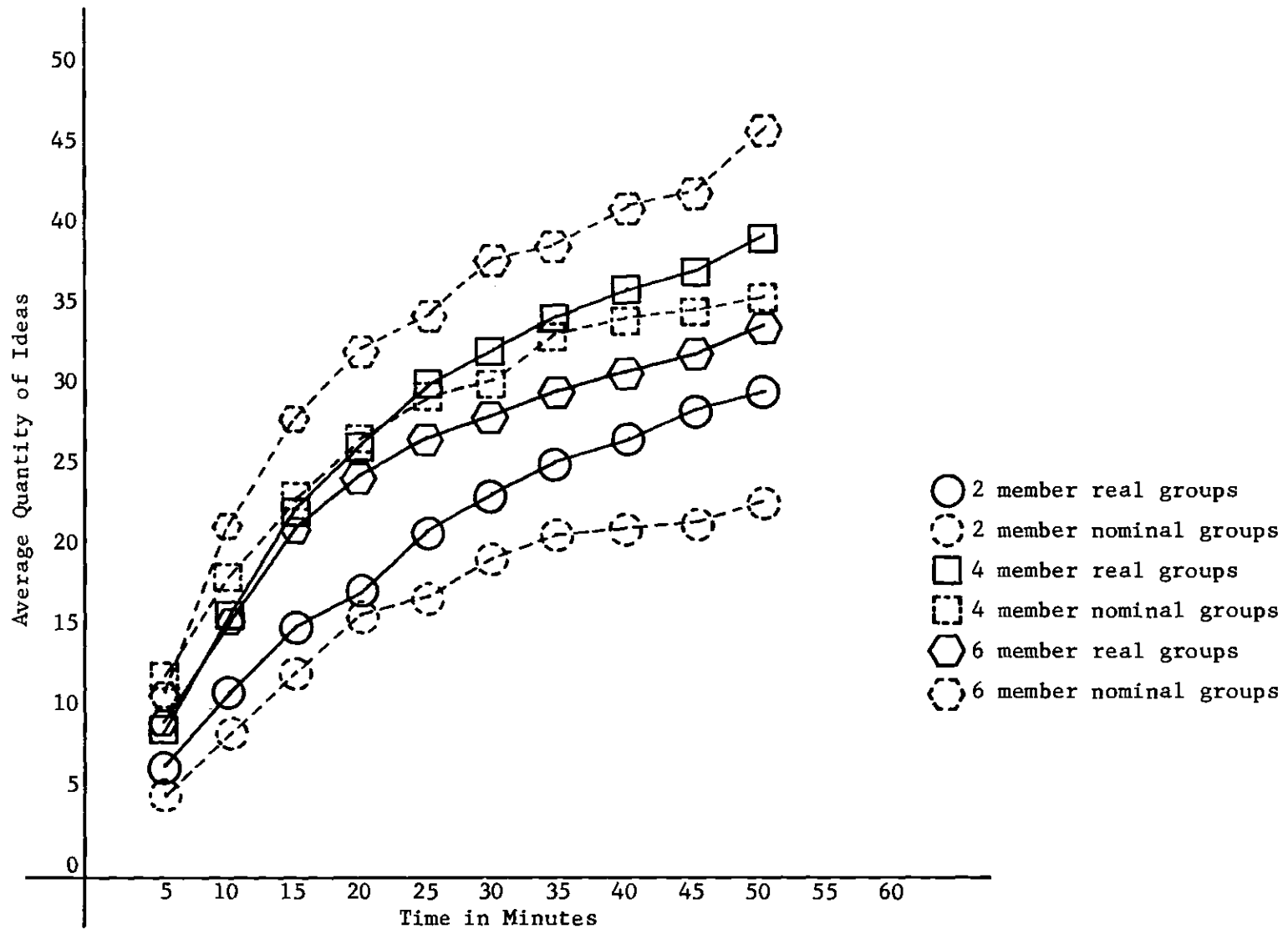


Figure 17. Cumulative Distribution of Average Quantity of Ideas Generated as a Function of Time for Groups of Size Two, Four, and Six in Experiment 1

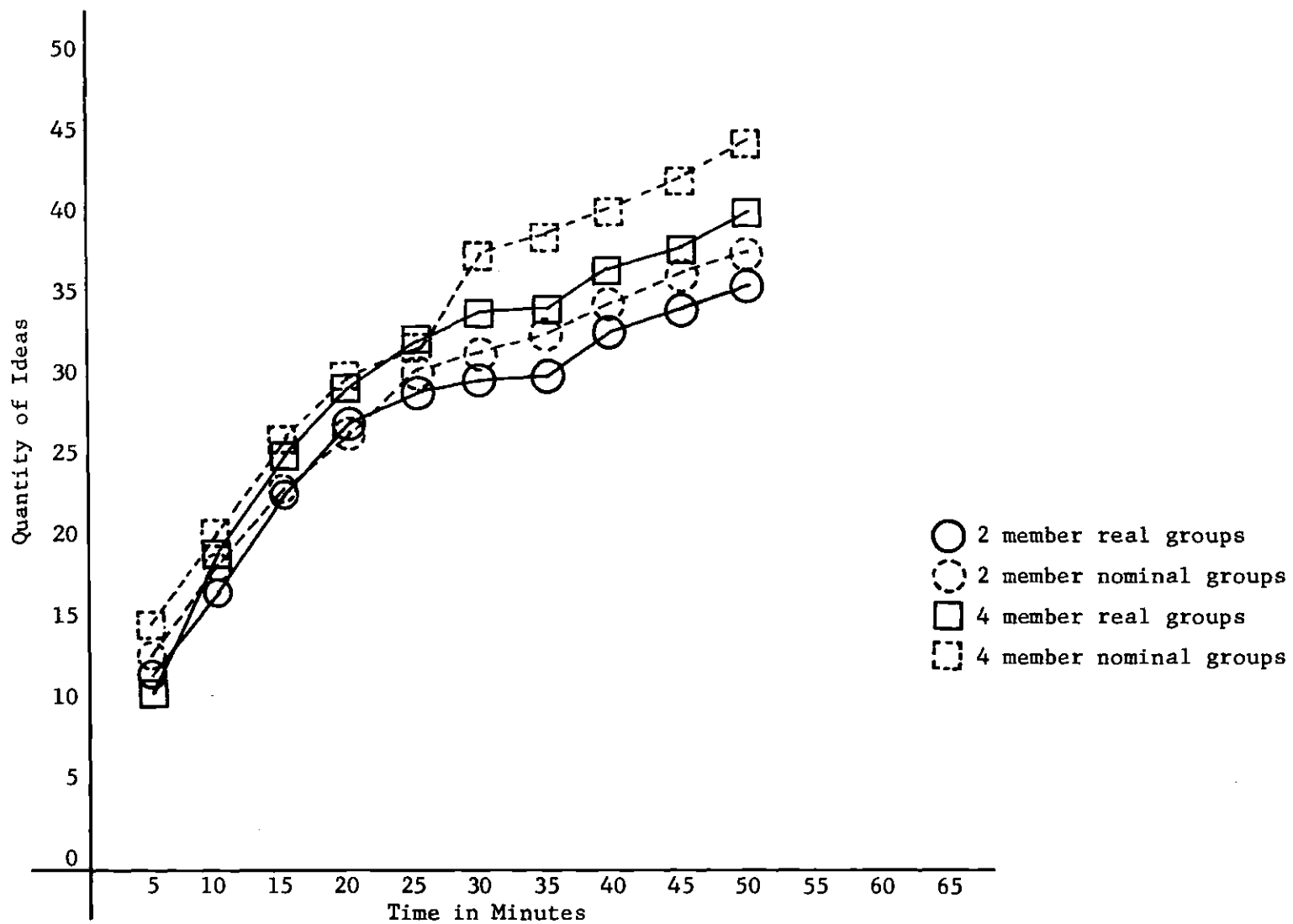


Figure 18. Cumulative Distribution of Average Quantity of Ideas Generated as a Function of Time for Groups of Size Two and Four in Experiment 2

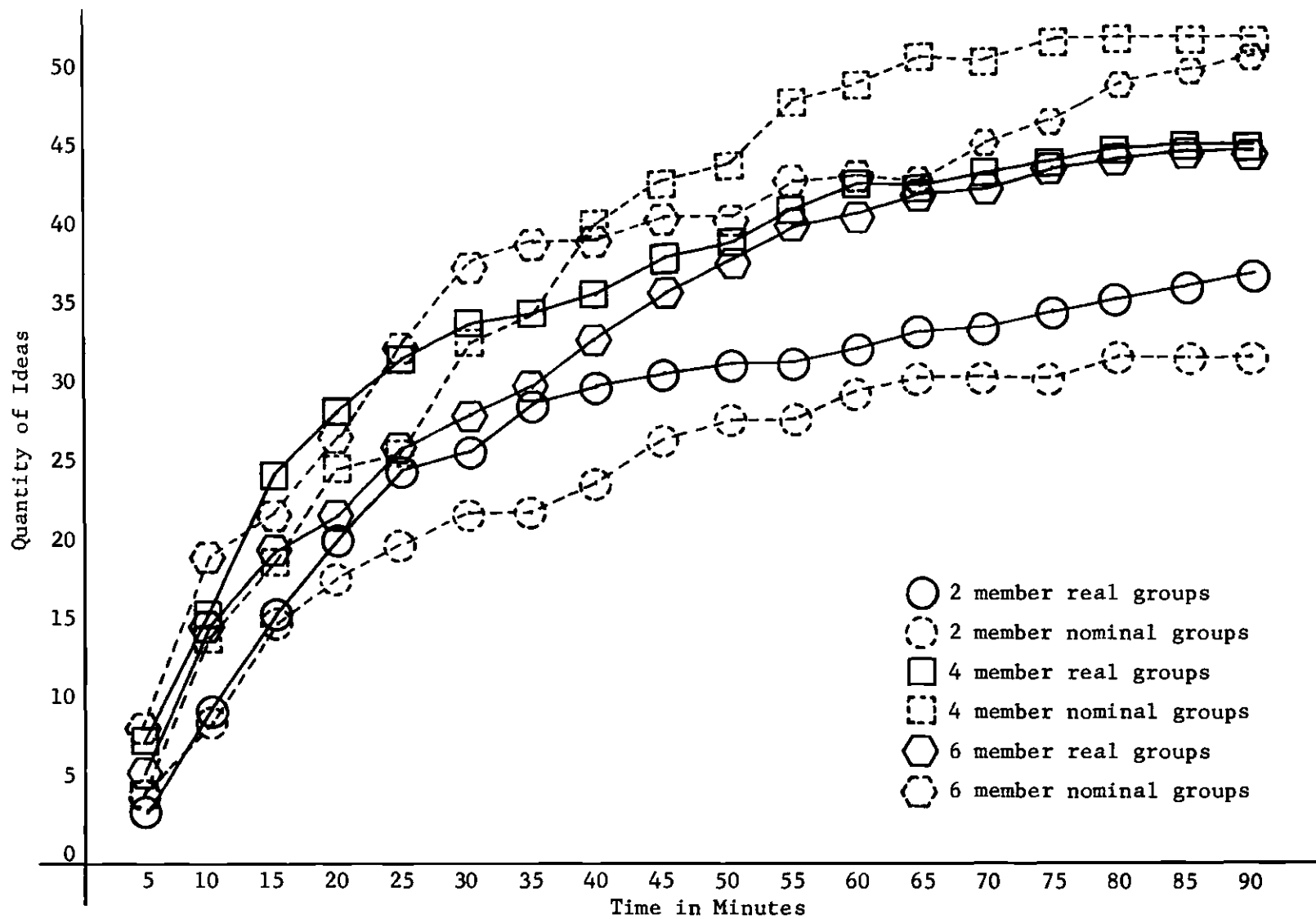


Figure 19. Cumulative Distribution of Average Quantity of Ideas Generated as a Function of Time for Groups of Size Two, Four, and Six in Experiment 3

No significant pattern or group effect was encountered from this analysis; therefore, another was performed at the 55 minute point yielding the results shown in Table 21.

Table 21. Factorial Analysis of Variance of Quantity of Ideas in Experiment 3 ( time = 55 minutes)

Source	df	MS	F
Group Size (G)	2	164.58	6.24*
Problem Solving Pattern (P)	3	36.77	1.40
Error and G × P	6	26.36	

\* p < .05

A possible explanation as to why a significant group effect required an additional five minutes to develop in this experiment over that of experiment 1 could be that subjects were more highly motivated to produce faster under the 50 minute time limit than under the 90 minute one.

The cumulative distribution of the quality of ideas generated over time for real groups of size two, four, and six is shown in Figure 20 with nominal groups of the same size. Since all of the qualitative measures yielded similar results, the additive scheme was the only one presented. Analysis of variance performed at the 55 minute point is shown in Table 22 and indicates a group effect significant at the ( $p = .10$ ) level rather than the ( $p = .05$ ) level with pattern effect remaining non-significant. Cumulative distribution data for the curves in Figures 17 through 20 appear in Appendix VIII.

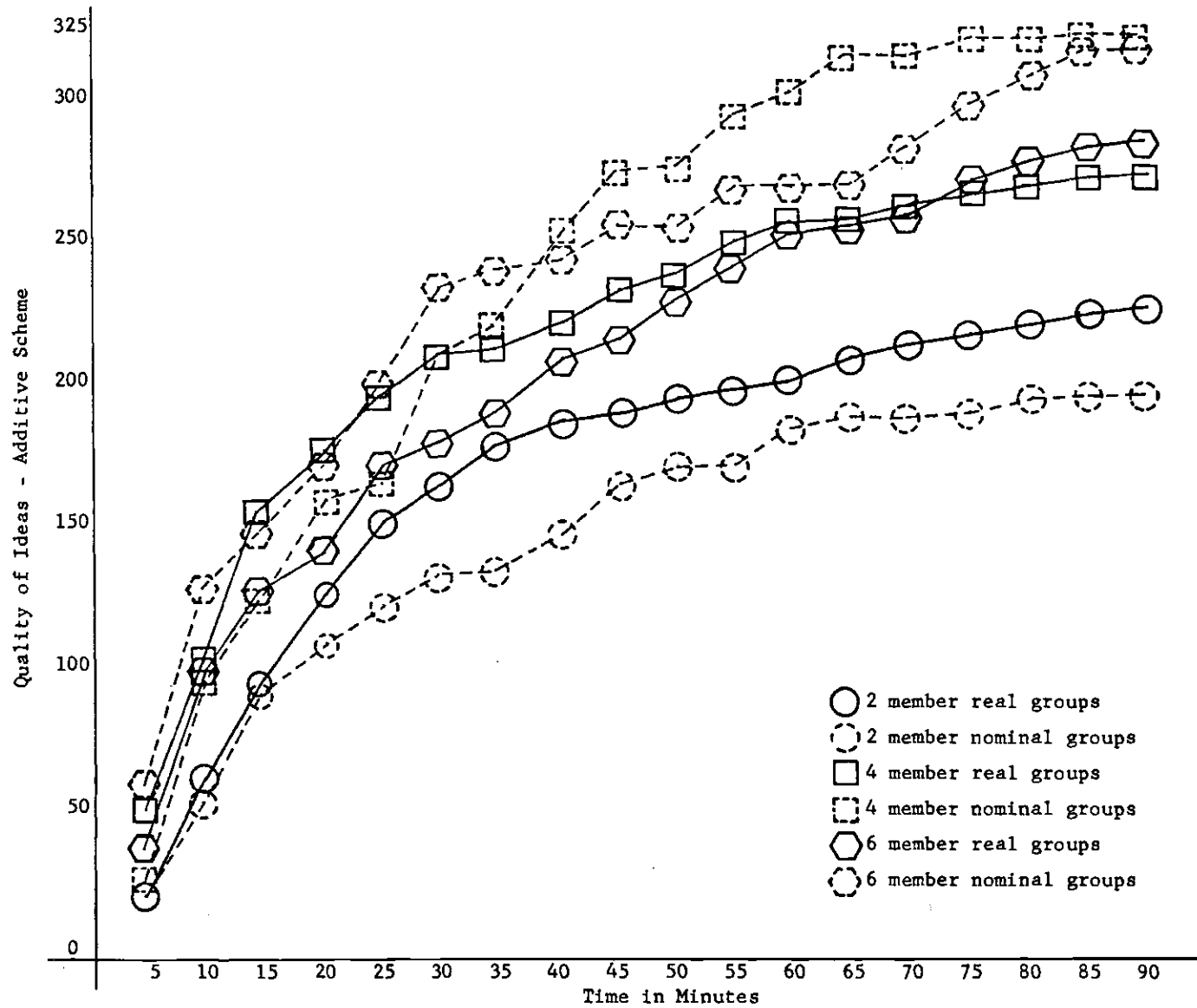


Figure 20. Cumulative Distribution of Average Quality of Ideas Generated as a Function of Time for Groups of Size Two, Four, and Six in Experiment 3

Table 22. Factorial Analysis of Variance of Quality of Ideas,  
Using Additive Scheme, in Experiment 3  
(time = 55 minutes)

Source	df	MS	F
Group Size (G)	2	5583.17	4.439*
Problem Solving Pattern (P)	3	1764.59	1.403
Error and G $\times$ P	6	1257.67	

\*  
p < .10

#### Man-Hour Analysis

Output of groups in all experiments in terms of quantity and quality of ideas as a function of man-hours is shown in Figures 21 and 22. Points representing one individual, or 5/6 of a man-hour for experiment 1 and 1.5 man-hours for experiment 3, were obtained by averaging the results of all subjects working alone for the particular experiments. The remaining points are averages of total output of real and nominal groups. The two types of groups are plotted separately for purposes of comparison. The superiority of nominal six-member groups over real six-member groups is clearly evident as is the superiority of executives over students. Transforming quantitative output to qualitative has little effect on the shapes of the curves as can be seen by comparing the figures. A very striking result is the apparent inefficiency of increasing real group sizes beyond four members for this problem. Total average quantity and quality of ideas generated by six-member groups was less than that of four-member groups for experiments 1 and 3. Since six-member groups were not available for experiment 2, curves cannot be drawn beyond their current position, but their shapes to that point are similar to those found in

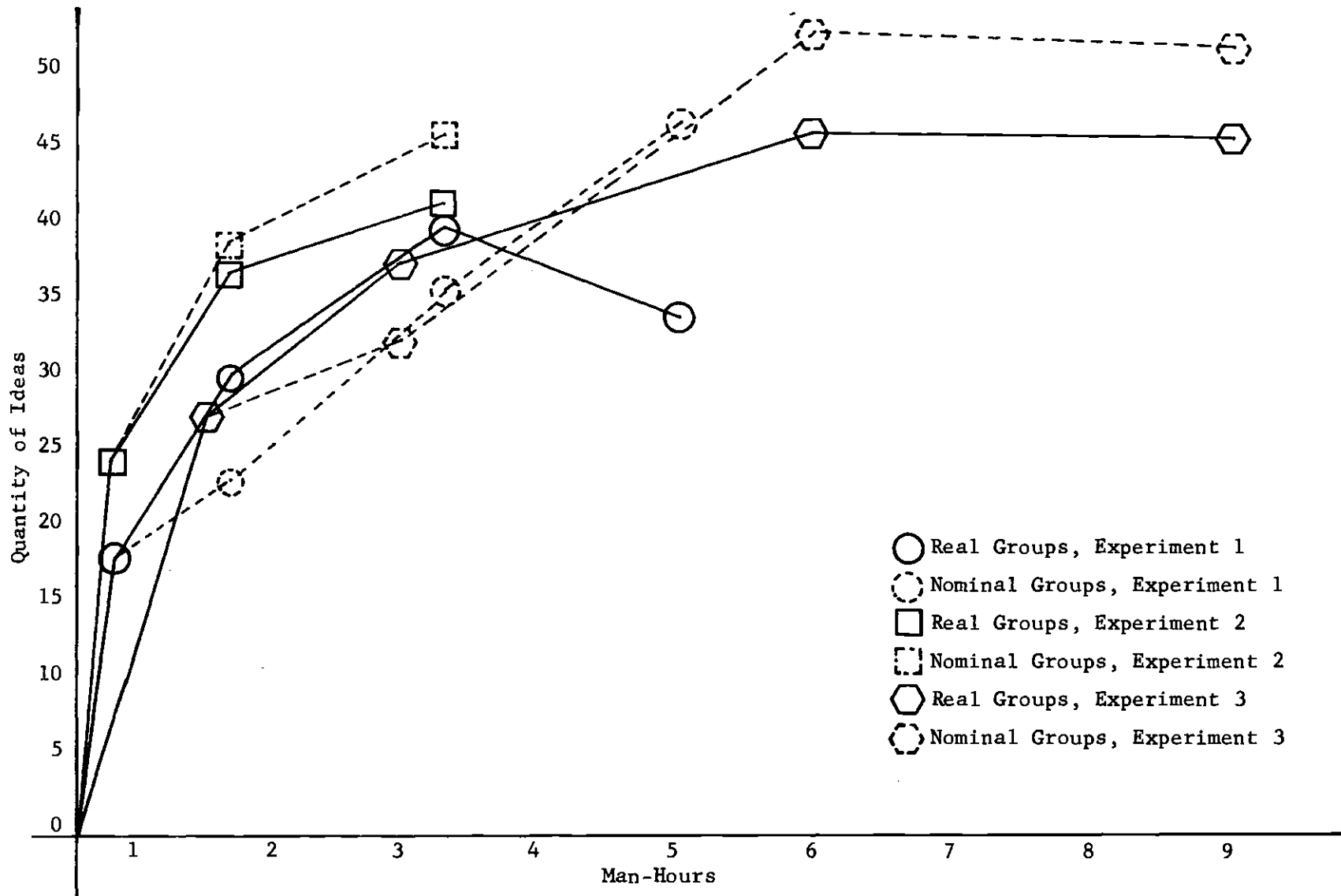


Figure 21. Total Number of Ideas Generated per Man-Hours Expended in Experiments 1, 2, and 3

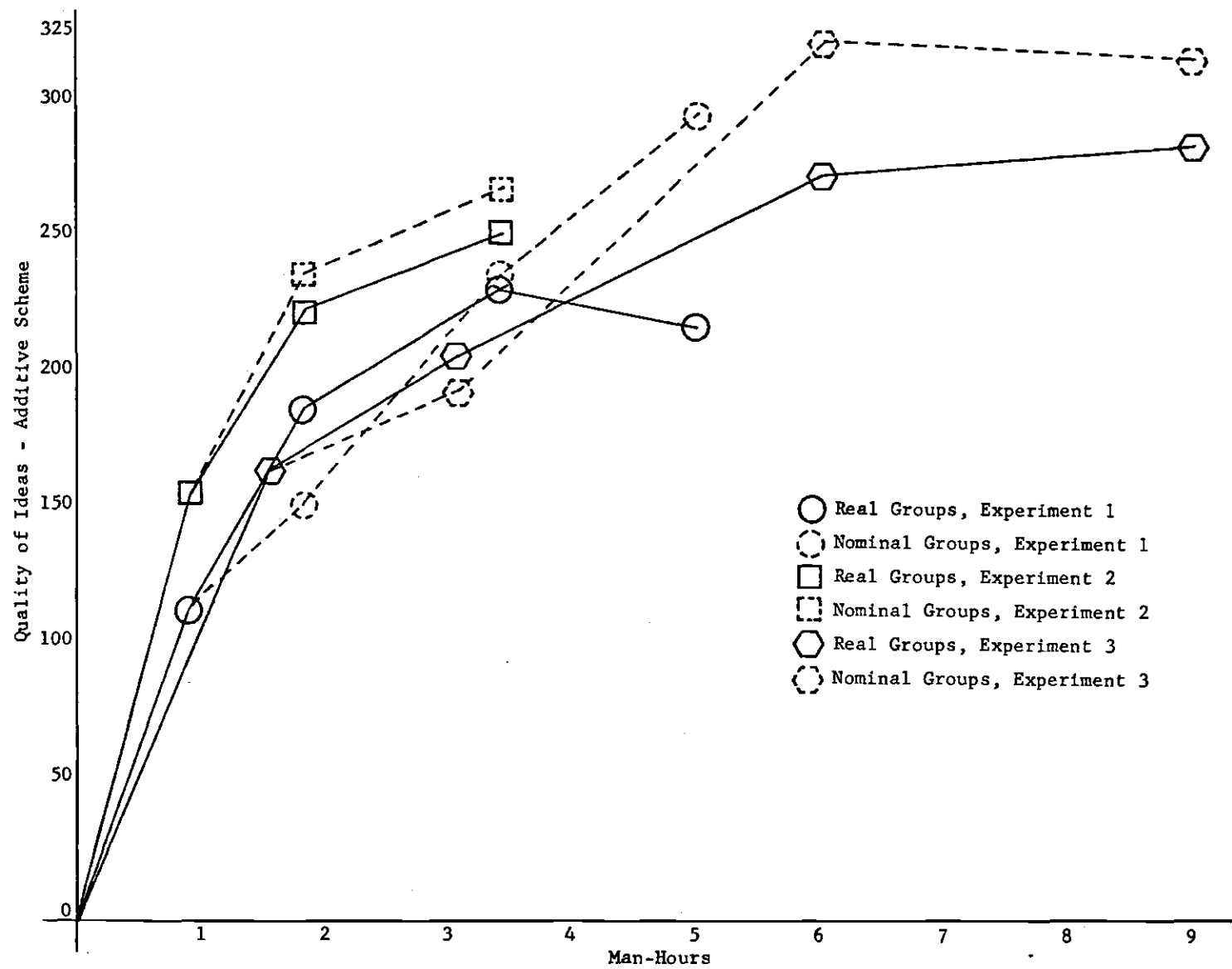


Figure 22. Total Quality of Ideas Generated per Man-Hours Expended in Experiments 1, 2, and 3, Using the Additive Scheme

the other experiments.

### Cleverness Analysis

The average cleverness of ideas recorded per five minute interval for different sized real groups was computed for each experiment and the results depicted in Figures 23 through 25. As may be seen in Tables 23 through 25, analysis of variance applied to the data indicates that variation with time was not significant. Variation between groups was also not significant and supporting data may be found in Appendix IX.

F' tests conducted on Tables 24 and 25 indicate a significant group effect at the ( $p = .05$ ) level for the results given in Table 25.

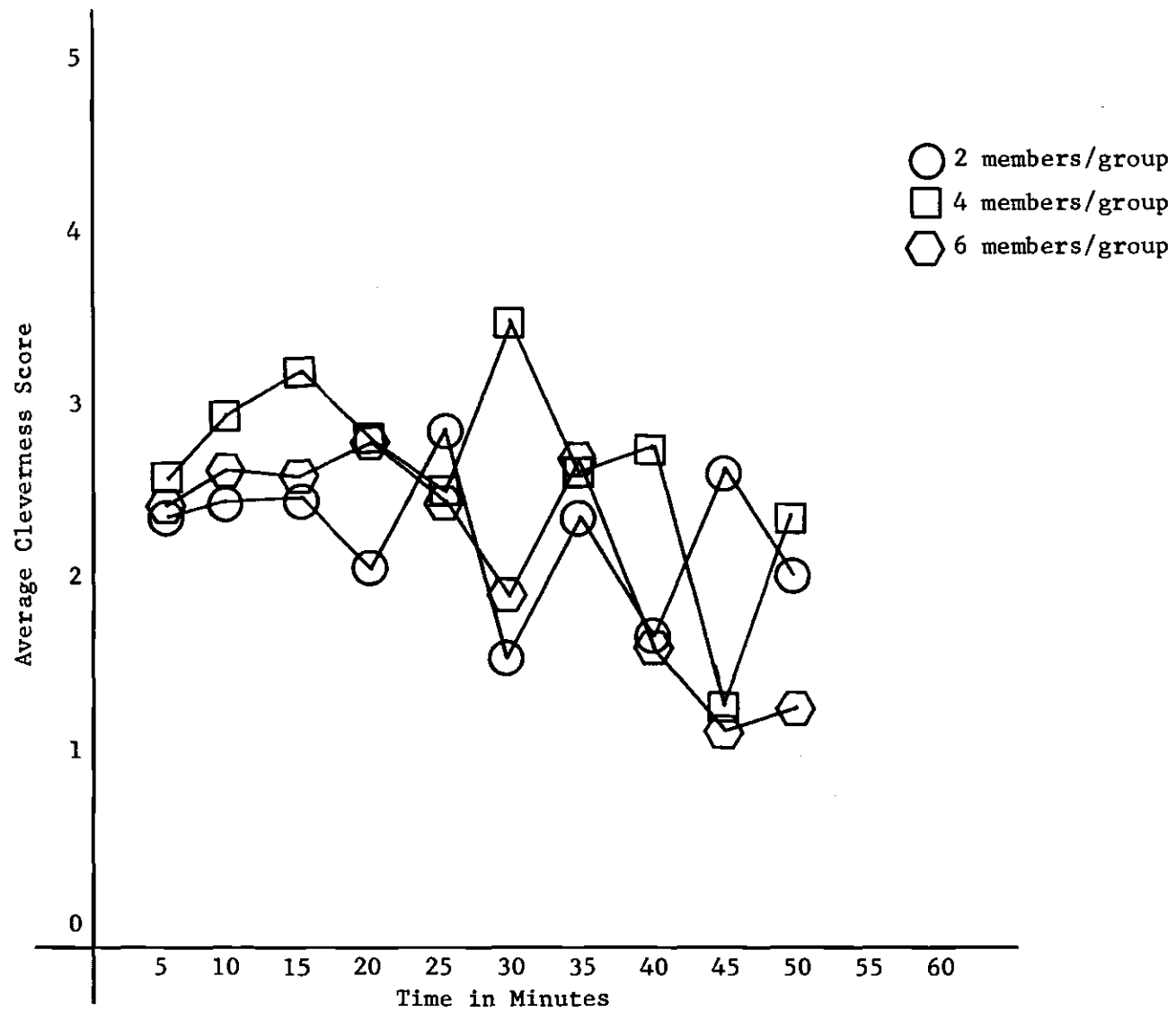


Figure 23. Average Cleverness Score for Real Groups of Three Different Sizes in Experiment 1

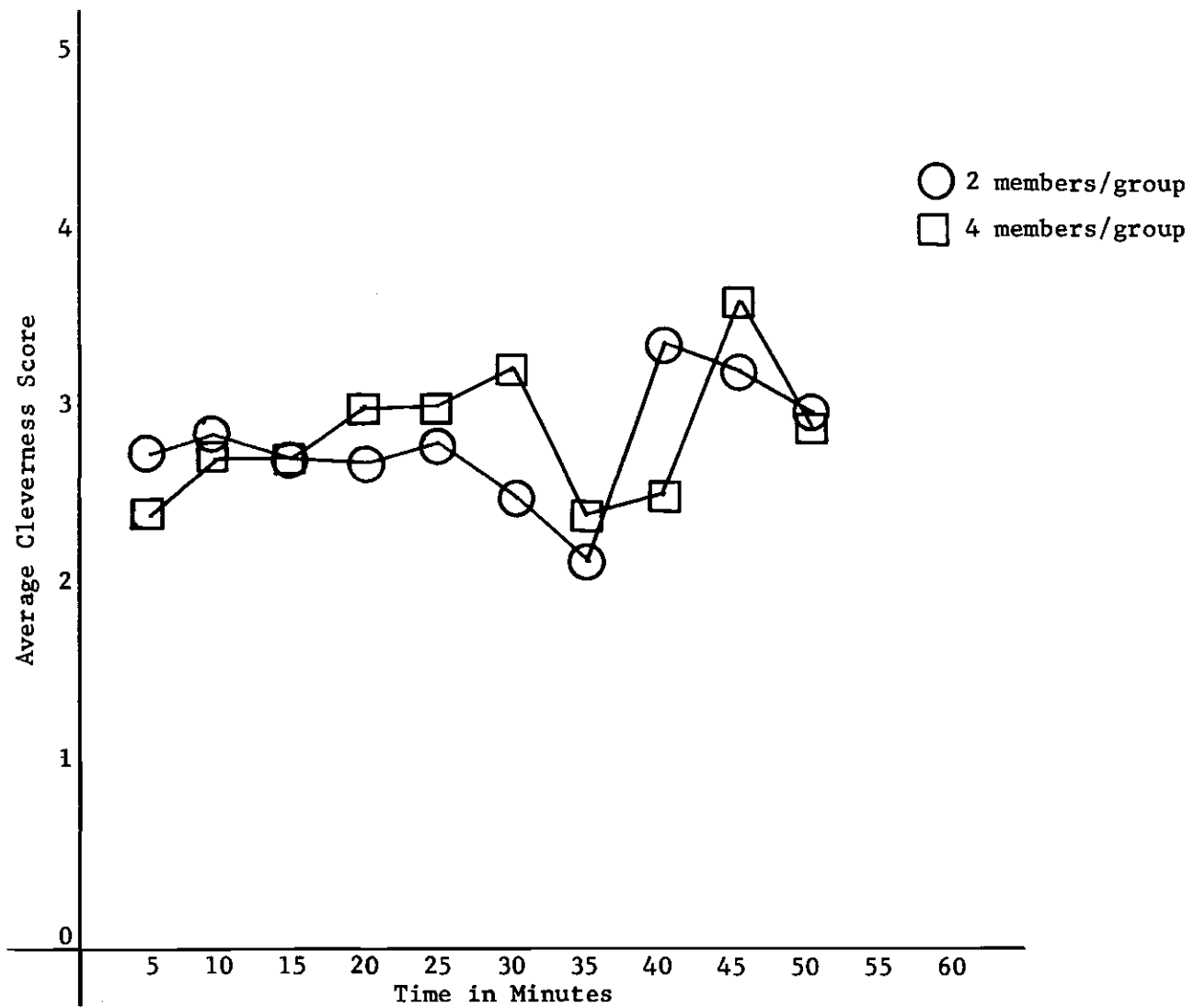


Figure 24. Average Cleverness Score for Real Groups of Two Different Sizes in Experiment 2

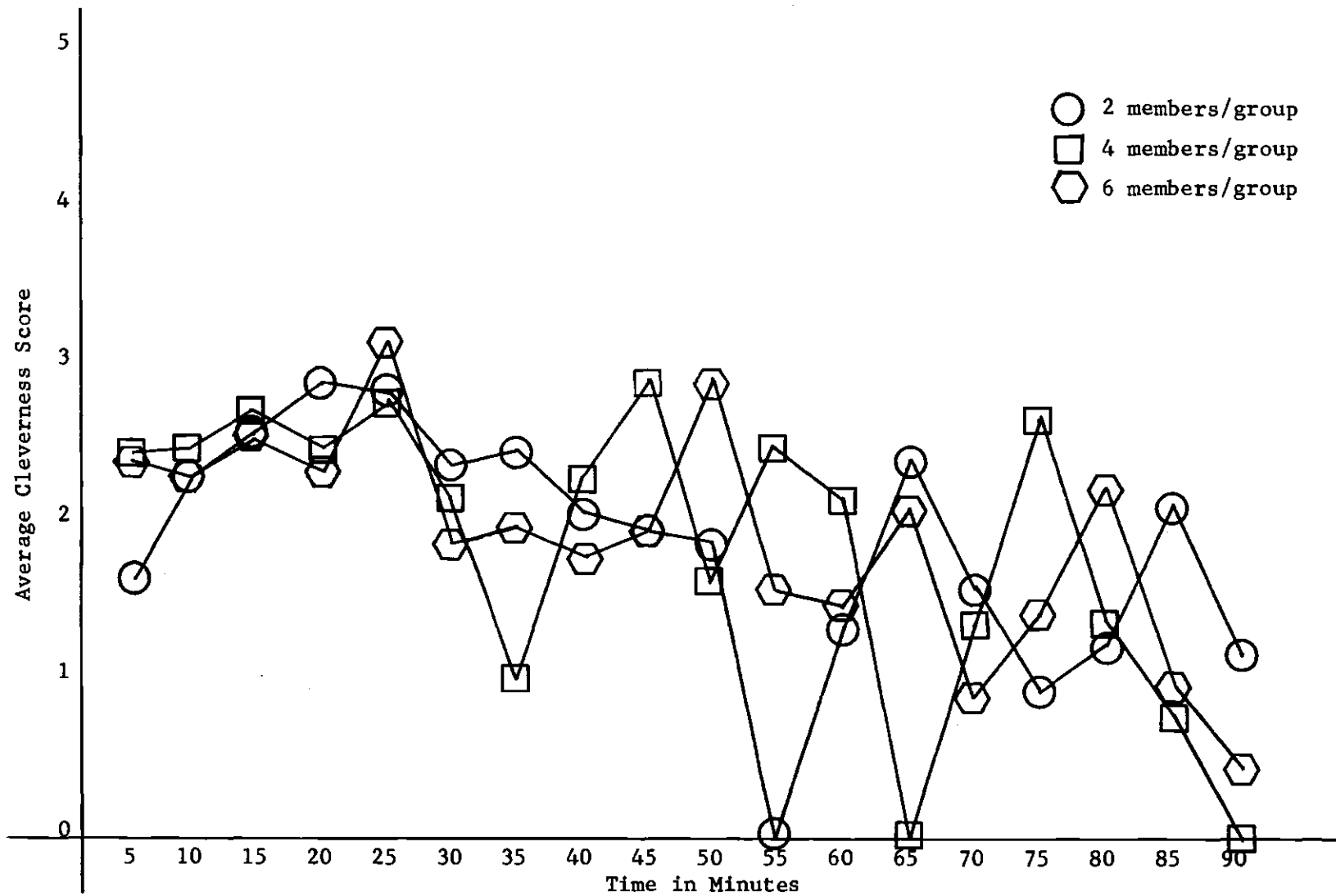


Figure 25. Average Cleverness Score for Groups of Three Different Sizes in Experiment 3

Table 23. Factorial Analysis of Variance of Cleverness  
of Ideas in Experiment 1

Source	df	MS	F
Group Size (G)	2	0.701	2.83
Time (T)	9	0.392	1.59
Error and G × T	18	0.247	

Table 24. Factorial Analysis of Variance of Cleverness  
of Ideas in Experiment 2

Source	df	MS	F
Group Size (G)	1	0.008	< 1
Time (T)	9	0.167	1.798
Error and G × T	9	0.835	

Table 25. Factorial Analysis of Variance of Cleverness  
of Ideas in Experiment 3

Source	df	MS	F
Group Size (G)	2	0.0133	< 1
Time (T)	17	1.0679	2.603
Error and G × T	34	0.4102	

## CHAPTER V

### CONCLUSIONS, DISCUSSION, AND RECOMMENDATIONS

The purpose of this experiment was to determine the relationship between quantity and quality of ideas generated as a function of time for groups of three sizes utilizing six separate problem solving patterns. Group sizes consisted of two, four, and six members and the six patterns are described in Chapter III. Average cleverness as a function of time for the three groups was also analyzed.

#### Conclusions

A significant group effect occurred in experiment 1 for all analyses of variance conducted, in accordance with the prediction of hypothesis 1. Duncan Multiple Range tests indicated that six-member nominal groups significantly outperformed real groups for all measures used and that no significant difference appeared between nominal and real groups of size four and two. The significant superiority of nominal six-member groups is consistent with experiments described in Chapter II. The fact that the same result did not hold for the smaller groups was interesting and is, therefore, discussed later in the chapter. The lack of a significant difference between problem solving patterns for experiment 1 supported hypothesis 3 when an analysis of variance was conducted on the data.

Analysis of experiment 2 supports hypothesis 3 but not hypothesis 1. The inconsistent performance of one four-member group was cited as a possible reason in Chapter IV for the lack of a significant group effect

in the analysis of variance; however, replication of the experiment is necessary before solid conclusions can be drawn. No predictions were made as to whether the executives would or would not outperform the students, but the fact that they did is not surprising considering the experience, training, and background present in these subjects compared to embryonic executives who have not yet had an opportunity to develop their skills. Problem solving patterns remained non-significant in the analyses of variance and Duncan Multiple Range tests conducted. This is consistent with the findings of experiment 1.

Experiment 3 also supports hypothesis 3 in that no significant differences were found between problem solving patterns. However, hypothesis 2 was rejected when the group effect predicted did not materialize. Through an analysis of previous experiments, it was suspected that nominal group superiority was primarily due to a lack of sufficient time for real groups to adjust to initial inhibiting effects as well as the retarding effect of being unable to record ideas as fast as they are generated in the minds of the members. When a single individual records group responses, or tape recorders and dictaphones are used, one and only one subject can speak or write at a time; therefore, since members of nominal groups record their own solutions, they are not constrained by the requirement of a single outlet for their ideas. When time allotted for the problem was extended, it was predicted that nominal group superiority would diminish as real groups overcame psychological and physical constraints and that quantitative and qualitative output would be even more significantly superior for larger groups than it was in experiments conducted over shorter time intervals. Duncan Multiple Range tests confirmed part

of this expectation in that nominal groups of six were no longer superior to real groups of the same size when time was increased, but an analysis of variance provided an unexpected result when it showed that no significant group effect was present. A possible explanation as to why this occurred is discussed later in the chapter; however, since experiment 3 was not replicated, findings are inconclusive.

As predicted, hypotheses 4 and 5 were supported. Inspection of Figures 17 through 20 depicts the ideation rate to be approximately linear through the first 15 minutes then decreases over time. Figures 23 and 25 appear to show a downward trend in average cleverness over time while an increase seems evident in Figure 24. Analysis of variance presented in Tables 23 through 25 clearly supports hypothesis 5 by showing the lack of a significant difference over time when cleverness is treated as a main effect.

The results to this point might be summarized by stating that the larger the problem solving group, the longer the ideation session should be. This allows sufficient time to overcome initial inhibitory and administrative effects which normally prevent all members from contributing. If large numbers of individuals are to generate ideas on problems where adequate time is not available, independent individual effort later combined is the most effective strategy. The larger the group and the shorter the time, the greater the apparent superiority of this strategy over those involving group effort, or combinations of group and individual effort. All results of this research are summarized in Table 26.

Table 26. Summary of Findings

Hypothesis	Experiment 1				Experiment 2				Experiment 3						
	Quantita- tive Analysis	Qualita- tive Analysis			Quantita- tive Analysis	Qualita- tive Analysis			Quantita- tive Analysis	Qualita- tive Analysis					
		1	2	3		4	1	2		3	4	1	2	3	4
1. Quantitative and qualitative output of larger groups is significantly greater than that of the smaller ones when time allowed on the problem is limited to 50 minutes.	S	S	S	S	S	NS	NS	NS	NS	S**	‡	‡	NS**	‡	
2. Quantitative and qualitative output of larger groups increases faster than that of smaller ones when time limit is extended to 90 minutes.	‡	‡	‡	‡	‡	‡	‡	‡	‡	NS	NS	NS	NS	NS	
3. No significant difference exists between problem solving strategies at 50 or 90 minutes.	S	S	S	S	S	S	S	S	S	S	S	S	S	S	
4. Ideation rate does not vary with time for approximately the first 15 minutes, then begins decreasing as time is extended	S***	‡	‡	‡	‡	S***	‡	‡	‡	‡	S***	‡	‡	S***	‡
5. Average cleverness of group output per five minute interval remains constant over time for all group sizes and problem solving strategies.	S	‡	‡	‡	‡	S	‡	‡	‡	‡	S	‡	‡	‡	‡

NOTES:

Col. 1 = Feasibility as a Measure of Quality  
 Col. 2 = Effectiveness as a Measure of Quality  
 Col. 3 = Feasibility + Effectiveness as a Measure of Quality  
 Col. 4 = Feasibility x Effectiveness as a Measure of Quality

S = Hypothesis Supported  
 NS = Hypothesis Not Supported  
 ‡ = Not Applicable or Not Tested

\* =  $\alpha = .05$   
 \*\* = Time = 55 minutes  
 \*\*\* = see Figs. 17-20

Discussion

As mentioned above, the loss of a group effect in experiment 3 was totally unexpected; therefore, in an attempt to offer a possible explanation, the following is presented for consideration.

Suppose that, with any open ended problem, i.e., one having many possible solutions, there is a finite number of these solutions which could be defined by the boundary labeled C in Figure 26. Further, consider that the percentage of total solutions obtainable by a group is primarily a function of the background, experience, training, and ability of the members of that group.

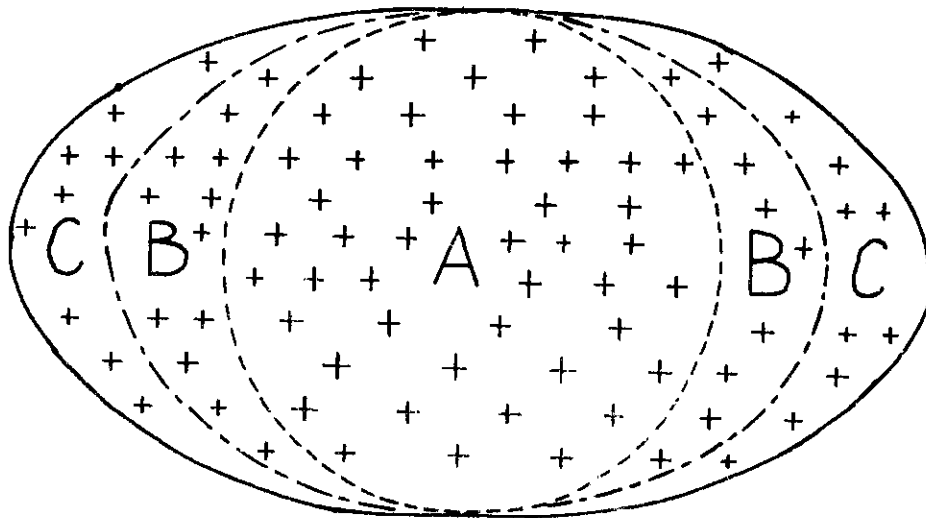


Figure 26. Set of All Possible Solutions Available  
for a Particular Problem

Therefore, the set of solutions defined by the boundary labeled A might be equivalent to the set that junior and senior industrial engineering and industrial management students are capable of generating, while the

boundary labeled B might describe the set that could be generated by more experienced executives. It seems reasonable to assume that, if a finite number of possible solutions exists for a particular population of subjects, larger groups will generate the set faster than smaller groups thus significantly outproducing the latter in the early stages of the ideation process. This occurred in experiment 1 as well as in many experiments described in Chapter II. As the number of available responses and solutions diminishes for a particular group, the ideation rate diminishes. This occurs more rapidly for larger groups than for smaller ones as the latter generate a significantly greater portion of the set at an earlier point in time. This, in effect, affords smaller groups an opportunity to catch up in terms of total output. Cumulative distribution functions depicted in Figures 19 and 20 appear to support this contention. Inspection of these curves shows smaller two-member groups to be generating ideas at a rate faster than the larger four- and six-member groups at times in excess of 55 minutes. An interesting test of the validity of this explanation would be to extend the allotted time for the problem beyond 90 minutes to determine if all curves would intersect at some distant point in time. If further experimentation showed this to be true, an interpretation of the results might, in effect be that the particular problem solving strategy or size of group is not as important in the generation of ideas as the man-hours of effort applied to the task. Larger groups will generate the solution set faster than smaller groups and the strategy of using nominal groups for very short periods of time appears to be more effective than the use of real groups for the same period; however, if time

is not a critical factor or manpower is scarce, smaller groups will accomplish the same objective if they are given sufficient time.

#### Recommendations

The effectiveness of groups versus that of combined independent individual effort has received considerable attention for the past several years. Most of the experiments have been conducted using one group size, typically consisting of four members, brainstorming a problem for a short period of time. No record is maintained of the rate, or flow of ideas, prior to or immediately after the point in time which is of interest to the experimenter. Therefore, the results while perfectly valid for 15, 20, 25, or 30 minutes for a particular group size, might not hold five minutes later. It goes without saying that using a different problem or changing conditions by using group leaders, providing training in brainstorming or similar techniques, or varying the composition of problem solving groups could alter the findings. In view of these considerations, the following experiments are recommended.

1. Replicate experiment 3 in order to separate interaction from the main effects thereby enabling a more complete analysis of the findings.

2. Replicate experiment 2 using a similar sample of executives for the same reason as stated above.

3. Extend the time allotted for the problem in experiment 3 to determine if the cumulative distribution functions in terms of quantity and quality of output converge for all group sizes at some later point in time.

4. Vary the tasks utilized in the experiments, but retain an

orientation toward realistic types of problems rather than those of the hypothetical or riddle-like type.

5. Investigate a possible biasing effect on members of groups utilizing problem solving pattern C involving individual effort preceded by group effort. There appeared to be a number of ideas in the individual phase that were simple restatements of ideas already presented by the group when the data were examined; however, the significance of this observation was not tested.

APPENDICES

APPENDIX I

INSTRUCTIONS TO SUBJECTS

## EXPERIMENT 1

## INSTRUCTIONS TO INDIVIDUALS

This is an experimental study in creative thinking using brainstorming as a technique. You have probably never worked on a problem in this way, so I will go over the procedure with you. The technique is a form of group interaction which is used to facilitate the flow of ideas. It is widely used in a large number of U.S. corporations generally when new, unique, original, and creative ideas are desired. It is not used to solve everyday problems. It is relatively straightforward and easy to comprehend. The following rules are for groups. You will be working alone. However, I would like you to apply these rules as best you can while working on the problem:

1. Criticism is ruled out. Adverse judgment of ideas must be withheld. There is a time for judicial thinking later. The fact that no one should criticize anyone else's ideas is clear for a group, but for an individual it means don't criticize any ideas that come to mind. Write down everything you think of.

2. Freewheeling is welcomed. The wilder the idea, the better. It is easier to tame down ideas than to think them up. Don't be afraid to write anything that comes to mind, the farther out the ideas, the better. This will stimulate more and better ideas.

3. Quantity is wanted. The greater the quantity of ideas, the more

likelihood of winners. Come up with as many as you can.

4. Combinations and improvements are sought. You should be willing to change suggestions you have written down. Don't be afraid to combine and improve on them. Let me repeat these rules. Now, the problem I would like you to consider has been distributed.

You will have approximately 50 minutes to work on it. Please record all ideas as they come to mind. At intervals of 5 minutes, I will ask you to draw a horizontal line below the last idea you have written, and then you are asked to continue with more ideas. In the event you have thought of nothing new since the previous signal, draw another line just the same.

Your efforts will be graded, and the results provided you and your instructor after the experiment is completed. Primary consideration in computation of scores will be the quantity of ideas generated, although quality will also be a factor.

You are asked not to discuss this experiment with anyone until you are furnished the results. All materials will be turned in to me at the end of the experiment.

Are there any questions before we begin?

## EXPERIMENT 1

## INSTRUCTIONS TO GROUPS

This is an experimental study in creative thinking using brainstorming as a technique. You have probably never worked on a problem in this way, so I will go over the procedure with you. The technique is a form of group interaction which is used to facilitate the flow of ideas. It is widely used in a large number of U. S. corporations generally when new, unique, original, and creative ideas are desired. It is not used to solve everyday problems. It is relatively straightforward and easy to comprehend. The following rules are to be observed:

1. Criticism is ruled out. Adverse judgment of ideas must be withheld. There is a time for judicial thinking later. Anyone who criticizes will cause a penalty to be incurred resulting in a reduction of the team score. Before you has been placed a list of "killer" phrases, so named because they are extremely effective in discouraging ideas. These are examples of the types of statements that will be counted against the team score if they are spoken.

2. Freewheeling is welcomed. The wilder the idea, the better. It is easier to tame down ideas than to think them up. Don't be afraid to say anything that comes to mind; the farther out the ideas, the better. A "can-you-top-this?" attitude often stimulates other participants to generate more and better ideas.

3. Quantity is wanted. The greater the quantity of ideas, the more likelihood of winners. Come up with as many as you can.

4. Combinations and improvements are sought. Since ideas are like building blocks, team members are encouraged to suggest how other's ideas can be made better--or, how two or more ideas can be turned into one idea that's still better than one alone. Let me repeat the rules. Now, the problem I would like you to consider has been distributed.

You will have approximately 50 minutes to work on it. Please have a member of your group record all ideas as they are originated. At intervals of five minutes, I will ask you to draw a horizontal line below the last idea you have written, and then you are asked to continue with more ideas. In the event you have thought of nothing new since the previous signal, draw another line just the same.

Your efforts will be graded, and the results provided you and your instructor after the experiment is completed. Primary consideration in the computation of scores will be the quantity of ideas generated, although quality will also be a factor. You are asked not to discuss this experiment with anyone until you are furnished the results. All materials will be turned in to me at the end of the experiment.

Are there any questions before we begin?

## EXPERIMENT 1

## INSTRUCTIONS TO GROUP-INDIVIDUALS

This is an experimental study in creative thinking using brainstorming as a technique. You have probably never worked on a problem in this way, so I will go over the procedure with you. The technique is a form of group interaction which is used to facilitate the flow of ideas. It is widely used in a large number of U. S. corporations generally when new, unique, original, and creative ideas are desired. It is not used to solve everyday problems. It is relatively straightforward and easy to comprehend. The following rules are for groups. You will be working with your group for the first half of the session and then alone for the second half. However, I would like you to apply these rules as best you can while working on the problem:

1. Criticism is ruled out. Adverse judgment of ideas must be withheld. There is a time for judicial thinking later. The fact that no one should criticize anyone else's ideas is clear for a group, but for an individual, it means don't criticize any ideas that come to mind. Write down everything you think of. Anyone who criticizes the ideas of others will cause a penalty to be incurred resulting in a reduction of the overall score. Before you has been placed a list of "killer" phrases," so named because they are extremely effective in discouraging ideas. These are examples of the types of statements that will be counted against the team score if they are spoken.

2. Freewheeling is welcomed. Don't be afraid to record anything that comes to mind either in the group or individual portion of the session, the farther out the ideas the better. This will stimulate more and better ideas.

3. Quantity is wanted. The greater the quantity of ideas, the more likelihood of winners. Come up with as many as you can.

4. Combinations and improvements are sought. Since ideas are like building blocks, you should be willing to change the suggestions you have written down, while working alone, as well as suggest how other ideas can be made better--or how two or more ideas can be turned into one idea that's still better when participating as a member of a team. Let me repeat these rules. Now, the problem I would like you to consider has been distributed.

You will have approximately 30 minutes to work on the problem as a member of a problem solving group followed by approximately 20 minutes of individual effort. A copy of the list of ideas generated by the group will be provided for your use during this latter period. Please record all ideas as they come to mind. At intervals of five minutes, I will ask you to draw a horizontal line below the last idea you have written, and then you are asked to continue with more ideas. In the event you have thought of nothing new since the previous signal, draw another line just the same.

Your efforts will be graded, and the results provided you and your instructor after the experiment is completed. Primary consideration in computation of scores will be quantity of ideas generated, although

quality will also be a factor. You are asked not to discuss the experiment with anyone until you are furnished the results. All materials will be turned in to me at the end of the experiment.

Are there any questions before we begin?

## EXPERIMENT 1

## INSTRUCTIONS TO INDIVIDUALS-GROUPS

This is an experimental study in creative thinking using brainstorming as a technique. You have probably never worked on a problem in this way, so I will go over the procedure with you. The technique is a form of group interaction which is used to facilitate the flow of ideas. It is widely used in a large number of U. S. corporations generally when new, unique, original, and creative ideas are desired. It is not used to solve everyday problems. It is relatively straightforward and easy to comprehend. The following rules are for groups. You will be working alone for the first half of the session and then with your group for the second half. However, during the time you are working alone, I would like you to apply these rules as best you can while working on the problem:

1. Criticism is ruled out. Adverse judgment of ideas must be withheld. There is a time for judicial thinking later. The fact that no one should criticize anyone else's ideas is clear for a group, but for an individual it means don't criticize any ideas that come to mind. Write down everything you think of. Anyone who criticizes the ideas of others will cause a penalty to be incurred resulting in a reduction of the overall score. Before you has been placed a list of "killer" phrases, so named because they are extremely effective in discouraging ideas. These are examples of the types of statements that will be counted against the

team score if they are spoken.

2. Freewheeling is welcomed. Don't be afraid to record anything that comes to mind either in the group or individual portion of the session, and the farther out the ideas the better. This will stimulate more and better ideas.

3. Quantity is wanted. The greater the quantity of ideas, the more likelihood of winners. Come up with as many as you can.

4. Combinations and improvements are sought. Since ideas are like building blocks, you should be willing to change the suggestions you have written down, while working alone, as well as suggest how other ideas can be made better--or how two or more ideas can be turned into one idea that's still better when participating as a member of a group. Let me repeat these rules. Now, the problem I would like you to consider has been distributed.

You will have approximately 30 minutes to work on it individually, then 20 minutes as a member of a problem solving group. Please record all ideas as they come to mind. During the initial 30 minutes, you are to record your ideas in a sufficient number of copies such that each team member will have one during the 20 minute group session. If you discover duplication of ideas during the group session, do not erase or eliminate these ideas from the initial individual lists. Please have a member of your group record all ideas on a separate list as they are generated. At intervals of five minutes, I will ask you to draw a horizontal line below the last idea you have written, and then you are asked to continue with more ideas. In the event you have thought of nothing new since the previous signal, draw another line just the same.

Your efforts will be graded, and the results provided you and your instructor after the experiment is completed. Primary consideration in computation of scores will be the quantity of ideas generated, although quality will also be a factor. You are asked not to discuss this experiment with anyone until you are furnished the results. All materials will be turned in to me at the end of the experiment.

Are there any questions before we begin?

## EXPERIMENT 2

## INSTRUCTIONS TO INDIVIDUALS

This is an experimental study in creative thinking using brainstorming as a technique. You have probably never worked on a problem in this way, so I will go over the procedure with you. The technique is a form of group interaction which is used to facilitate the flow of ideas. It is widely used in a large number of U. S. corporations generally when new, unique, original, and creative ideas are desired. It is not used to solve everyday problems. It is relatively straightforward and easy to comprehend. The following rules are for groups. You will be working alone. However, I would like you to apply these rules as best you can while working on the problem:

1. Criticism is ruled out. Adverse judgment of ideas must be withheld. There is a time for judicial thinking later. The fact that no one should criticize anyone else's ideas is clear for a group, but for an individual it means don't criticize any ideas that come to mind. Write down everything you think of.

2. Freewheeling is welcomed. The wilder the idea, the better. It is easier to tame down ideas than to think them up. Don't be afraid to write anything that comes to mind, the farther out the ideas the better. This will stimulate more and better ideas.

3. Quantity is wanted. The greater the quantity of ideas, the

more likelihood of winners. Come up with as many as you can.

4. Combinations and improvements are sought. You should be willing to change suggestions you have written down. Don't be afraid to combine and improve on them. Let me repeat these rules. Now, the problem I would like you to consider has been distributed.

You will have approximately 50 minutes to work on it. Please record all ideas as they come to mind. At intervals of five minutes I will ask you to draw a horizontal line below the last idea you have written, and then you are asked to continue with more ideas. In the event you have thought of nothing new since the previous signal, draw another line just the same.

Are there any questions before we begin?

## EXPERIMENT 2

### INSTRUCTIONS TO GROUPS

This is an experimental study in creative thinking using brainstorming as a technique. You have probably never worked on a problem in this way, so I will go over the procedure with you. The technique is a form of group interaction which is used to facilitate the flow of ideas. It is widely used in a large number of U. S. corporations generally when new, unique, original, and creative ideas are desired. It is not used to solve everyday problems. It is relatively straightforward and easy to comprehend. The following rules are to be observed:

1. Criticism is ruled out. Adverse judgment of ideas must be withheld. There is a time for judicial thinking later. Anyone who criticizes will cause a penalty to be incurred resulting in a reduction of the team score. Before you has been placed a list of "killer" phrases, so named because they are extremely effective in discouraging ideas. These are examples of the types of statements that will be counted against the team score if they are spoken.

2. Freewheeling is welcomed. The wilder the idea, the better. It is easier to tame down ideas than to think them up. Don't be afraid to say anything that comes to mind; the farther out the ideas, the better. A "can-you-top-this?" attitude often stimulates other participants to generate more and better ideas.

3. Quantity is wanted. The greater the quantity of ideas, the more likelihood of winners. Come up with as many as you can.

4. Combinations and improvements are sought. Since ideas are like building blocks, team members are encouraged to suggest how other's ideas can be made better--or, how two or more ideas can be turned into one idea that's still better than one alone. Let me repeat the rules. Now, the problem I would like you to consider has been distributed.

You will have approximately 50 minutes to work on it. Please have a member of your group record all ideas as they are originated. At intervals of five minutes, I will ask you to draw a horizontal line below the last idea you have written, and then you are asked to continue with more ideas. In the event you have thought of nothing new since the previous signal, draw another line just the same.

Are there any questions before we begin?

## EXPERIMENT 2

## INSTRUCTIONS TO GROUP-INDIVIDUALS

This is an experimental study in creative thinking using brainstorming as a technique. You have probably never worked on a problem in this way, so I will go over the procedure with you. The technique is a form of group interaction which is used to facilitate the flow of ideas. It is widely used in a large number of U. S. corporations generally when new, unique, original, and creative ideas are desired. It is not used to solve everyday problems. It is relatively straightforward and easy to comprehend. The following rules are for groups. You will be working with your group for the first half of the session and then alone for the second half. However, I would like you to apply these rules as best you can while working on the problem:

1. Criticism is ruled out. Adverse judgment of ideas must be withheld. There is a time for judicial thinking later. The fact that no one should criticize anyone else's ideas is clear for a group, but for an individual, it means don't criticize any ideas that come to mind. Write down everything you think of. Anyone who criticizes the ideas of others will cause a penalty to be incurred resulting in a reduction of the overall score. Before you has been placed a list of "killer" phrases, so named because they are extremely effective in discouraging ideas. These are examples of the types of statements that will be counted against the team score if they are spoken.

2. Freewheeling is welcomed. Don't be afraid to record anything that comes to mind either in the group or individual portion of the session, the farther out the ideas the better. This will stimulate more and better ideas.

3. Quantity is wanted. The greater the quantity of ideas, the more likelihood of winners. Come up with as many as you can.

4. Combinations and improvements are sought. Since ideas are like building blocks, you should be willing to change the suggestions you have written down, while working alone, as well as suggest how other ideas can be made better--or how two or more ideas can be turned into one idea that's still better when participating as a member of a group. Let me repeat these rules. Now, the problem I would like you to consider has been distributed.

You will have approximately 30 minutes to work on the problem as a member of a problem solving group followed by approximately 20 minutes of individual effort. A copy of the list of ideas generated by the group will be provided for your use during this latter period. Please record all ideas as they come to mind. At intervals of five minutes, I will ask you to draw a horizontal line below the last idea you have written, and then you are asked to continue with more ideas. In the event you have thought of nothing new since the previous signal, draw another line just the same.

Are there any questions before we begin?

## EXPERIMENT 2

## INSTRUCTIONS TO INDIVIDUALS-GROUPS

This is an experimental study in creative thinking using brainstorming as a technique. You have probably never worked on a problem in this way, so I will go over the procedure with you. The technique is a form of group interaction which is used to facilitate the flow of ideas. It is widely used in a large number of U. S. corporations generally when new, unique, original, and creative ideas are desired. It is not used to solve everyday problems. It is relatively straightforward and easy to comprehend. The following rules are for groups. You will be working alone for the first half of the session and then with your group for the second half. However, during the time you are working alone, I would like you to apply these rules as best you can while working on the problem:

1. Criticism is ruled out. Adverse judgment of ideas must be withheld. There is a time for judicial thinking later. The fact that no one should criticize anyone else's ideas is clear for a group, but for an individual it means don't criticize any ideas that come to mind. Write down everything you think of. Anyone who criticizes the ideas of others will cause a penalty to be incurred resulting in a reduction of the overall score. Before you has been placed a list of "killer" phrases, so named because they are extremely effective in discouraging ideas. These are examples of the types of statements that will be counted against the team score if they are spoken.

2. Freewheeling is welcomed. Don't be afraid to record anything that comes to mind either in the group or individual portion of the session, and the farther out the ideas the better. This will stimulate more and better ideas.

3. Quantity is wanted. The greater the quantity of ideas, the more likelihood of winners. Come up with as many as you can.

4. Combinations and improvements are sought. Since ideas are like building blocks, you should be willing to change the suggestions you have written down, while working alone, as well as suggest how other ideas can be made better--or how two or more ideas can be turned into one idea that's still better when participating as a member of a group. Let me repeat these rules. Now, the problem I would like you to consider has been distributed.

You will have approximately 30 minutes to work on it individually, then 20 minutes as a member of a problem solving team. Please record all ideas as they come to mind. During the initial 30 minutes, you are to record your ideas in a sufficient number of copies such that each group member will have one during the 20 minute team session. If you discover duplication of ideas during the group session, do not erase or eliminate these ideas from the initial individual lists. Please have a member of your group record all ideas on a separate list as they are generated. At intervals of five minutes, I will ask you to draw a horizontal line below the last idea you have written, and then you are asked to continue with more ideas. In the event you have thought of nothing new since the previous signal, draw another line just the same.

Are there any questions before we begin?

## EXPERIMENT 3

## INSTRUCTIONS TO INDIVIDUALS

This is an experimental study in creative thinking using brainstorming as a technique. You have probably never worked on a problem in this way, so I will go over the procedure with you. The technique is a form of group interaction which is used to facilitate the flow of ideas. It is widely used in a large number of U. S. corporations generally when new, unique, original, and creative ideas are desired. It is not used to solve everyday problems. It is relatively straightforward and easy to comprehend. The following rules are for groups. You will be working alone. However, I would like you to apply these rules as best you can while working on the problem:

1. Criticism is ruled out. Adverse judgment of ideas must be withheld. There is a time for judicial thinking later. The fact that no one should criticize anyone else's ideas is clear for a group, but for an individual it means don't criticize any ideas that come to mind. Write down everything you think of.

2. Freewheeling is welcomed. The wilder the idea, the better. It is easier to tame down ideas than to think them up. Don't be afraid to write anything that comes to mind, the farther out the ideas the better. This will stimulate more and better ideas.

3. Quantity is wanted. The greater the quantity of ideas, the more likelihood of winners. Come up with as many as you can.

4. Combinations and improvements are sought. You should be willing to change suggestions you have written down. Don't be afraid to combine and improve on them. Let me repeat these rules. Now, the problem I would like you to consider has been distributed.

You will have approximately 90 minutes to work on it. Please record all ideas as they come to mind. At intervals of five minutes, I will ask you to draw a horizontal line below the last idea you have written, and then you are asked to continue with more ideas. In the event you have thought of nothing new since the previous signal, draw another line just the same.

Your efforts will be graded, and the results provided you and your instructor after the experiment is completed. Primary consideration in computation of scores will be the quantity of ideas generated, although quality will also be a factor.

You are asked not to discuss this experiment with anyone until you are furnished the results. All materials will be turned in to me at the end of the experiment.

Are there any questions before we begin?

## EXPERIMENT 3

### INSTRUCTIONS TO GROUPS

This is an experimental study in creative thinking using brainstorming as a technique. You have probably never worked on a problem in this way, so I will go over the procedure with you. The technique is a form of group interaction which is used to facilitate the flow of ideas. It is widely used in a large number of U. S. corporations generally when new, unique, original, and creative ideas are desired. It is not used to solve everyday problems. It is relatively straightforward and easy to comprehend. The following rules are to be observed:

1. Criticism is ruled out. Adverse judgment of ideas must be withheld. There is a time for judicial thinking later. Anyone who criticizes will cause a penalty to be incurred resulting in a reduction of the team score. Before you has been placed a list of "killer" phrases, so named because they are extremely effective in discouraging ideas. These are examples of the types of statements that will be counted against the team score if they are spoken.

2. Freewheeling is welcomed. The wilder the idea, the better. It is easier to tame down ideas than to think them up. Don't be afraid to say anything that comes to mind; the farther out the ideas, the better. A "can-you-top-this?" attitude often stimulates other participants to generate more and better ideas.

3. Quantity is wanted. The greater the quantity of ideas, the

more likelihood of winners. Come up with as many as you can.

4. Combinations and improvements are sought. Since ideas are like building blocks, team members are encouraged to suggest how other's ideas can be made better--or, how two or more ideas can be turned into one idea that's still better than one alone. Let me repeat the rules. The problem I would like you to consider has been distributed.

You will have approximately 90 minutes to work on it. Please have a member of your group record all ideas as they are originated. At intervals of five minutes, I will ask you to draw a horizontal line below the last idea you have written, and then you are asked to continue with more ideas. In the event you have thought of nothing new since the previous signal, draw another line just the same.

Your efforts will be graded, and the results provided you and your instructor after the experiment is completed. Primary consideration in the computation of scores will be the quantity of ideas generated, although quality will also be a factor. You are asked not to discuss this experiment with anyone until you are furnished the results. All materials will be turned in to me at the end of the experiment.

Are there any questions before we begin?

## EXPERIMENT 3

## GROUP-INDIVIDUAL-GROUP

This is an experimental study in creative thinking using brainstorming as a technique. You have probably never worked on a problem in this way, so I will go over the procedure with you. The technique is a form of group interaction which is used to facilitate the flow of ideas. It is widely used in a large number of U. S. corporations generally when new, unique, original, and creative ideas are desired. It is not used to solve everyday problems. It is relatively straightforward and easy to comprehend. The following rules are for groups. You will be working together for the first 30 minutes, then individually for the next 40 minutes, and again as a group for the remaining 20 minutes. During the time you are working alone, as well as together, I would like you to apply these rules as best you can.

1. Criticism is ruled out. Adverse judgment of ideas must be withheld. There is a time for judicial thinking later. Anyone who criticizes will cause a penalty to be incurred resulting in a reduction of the team score. Before you has been placed a list of "killer" phrases, so named because they are extremely effective in discouraging ideas. These are examples of the types of statements that will be counted against the team score if they are spoken.

2. Freewheeling is welcomed. The wilder the idea, the better. It is easier to tame down ideas than to think them up. Don't be afraid

to say anything that comes to mind; the farther out the ideas, the better. A "can-you-top-this?" attitude often stimulates other participants to generate more and better ideas.

3. Quantity is wanted. The greater the quantity of ideas, the more likelihood of winners. Come up with as many as you can.

4. Combinations and improvements are sought. Since ideas are like building blocks, group members are encouraged to suggest how other's ideas can be made better--or, how two or more ideas can be turned into one idea that's still better than one alone. Let me repeat the rules. The problem I would like you to consider has been distributed.

During the initial 30 minute period, please have a member of your team record all ideas on a separate list in sufficient copies so that each individual will have a record of all ideas generated for the 40 minutes of individual effort. During the final 20 minutes of group session, if you discover duplication of ideas, do not eliminate these ideas from the lists. Again, please have a member of your group record all ideas on a separate list. At intervals of five minutes, I will ask you to draw a horizontal line below the last idea you have written, and then you are asked to continue with more ideas. In the event you have thought of nothing new since the previous signal, draw another line just the same.

Your efforts will be graded, and the results provided you and your instructor after the experiment is completed. Primary consideration in the computation of scores will be the quantity of ideas generated, although quality will also be a factor. You are asked not to discuss this experiment with anyone until you are furnished the results. All materials will

be turned in to me after the experiment.

Are there any questions before we begin?

## EXPERIMENT 3

## INDIVIDUALS-GROUPS-INDIVIDUALS

This is an experimental study in creative thinking using brainstorming as a technique. You have probably never worked on a problem in this way, so I will go over the procedure with you. The technique is a form of group interaction which is used to facilitate the flow of ideas. It is widely used in a large number of U. S. corporations generally when new, unique, original, and creative ideas are desired. It is not used to solve everyday problems. It is relatively straightforward and easy to comprehend. The following rules are for groups. You will be working alone for the first 30 minutes, then as a group for the next 40 minutes and finally, complete the session with another 20 minutes of individual effort. During the time you are working alone, as well as with your group, I would like you to apply these rules as best you can:

1. Criticism is ruled out. Adverse judgment of ideas must be withheld. There is a time for judicial thinking later. Anyone who criticizes will cause a penalty to be incurred resulting in a reduction of the group score. Before you has been placed a list of "killer" phrases, so named because they are extremely effective in discouraging ideas. These are examples of the types of statements that will be counted against the team score if they are spoken.

2. Freewheeling is welcomed. The wilder the idea, the better. It is easier to tame down ideas than to think them up. Don't be afraid

to say anything that comes to mind; the farther out the ideas, the better. A "can-you-top-this?" attitude often stimulates other participants to generate more and better ideas.

3. Quantity is wanted. The greater the quantity of ideas, the more likelihood of winners. Come up with as many as you can.

4. Combinations and improvements are sought. Since ideas are like building blocks, group members are encouraged to suggest how other's ideas can be made better--or, how two or more ideas can be turned into one idea that's still better than one alone. Let me repeat the rules. The problem I would like you to consider has been distributed.

During the initial 30 minute period, you are to record your ideas on the sheets provided. During the 40 minutes of group effort please have a member of your group record all ideas on a separate list in sufficient copies such that each individual will have a record of all ideas generated for the final 20 minutes of individual effort.

At intervals of five minutes, I will ask you to draw a horizontal line below the last idea you have written, and then you are asked to continue with more ideas. In the event you have thought of nothing new since the previous signal, draw another line just the same.

Your efforts will be graded, and the results provided you and your instructor after the experiment is completed. Primary consideration in the computation of scores will be the quantity of ideas generated, although quality will also be a factor. You are asked not to discuss this experiment with anyone until you are furnished the results. All materials will be handed in to me after the experiment.

Are there any questions before we begin?

## APPENDIX II

## "KILLER" PHRASES

That has been tried before.

That's ridiculous.

That's too radical.

Let's form a committee to consider it.

That's contrary to policy.

Has anyone ever tried it?

It won't work.

That's too obvious to be considered.

It will never sell.

That's interesting, but there isn't enough time or manpower  
available to accomplish it.

That's not the kind of idea we expect from you.

Tell me right now--what potential does it have?

## APPENDIX III

IDEAS GENERATED AS SUGGESTED IMPROVEMENTS  
TO SUGAR STORAGE AND HANDLING PROBLEM

1. Load all bags to rear of delivery truck.
2. Conveyor-truck to loading dock.
3. Ramp-truck to loading dock.
4. Worker No. 2 place hand truck closer to delivery truck.
5. Hand, rather than toss bags to second worker.
6. Conveyor-truck to elevator.
7. Handtruck, pallet or cart - pushed or driven from truck to elevator.
8. "Bucket brigade" - truck to elevator to storage.
9. Increase the work force by one or more workers.
10. Decrease the work force by one worker.
11. Decrease the work force by two workers.
12. Decrease the work force by three workers.
13. Contract handling of sugar to independent operator.
14. Prepackage sugar in containers or on pallets which can be pushed or driven to elevator and permanent storage.
15. Worker No. 2 load pallet in elevator from handtruck.
16. Use a "dumb-waiter" or vertical conveyor to lower pallets to basement.
17. Conveyor, cart, dolly, forklift, or handtruck - elevator (in basement) to storage area.

18. Increase number of bags per handtruck trip, or increase capacity of handtruck.
19. Use more than one handtruck, cart, or forklift.
20. Increase capacity of the elevator, or place more bags per load on it.
21. Decrease load on the elevator, or send it to basement with each handtruck load.
22. Place an elevator door on side facing unloading dock and permanent storage area.
23. Place an elevator door on side facing office and temporary storage area.
24. Re-position elevator on dock or allow truck to back to elevator door.
25. Re-position elevator closer to filling machine.
26. Conveyor or chute - truck to temporary storage.
27. Conveyor or chute - truck to permanent storage.
28. Utilize a device which automatically receives and stores bags, barrels, drums and pallets.
29. Ramp or stairway - from truck to basement, large enough for forklift, handtruck, man, or animal to walk or ride down on with bags.
30. Tear open bags manually or automatically and pour sugar down chute to storage bin.
31. Construct a driveway or ramp to basement, or lower truck by hydraulic lift to basement storage area.
32. Lower sugar through hole in floor to permanent storage using overhead crane.
33. Transfer powdered, granulated bulk, or liquid sugar from truck,

- railway, or other conveyance to storage bin by chute or pipeline.
34. Use conveyance (truck, railway car, Sealand van, boat, etc.) as a storage area, and directly feed process as required.
  35. Ship sugar by a conveyance other than truck e.g., helicopter, boat, rail, etc.
  36. Pump sugar (liquified or granulated) direct from distributor to user as required.
  37. Provide conveyance (conveyor, chute, pipeline, etc.) from storage bin to next point of use (cooking room).
  38. Produce syrup at a central location and pipe into bottling plant.
  39. Use a sugar substitute, concentrate, capsule, or provide a diet or sugarless soft drink.
  40. Relocate permanent storage to first floor.
  41. Relocate permanent or temporary storage anywhere in basement.
  42. Relocate permanent storage on roof - employ gravity feed to cooking room.
  43. Relocate storage in an adjacent or underground silo, grain elevator, or similar facility.
  44. Store sugar between walls of current building.
  45. Eliminate, or reduce use of temporary storage. Combine with permanent storage.
  46. Increase size of permanent or temporary storage areas.
  47. Leave sugar stored on roller conveyor system in building.
  48. Reduce or eliminate the need for storage through smaller, more frequent deliveries or increased output.

49. Maintain a First-In-First-Out system as part of the storage procedures.
50. Employ a meter or monitor to record usage rate and on-hand inventory balances.
51. Relocate filling machine to first floor.
52. Relocate cooking room and equipment to basement.
53. Relocate office.
54. Relocate loading dock to rear of building by cooking room, or move cooking room to current office location.
55. Sell the business.
56. Purchase bottled product - just deliver.
57. Increase quantity of sugar delivered at a time in order to handle less frequently.
58. Just produce syrup - do not bottle.
59. Alter current duties of workers by rotating duties or work stations.
60. Improve environment and increase motivation through installation of air-conditioning, music, lounges, regular breaks, refreshments, wage incentive plan, etc.
61. Improve efficiency by providing labor saving devices such as light handtrucks, smaller sugar bags, materials handling training programs, etc.
62. Hire cheapest labor available.
63. Seek assistance in redesigning plant layout by hiring a consultant, seeking employee ideas, or initiating a Suggestion Award system.
64. Employ automatic feed between cooking room and filling and capping machine.

65. Send bottled product to delivery vehicle by conveyors.
66. Build a completely automated plant with conveyors which unload, load, and maintain usage rate and inventory data.
67. Locate plant next to sugar fields or refinery or grow and refine sugar.
68. Convert sugar to energy. Transmit it to bottling plant, then convert back to sugar.
69. Convert sugar to vapor. Transmit it to bottling plant in the form of a gas, then convert back to sugar.
70. Use mechanical robots or devices to unload conveyances.
71. Don't change current system - leave as is.
72. Perform bottling operation on conveyance delivering soft drink.
73. House operations in more than one building, or erect a multi-level structure with storage on 3rd floor, cooking on 2nd floor, bottling on ground level. Employ gravity feed from 3rd to 2nd to 1st floor.
74. Eliminate wasted space to left of cooking room.
75. Idea is illogical, absurd, or bears no relation to problem under study.

## APPENDIX IV

DESCRIPTION OF ATTRIBUTES UTILIZED IN QUALITATIVE ANALYSIS  
OF SUGGESTED IMPROVEMENTS

**Feasibility:** capable of immediate implementation, given the current technology and operating conditions of the problem.

**Effectiveness:** impressive; will improve current procedures resulting in a probable reduction of overall operating costs.

**Cleverness:** suggestion indicates practical intelligence, mental quickness, and resourcefulness.

**Future Effectiveness:** will probably improve current procedures resulting in overall cost reduction once technological and/or operational obstacles are overcome.

APPENDIX V

QUALITATIVE RATINGS OF FIVE JUDGES ON SUGGESTED IMPROVEMENTS TO THE SUGAR  
HANDLING AND STORAGE PROBLEM

Idea No.	Feasibility						Effectiveness						Cleverness						Future Effectiveness					
	Rater	1	2	3	4	5	Avg.	1	2	3	4	5	Avg.	1	2	3	4	5	Avg.	1	2	3	4	5
1		5	5	5	5	5	5	1	1	1	2	2	1.4	1	1	1	2	2	1.4	1	1	1	2	2
		5	5	5	2	5	4.6																	
2		5	5	5	5	5	5	2	2	3	3	3	2.6	1	1	2	3	3	2	2	2	2	3	2
3		5	5	5	5	5	5	2	2	2	3	2	2.2	1	1	2	3	3	2	2	2	1	3	2
4		5	5	5	5	5	5	1	2	2	3	1	1.8	1	1	1	3	1	1.4	1	2	2	3	1
5		5	5	5	5	5	5	1	2	1	1	1	1.2	1	1	1	3	1	1.4	1	2	1	1	1
6		5	5	5	5	5	5	2	3	3	3	4	3	2	2	3	2	3	2.6	2	2	2	3	4
														1	2	2	4	4	2.4					
7		5	5	5	5	3	4.6	2	3	3	3	2	2.6	1	2	2	3	3	2.2	2	2	2	3	2
8		5	5	5	5	3	4.6	1	2	2	2	1	1.6	1	2	1	3	1	1.6	1	1	1	2	1
9		5	4	5	5	5	4.8	1	2	2	2	3	2	1	1	1	3	3	1.8	1	2	1	2	2
10		5	3	5	5	5	4.6	2	1	1	2	1	1.4	1	2	1	3	1	1.6	2	1	1	2	1
11		5	3	3	5	5	4.2	2	1	1	2	1	1.4	1	2	1	3	1	1.6	2	1	1	2	1
		5	2	1	5	5	3.6																	

APPENDIX V (Continued)

Rater	Feasibility						Effectiveness						Cleverness						Future Effectiveness				
	1	2	3	4	5	Avg.	1	2	3	4	5	Avg.	1	2	3	4	5	Avg.	1	2	3	4	5
Idea No.																							
12	1	1	1	1	1	1	3	1	1	2	1	1.6	1	1	1	3	1	1.4	3	1	1	2	1
13	4	3	5	5	4	4.2	1	2	1	2	3	1.8	1	3	1	2	3	2	1	1	1	2	3
14	5	4	5	4	4	4.4	4	3	3	2	4	3.2	2	3	3	4	4	3.2	4	3	3	3	3
15	5	5	5	5	5	5	2	2	1	3	2	2	1	2	1	3	2	1.8	2	2	1	3	1
16	5	3	5	4	5	4.4	4	4	3	2	4	3.4	2	4	2	3	4	3	4	4	3	2	4
17	5	5	5	5	5	5	3	3	2	3	2	2.6	2	2	2	4	2	2.4	3	3	1	3	1
18	5	5	5	5	4	4.8	2	2	3	3	4	2.8	1	2	1	3	2	1.8	2	2	2	3	1
19	5	5	5	5	3	4.6	1	2	3	3	3	2.4	1	2	2	3	2	2	1	2	2	3	1
20	5	3	3	3	3	3.4	1	2	1	3	3	2	1	2	2	3	2	2	1	2	1	3	1
21	5	5	5	5	4	4.8	1	2	2	2	3	2	1	2	1	3	2	1.8	1	1	1	2	1
22	5	4	5	3	4	4.2	1	2	3	3	2	2.2	2	3	4	4	3	3.2	1	2	3	3	1
23	5	4	5	3	4	4.2	1	2	2	3	2	2	2	3	3	4	3	3	1	2	2	3	1
24	5	3	4	3	4	3.8	3	4	4	3	4	3.6	2	3	3	4	4	3.2	3	3	3	3	3
25	5	3	3	3	4	3.6	1	1	1	1	2	1.2	1	1	2	3	2	1.8	1	1	1	1	1
26	5	3	4	4	4	4	3	3	2	4	4	3.2	2	2	2	4	4	2.8	3	2	2	4	5

APPENDIX V (Continued)

Rater	Feasibility						Effectiveness						Cleverness						Future Effectiveness				
	1	2	3	4	5	Avg.	1	2	3	4	5	Avg.	1	2	3	4	5	Avg.	1	2	3	4	5
Idea No.																							
27	5	3	4	4	4	4	4	3	3	4	3	3.4	2	2	2	4	3	2.6	4	2	2	4	3
28	4	3	2	3	2	2.8	4	4	4	2	4	3.6	3	4	3	4	3	3.4	5	4	4	3	5
29	5	3	4	3	4	3.8	4	3	4	3	3	3.4	3	4	2	4	2	3	4	3	1	4	1
30	5	3	4	4	4	4	4	3	3	4	4	3.6	3	3	4	4	5	3.8	4	3	1	4	5
31	5	3	4	3	3	3.6	4	3	3	3	4	3.4	3	3	2	4	4	3.2	4	3	1	4	4
32	5	3	3	3	3	3.4	3	3	2	2	3	2.6	4	4	3	3	4	3.6	2	3	1	2	2
33	4	3	4	4	3	3.6	5	4	3	5	5	3.4	4	3	4	4	5	4	5	4	2	5	5
34	4	3	3	3	2	3	5	5	4	3	3	4	5	5	4	5	3	4.4	5	4	4	4	2
35	4	3	2	3	2	2.8	3	1	1	2	1	1.6	3	2	3	4	2	2.8	3	2	1	4	1
36	3	2	-	2	1	2	3	4	3	2	4	3.2	5	5	-	5	5	5	5	5	-	3	5
37	4	3	4	5	3	3.8	2	3	3	4	2	2.8	2	3	2	3	2	2.4	2	3	2	4	2
38	3	2	3	3	1	2.4	5	5	4	3	3	4	5	5	4	5	4	4.6	5	5	3	4	5
39	3	3	2	1	1	2	3	3	1	3	1	2.2	5	3	3	4	3	3.6	4	3	1	4	1
40	5	4	4	5	3	4.2	2	3	2	4	2	2.6	3	2	2	3	1	2.2	2	3	1	5	1
41	5	5	5	5	4	4.8	1	2	1	3	1	1.6	1	2	1	3	1	1.6	1	2	1	3	1

APPENDIX V (Continued)

Rater	Feasibility						Effectiveness						Cleverness						Future Effectiveness				
	1	2	3	4	5	Avg.	1	2	3	4	5	Avg.	1	2	3	4	5	Avg.	1	2	3	4	5
Idea No.																							
42	3	3	3	3	2	2.8	3	3	2	2	1	2.2	4	3	4	3	2	3.4	4	3	2	4	1
	5	3	2	3	1	2.8	4	3	2	2	1	2.4	5	4	3	4	1	3.4					
43	5	3	3	3	3	3.4	3	3	2	2	2	2.4	4	3	3	4	4	3.6	3	2	1	3	3
44	3	1	1	1	1	1.4	2	1	1	2	1	1.4	5	5	3	4	3	4	2	1	1	3	1
45	5	5	4	4	5	4.6	5	3	3	3	3	3.4	3	2	3	3	3	2.8	3	2	2	3	3
													1	2	3	4	4	2.8					
46	5	4	4	4	4	4.2	1	2	2	3	3	2.2	1	2	2	3	2	2	1	2	1	3	1
47	5	3	3	4	3	3.6	4	3	3	4	2	3.2	3	4	4	4	2	3.4	3	2	2	5	1
48	5	3	3	3	5	3.8	3	4	3	3	2	3	4	3	2	4	2	3	5	2	1	3	1
							5	3	2	3	2	3											
49	4	5	5	4	5	4.6	4	2	2	3	3	2.8	3	3	2	4	3	3	4	2	1	3	2
50	5	4	5	3	3	4	1	2	1	3	3	2	1	3	2	3	3	2.4	1	2	1	3	2
51	5	3	3	3	3	3.4	3	2	4	3	3	3	2	3	3	4	2	2.8	4	3	2	2	1
							5	3	3	2	3	3											
52	3	3	3	3	3	3	3	3	3	4	2	3	3	3	3	3	1	2.6	4	3	1	4	1
	5	3	2	3	3	3.2	4	3	1	4	1	2.6	2	3	1	4	1	2.2					
53	5	4	5	3	4	4.2	1	2	1	2	1	1.4	1	2	1	3	1	1.6	1	2	1	2	1
54	5	3	3	4	3	3.6	3	3	2	2	2	2.4	1	3	2	3	2	2.2	2	3	1	2	2
55	1	1	-	1	1	1	1	1	-	1	1	1	2	3	3	2	1	2.2	1	1	-	1	1
													2	2	5	1	1	2.2					
56	2	1	-	1	1	1.2	2	1	-	1	1	1.2	2	3	4	2	2	2.6	2	1	-	1	1
													2	3	5	3	3	3					

APPENDIX V (Continued)

Rater	Feasibility						Effectiveness						Cleverness						Future Effectiveness				
	1	2	3	4	5	Avg.	1	2	3	4	5	Avg.	1	2	3	4	5	Avg.	1	2	3	4	5
Idea No.																							
57	3	3	4	4	5	3.8	1	1	3	2	3	2	2	1	3	3	3	2.4	1	1	2	2	2
	5	4	5	2	3	3.8																	
58	2	3	3	1	1	2	1	2	-	1	1	1.2	2	4	3	3	2	2.8	1	2	-	1	1
59	5	5	5	5	5	5	2	2	3	2	3	2.8	1	2	2	3	3	2.2	2	2	2	3	4
60	5	4	5	4	3	4.2	2	2	3	2	3	2.4	1	2	2	3	3	2.2	2	2	2	2	3
61	5	5	5	4	3	4.4	3	2	3	3	3	2.8	1	2	2	3	3	2.2	2	2	2	3	3
62	5	5	5	4	3	4.4	2	2	1	3	3	2.2	2	2	2	3	2	2.2	2	2	1	3	1
63	5	5	5	3	3	4.2	4	3	3	3	4	3.4	3	2	3	2	4	2.8	5	4	2	2	5
							5	4	3	2	4	3.6											
64	5	4	3	4	4	4	4	4	3	4	2	3.4	2	3	2	4	2	2.6	3	4	2	4	1
65	5	5	-	4	3	4.2	1	2	-	3	1	1.8	1	3	-	3	1	2	1	3	-	3	1
66	1	2	3	2	1	1.8	3	4	3	2	2	2.8	3	4	4	3	4	3.6	5	5	3	2	5
							2	2	4	1	5	2.8											
67	1	1	2	1	1	1.2	3	2	3	2	1	2.2	4	3	4	3	2	3.2	3	4	3	4	1
							2	3	4	1	1	2.2											
68	1	1	1	1	1	1	1	1	1	1	1	1	5	5	4	3	4	4.2	3	5	1	4	3
69	1	1	1	1	1	1	1	1	1	1	1	1	5	5	4	3	3	4	5	5	1	4	2
70	3	1	2	1	1	1.6	3	3	3	2	1	2.2	5	4	4	3	3	3.8	5	5	3	1	3
							4	4	3	1	1	2.6											
71	5	5	5	3	5	4.6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

APPENDIX V (Concluded)

Rater	Feasibility						Effectiveness						Cleverness						Future Effectiveness				
	1	2	3	4	5	Avg.	1	2	3	4	5	Avg.	1	2	3	4	5	Avg.	1	2	3	4	5
Idea No.																							
72	1	1	-	1	1	1	2	1	-	1	1	1.2	5	5	-	3	3	4	4	1	-	4	1
73	3	2	2	2	4	2.6	3	3	3	3	1	2.6	4	4	4	3	3	3.6	4	4	3	3	2
74	3	3	4	3	5	3.6	1	2	-	1	1	1.2	1	1	-	2	1	1.2	1	1	-	1	1
75	-	1	-	-	1	1	-	1	-	-	1	1	-	1	-	-	1	1	-	1	-	-	1

## APPENDIX VI

FRIEDMAN ANALYSIS OF VARIANCE OF THE RATINGS SUBMITTED BY FIVE  
 JUDGES ON THE EFFECTIVENESS AND FUTURE EFFECTIVENESS  
 OF SUGGESTED IMPROVEMENTS TO SUGAR HANDLING PROBLEM

Rater	I		II		III		IV		V	
	Effectiveness	Future Effectiveness	Effectiveness	Future Effectiveness	Effectiveness	Future Effectiveness	Effectiveness	Future Effectiveness	Effectiveness	Future Effectiveness
Idea No.										
1	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
2	1.5	1.5	1.5	1.5	2	1	1.5	1.5	2	1
3	1.5	1.5	1.5	1.5	2	1	1.5	1.5	1.5	1.5
4	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
6	1.5	1.5	2	1	2	1	1.5	1.5	1.5	1.5
7	1.5	1.5	2	1	2	1	1.5	1.5	1.5	1.5
8	1.5	1.5	2	1	2	1	1.5	1.5	1.5	1.5
9	1.5	1.5	1.5	1.5	2	1	1.5	1.5	2	1
10	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
11	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
12	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
13	1.5	1.5	2	1	1.5	1.5	1.5	1.5	1.5	1.5
14	1.5	1.5	1.5	1.5	1.5	1.5	1	2	2	1
15	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	2	1
16	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
17	1.5	1.5	1.5	1.5	2	1	1.5	1.5	2	1
18	1.5	1.5	1.5	1.5	2	1	1.5	1.5	2	1
19	1.5	1.5	1.5	1.5	2	1	1.5	1.5	2	1
20	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	2	1
21	1.5	1.5	2	1	2	1	1.5	1.5	2	1
22	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	2	1
23	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	2	1
24	1.5	1.5	2	1	2	1	1.5	1.5	2	1

## APPENDIX VI (Continued)

Rater	I		II		III		IV		V	
	Effectiveness	Future Effectiveness	Effectiveness	Future Effectiveness	Effectiveness	Future Effectiveness	Effectiveness	Future Effectiveness	Effectiveness	Future Effectiveness
Idea No.										
25	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	2	1
26	1.5	1.5	2	1	1.5	1.5	1.5	1.5	1	2
27	1.5	1.5	2	1	2	1	1.5	1.5	1.5	1.5
28	1	2	1.5	1.5	1.5	1.5	1	2	1	2
29	1.5	1.5	1.5	1.5	2	1	1	2	2	1
30	1.5	1.5	1.5	1.5	2	1	1.5	1.5	1	2
31	1.5	1.5	1.5	1.5	2	1	1	2	1.5	1.5
32	2	1	1.5	1.5	2	1	1.5	1.5	2	1
33	1.5	1.5	1.5	1.5	2	1	1.5	1.5	1.5	1.5
34	1.5	1.5	2	1	1.5	1.5	1	2	2	1
35	1.5	1.5	1	2	1.5	1.5	1	2	1.5	1.5
36	1.5	1.5	1.5	1.5	1.5	1.5	1	2	1	2
37	1.5	1.5	1.5	1.5	2	1	1.5	1.5	1.5	1.5
38	1.5	1.5	1.5	1.5	2	1	1	2	1	2
39	1	2	1.5	1.5	1.5	1.5	1	2	1.5	1.5
40	1.5	1.5	1.5	1.5	2	1	1	2	2	1
41	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
42	1.5	1.5	1.5	1.5	1.5	1.5	1	2	1.5	1.5
43	2	1	2	1	2	1	1	2	1	2
44	1.5	1.5	1.5	1.5	1.5	1.5	1	2	1.5	1.5
45	2	1	2	1	2	1	1.5	1.5	1.5	1.5
46	1.5	1.5	1.5	1.5	2	1	1.5	1.5	2	1
47	2	1	2	1	2	1	1	2	2	1
48	1.5	1.5	2	1	2	1	1.5	1.5	2	1
49	1.5	1.5	1.5	1.5	2	1	1.5	1.5	2	1
50	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	2	1
51	2	1	1.5	1.5	2	1	1.5	1.5	2	1
52	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
53	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
54	2	1	1.5	1.5	2	1	1.5	1.5	1.5	1.5
55	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
56	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
57	1.5	1.5	1.5	1.5	2	1	1.5	1.5	2	1
58	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
59	1.5	1.5	1.5	1.5	2	1	1.5	1.5	1	2

## APPENDIX VI (Continued)

Rater	I		II		III		IV		V	
	Effectiveness	Future Effectiveness	Effectiveness	Future Effectiveness	Effectiveness	Future Effectiveness	Effectiveness	Future Effectiveness	Effectiveness	Future Effectiveness
Idea No.										
60	1.5	1.5	1.5	1.5	2	1	1.5	1.5	1.5	1.5
61	2	1	1.5	1.5	2	1	1.5	1.5	1.5	1.5
62	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	2	1
63	1.5	1.5	1.5	1.5	2	1	1.5	1.5	1	2
64	1.5	1.5	2	1	2	1	1.5	1.5	2	1
65	1	2	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
66	1	2	1	2	2	1	1	2	1.5	1.5
67	1	2	1	2	2	1	1	2	1.5	1.5
68	1	2	1	2	1.5	1.5	1	2	1	2
69	1	2	1	2	1.5	1.5	1	2	1	2
70	1	2	1	2	1.5	1.5	1.5	1.5	1	2
71	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
72	1	2	1.5	1.5	1.5	1.5	1	2	1.5	1.5
73	1.5	1.5	1.5	1.5	1.5	1.5	1	2	1	2
74	1.5	1.5	2	1	1.5	1.5	1.5	1.5	1.5	1.5
75	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
$R_j$ =Total	112	113	116	102	130	95	102.5	122.5	119	106

$$\chi^2 = \frac{12}{N(K+1)(K)} \sum_{j=1}^n (R_j)^2 - 3N(K+1) = \chi^2_{.05,1} \cong 3.82$$

where

$$N = 75$$

$$k = 2$$

$$\alpha = .05$$

Rater I

$$\chi^2 = \frac{12}{75(3)(2)} [(112)^2 + (113)^2] - 3(75)(3) = 0.01 < 3.82$$

## APPENDIX VI (Concluded)

Rater II

$$\chi^2 = \frac{12}{75(3)(2)} [(116)^2 + (109)^2] - 3(75)(3) = 0.65 < 3.82$$

Rater III

$$\chi^2 = \frac{12}{75(3)(2)} [(130)^2 + (95)^2] - 3(75)(3) = 10.83 > 3.82$$

Rater IV

$$\chi^2 = \frac{12}{75(3)(2)} [(102.5)^2 + (122.5)^2] - 3(75)(3) = 5.3 < 5.41$$

where  $\chi^2_{.02,1} = 5.41$

Rater V

$$\chi^2 = \frac{12}{75(3)(2)} [(119)^2 + (106)^2] - 3(75)(3) = 2.2 < 3.82$$

## APPENDIX VII

TOTAL QUANTITATIVE AND QUALITATIVE OUTPUT OF THREE GROUP SIZES  
UNDER FOUR PROBLEM SOLVING PATTERNS FOR EXPERIMENTS 1 THROUGH 3

## Quantity of Ideas in Experiment 1

Problem Solving Pattern	Group Size					
	2		4		6	
A	24 21	45	28 42	70	46 46	92
B	31 33	64	37 37	74	37 27	64
C	29 26	55	33 39	72	31 35	66
D	33 24	57	45 43	88	35 38	73

Quality of Ideas in Experiment 1  
Feasibility

Problem Solving Pattern	Group Size					
	2		4		6	
A	91.8 88.6	180.4	107.4 150.8	258.2	173.4 177.0	350.4
B	129.9 123.0	235.9	147.4 124.4	271.8	135.0 110.0	245.0
C	111.8 100.8	212.6	104.4 133.4	237.8	113.5 137.5	251.0
D	125.0 89.8	214.8	163.7 147.0	310.9	128.3 152.8	281.1

Quality of Ideas in Experiment 1  
Effectiveness

Problem Solving Pattern	Group Size					
	2		4		6	
A	64.0	121.8	82.0	186.4	238.4	238.4
	57.8		104.4		119.6	
B	78.2	161.4	92.8	183.4	92.2	162.0
	83.2		90.6		69.8	
C	75.8	143.8	86.4	180.2	83.4	172.6
	63.0		93.8		89.2	
D	86.4	150.2	110.6	222.6	85.4	184.6
	63.8		112.0		99.2	

Quality of Ideas in Experiment 1  
Feasibility and Effectiveness

Problem Solving Pattern	Group Size					
	2		4		6	
A	158.8	302.2	189.4	444.6	292.2	588.8
	146.4		255.2		296.6	
B	191.1	397.3	240.2	455.2	227.2	407.0
	206.2		215.0		179.8	
C	187.6	356.4	190.8	418.0	197.9	425.6
	168.8		227.2		227.7	
D	211.4	365.0	274.5	533.5	252.0	465.7
	153.6		259.0		213.7	

Quality of Ideas in Experiment 1  
Feasibility X Effectiveness

Problem Solving Pattern	Group Size					
	2		4		6	
A	232.8	478.3	295.5	701.1	455.9	918.8
	245.5		401.6		462.9	
B	294.7	608.2	364.6	677.3	348.6	637.3
	313.5		312.7		288.7	
C	291.7	555.8	292.5	631.0	313.2	664.7
	264.1		338.5		351.5	
D	328.8	569.8	408.9	806.7	316.8	712.5
	241.0		397.8		395.7	

Quantity of Ideas in Experiment 2

Problem Solving Pattern	Group Size	
	2	4
A	38	45
B	38	37
C	36	47
D	34	38

Quality of Ideas in Experiment 2  
Feasibility

Problem Solving Pattern	Group Size	
	2	4
A	134.6	158.8
B	136.4	131.2
C	116.6	164.0
D	129.0	141.6

## Quality of Ideas in Experiment 2

Problem Solving Pattern	Group Size	
	2	4
A	99.8	108.6
B	102.8	95.6
C	90.6	118.6
D	92.4	101.8

Quality of Ideas in Experiment 2  
Feasibility and Effectiveness

Problem Solving Pattern	Group Size	
	2	4
A	234.4	267.4
B	239.2	226.8
C	207.2	282.6
D	221.4	243.4

Quality of Ideas in Experiment 2  
Feasibility X Effectiveness

Problem Solving Pattern	Group Size	
	2	4
A	362.0	410.5
B	377.0	346.9
C	314.3	424.4
D	348.1	377.8

## Quantity of Ideas in Experiment 3

Problem Solving Pattern	Group Size		
	2	4	6
A	32	52	51
B	29	40	47
C	43	53	41
D	39	43	48

Quality of Ideas in Experiment 3  
Feasibility

Problem Solving Pattern	Group Size		
	2	4	6
A	111.5	185.2	181.0
B	102.4	142.7	171.6
C	156.2	193.2	149.6
D	135.2	144.8	180.0

Quality of Ideas in Experiment 3  
Effectiveness

Problem Solving Pattern	Group Size		
	2	4	6
A	82.8	132.6	132.4
B	69.0	99.0	119.4
C	110.2	126.8	105.2
D	100.4	104.8	122.8

Quality of Ideas in Experiment 3  
Feasibility and Effectiveness

Problem Solving Pattern	Group Size		
	2	4	6
A	194.3	318.2	313.4
B	117.4	241.7	291.0
C	266.4	320.0	254.8
D	235.6	249.6	302.8

Quality of Ideas in Experiment 3  
Feasibility  $\times$  Effectiveness

Problem Solving Pattern	Group Size		
	2	4	6
A	294.3	480.7	479.9
B	246.8	353.9	438.9
C	408.5	469.3	391.4
D	355.1	367.1	463.5

APPENDIX VIII

QUANTITATIVE AND QUALITATIVE CUMULATIVE  
DISTRIBUTION FUNCTIONS

Cumulative Distribution Functions  
Experiment 1

Average Number of Ideas Real Groups				Average Number of Ideas Nominal Groups			
Group Size	2	4	6	Group Size	2	4	6
Minutes				Minutes			
5	6.33	8.00	8.83	5	4.00	11.50	10.50
10	11.17	15.50	15.33	10	8.50	18.00	21.00
15	15.17	22.00	21.00	15	12.00	22.50	27.50
20	17.00	25.33	23.66	20	15.50	26.00	32.00
25	21.30	29.50	26.50	25	16.50	28.50	34.00
30	22.80	31.67	27.67	30	19.00	30.00	37.50
35	24.50	33.83	29.33	35	20.50	33.00	38.50
40	25.80	35.83	30.67	40	21.00	33.50	41.00
45	27.80	36.50	31.83	45	21.50	34.50	42.00
50	29.17	39.00	33.67	50	22.50	35.00	46.00

Cumulative Distribution Functions  
Experiment 2

Average Number of Ideas Real Groups			Average Number of Ideas Nominal Groups		
Group Size	2	4	Group Size	2	4
Minutes			Minutes		
5	12.00	10.67	5	13	15
10	17.00	19.33	10	19	21
15	23.33	25.00	15	23	26
20	27.33	29.67	20	27	30
25	29.33	32.33	25	31	32
30	30.00	34.67	30	32	38
35	30.33	34.67	35	33	39
40	33.00	37.00	40	35	41
45	34.67	38.67	45	37	43
50	36.00	40.67	50	38	45

Cumulative Distribution Functions  
Experiment 3

Average Number of Ideas Real Groups				Average Number of Ideas Nominal Groups			
Group Size	2	4	6	Group Size	2	4	6
Minutes				Minutes			
5	3.33	7.67	5.67	5	4	4	8
10	9.67	16.00	15.00	10	9	14	19
15	15.67	24.67	19.33	15	15	19	22
20	20.67	28.33	22.00	20	18	25	27
25	24.67	32.00	26.67	25	20	26	33
30	26.33	34.00	28.00	30	22	33	38
35	29.00	34.67	30.00	35	22	35	39
40	30.00	36.00	33.00	40	24	40	39
45	30.67	38.00	34.00	45	27	43	41
50	31.67	39.33	36.33	50	28	44	41
55	31.67	41.67	38.33	55	28	48	43
60	32.33	43.00	40.67	60	30	49	43
65	33.67	43.00	41.00	65	31	51	43
70	34.00	43.67	42.33	70	31	51	46
75	35.00	44.33	43.00	75	31	52	47
80	35.67	45.00	44.00	80	32	52	49
85	36.33	45.33	44.33	85	32	52	50
90	37.00	45.33	45.00	90	32	52	51

Cumulative Distribution Functions  
Experiment 3

Average Quality of Ideas Additive Scheme-Real Groups				Average Quality of Ideas Additive Scheme-Nominal Groups			
Group Size	2	4	6	Group Size	2	4	6
Minutes				Minutes			
5	22.47	50.13	39.15	5	23.60	27.40	61.20
10	63.00	103.00	99.93	10	55.40	96.00	129.20
15	96.00	156.40	126.53	15	92.80	125.80	149.20
20	127.13	177.00	141.60	20	111.20	161.60	175.60
25	153.40	198.60	171.40	25	124.40	166.20	201.40
30	165.53	210.40	180.20	30	134.70	212.00	234.20
35	179.73	214.60	190.73	35	134.70	221.40	240.40
40	187.40	222.60	209.21	40	147.70	254.20	247.00
45	191.93	232.93	215.73	45	166.70	275.20	255.00
50	197.13	239.13	230.06	50	172.70	277.20	255.00
55	197.13	251.60	241.80	55	172.70	294.40	269.20
60	201.13	257.53	252.67	60	185.70	301.00	269.20
65	210.02	257.53	258.73	65	189.30	314.40	269.20
70	212.13	261.23	269.40	70	189.30	314.40	283.20
75	216.60	263.90	270.07	75	189.30	318.20	295.00
80	219.90	268.30	275.53	80	194.30	318.20	307.00
85	222.40	270.43	278.20	85	194.30	318.20	313.40
90	224.50	270.43	282.87	90	194.30	318.20	313.40

## APPENDIX IX

AVERAGE CLEVERNESS SCORES PER FIVE-MINUTE INTERVALS  
FOR REAL GROUPS IN EXPERIMENTS 1 THROUGH 3

Average Cleverness Score per Five-Minute Interval  
Experiment 1

Group Sizes	2	4	6
Minutes			
5	2.34	2.53	2.39
10	2.43	2.90	2.61
15	2.47	3.16	2.55
20	2.05	2.79	2.79
25	2.83	2.49	2.42
30	1.55	3.45	1.89
35	2.33	2.61	2.68
40	1.68	2.76	1.62
45	2.60	1.24	1.12
50	2.02	2.38	1.34

Average Cleverness Score per Five-Minute Interval  
Experiment 2

Group Sizes	2	4
Minutes		
5	2.69	2.35
10	2.77	2.67
15	2.67	2.65
20	2.63	2.96
25	2.76	2.96
30	2.47	3.17
35	2.10	2.33
40	3.33	2.47
45	3.17	3.52
50	2.90	2.83

Average Cleverness Score per Five-Minute Interval  
Experiment 3

Group Sizes	2	4	6
Minutes			
5	1.66	2.46	2.38
10	2.29	2.47	2.50
15	2.54	2.71	2.51
20	2.88	2.48	2.31
25	2.81	2.76	3.13
30	2.33	2.13	1.87
35	2.42	1.00	1.95
40	2.03	2.27	1.78
45	1.93	2.89	1.98
50	1.87	1.60	2.87
55	0.00	2.45	1.55
60	1.30	2.12	1.42
65	2.23	0.00	2.03
70	1.53	1.29	0.88
75	0.90	2.60	1.40
80	1.20	1.33	2.17
85	2.07	0.73	0.93
90	1.13	0.00	0.43

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