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The effects of changes in patterns of communication on the behaviors of problem-solving groups.

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THE EFFECTS OF CHANGES IN PATTERNS OF COMMUNICATION ON THE BEHAVIORS OF PROBLEM-SOLVING GROUPS

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Introduction

Within the last ten years more work has been done in the area of small groups experimentation than in all the years preceding.[1] One reason for such increased activity is the growing awareness on the part of behavioral scientists that many of the elements of larger systems exist and develop in small groups. Further, there are strong parallels between the problems of a small group and those of larger organizations such as Public Administration and industrial bureaucracies.

This thesis is a laboratory study of change in small problem-solving groups. Changes in communication conditions will be introduced. These changes will be in terms of 'who may communicate to whom'. Patterns can be set up that vary in centrality. The concept of Centrality will be used to predict and understand the effects of such changes in the positions of the members of problem-solving groups. The effects of such changes on the organizational variables of time taken to solve problems and number of problems correctly solved will be studied.

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[1] This is illustrated by the extensive bibliography of small groups research cited in Small Groups ed. by Paul A. Hare, Edgar Borgatta, and Robert Bales, (New York: Alfred A. Knopf, 1955)

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I. The Overall Objective of the Thesis

The overall objective of the thesis is to experimentally examine how the historical conditions of small groups (and organizations) affect the subsequent group behaviors in terms of problem-solving activities. Specifically, the major question to be asked is: In what ways do the antecedent conditions of the groups influence its future behaviors? By antecedent conditions is mean the types of communication patterns that have been used before the group.

Another way of phrasing the overall question of the project is: When the communication patterns of an organization or small group are changed, what effects do the previous communication patterns

have on the dependent variables being measured in the present communication patterns?

II. Communication as the Independent Variable

Communication patterns will be used as the antecedent organizational conditions for the study of change effects. Communication has been selected as the variable to be manipulated because there is a considerable body of material relating types of communication patterns to group behaviors. Consequently, there is a great amount of information on the basis of which predictions about change effects in organizations can be developed and tested. Further, communication patterns can be clearly established and varied experimentally.

The discovery of variables such as communication, which have general application, subsume important social phenomena and are capable of operational definition, is important. It is important because it has enabled behavioral scientists to go beyond the stage of fact gathering, undirected by hypothesis.

The concept of communication has been central to the works of a number of investigators. Festinger[2] has investigated the exertion of group pressures on members and the development and operation of group standards. The major emphasis was on the nature of the

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[2] Leon Festinger, "INFORMAL SOCIAL COMMUNICATION", Group Dynamics, ed. by Dorwin Cartwright, and Alvin Zander (New York: Row, Peterson and Company, 1953)

that develop in the groups under various conditions of cohesiveness and member conformity. Festinger et al have typically used communication as a dependent variable.

Communication has occupied a central place in the 'change' studies of Coch and French[3], Levine and Butler[4], and Lewin[5]. Such studies have examined the kinds of communication methods that would lead to more effective change decisions and reduce resistances to change. Further, communication, as a factor major to any change program, has been integrated into the Lewinian theoretical framework of "Quasi-stationary equilibrium" and "force-field analysis"[4]. Such investigators have used communication as an intervening variable, i.e., between (a) types of group meetings and leadership, and (b) behavior that results from these forces. Homans[6] in the 'The Human Group' uses the concept of Interaction as a main part of his system for analysis of groups. In essence, the concept of Interaction refers to both verbal and non-verbal communication between people.

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[3] Lester Coch and John French, "Overcoming Resistance to Change", Group Dynamics, ed. by Dorwin Cartwright and Alvin Zander (New York: Peterson and Co., 1953)

[4] Jacob Levine and John Butler, "Lecture vs. Group Decision in Changing Behavior", Ibid.

[5] Kurt Lewin, "Studies in Group Decision", Ibid.

[6] George C. Homans, The Human Group (New York: Harcourt Brace, 1950)

Frequency, order and duration of communicative acts, according to Homans, play a central role in the behaviors of groups. March and Simon[7] develop many fruitful hypotheses about a variety of organizational variables. They focus on the organization as a complex information processing machine which is complicated by the human element. Communications in an organization are seen as central to such important social pehnomena as: decisions to participate and produce, problems of delegation, morale, co-ordination and productivity. Newcomb[8] points to the possibility that certain group properties are pre-determined by the conditions and consequences of communicative acts. His basic assumption is that communication among humans performs the essential function of enabling two or more individuals to maintain simultaneous orientation toward one another as communicators and toward objects of communication. Newcomb has offered evidence that propositions derived from such assumptions are supported by empirical findings.

III. Results of Others

The work discussed in the following section will be concerned with laboratory studies of the behaviors of groups working within

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[7] James G. March and Herbert A. Simon, Organizations, (New York: John Wiley and Sons, Inc., 1958)

[8] Theodore M. Newcomb, "An Approach to the Study of Communicative Acts", Small Groups, ed. by Paul A. Hare, Edgar Borgetta, and Robert Bales (New York: Alfred A. Knopf, 1955)

specific kinds of communication networks in problem-solving activities. Communication in these studies has been used as an independent variable. Initially, there will be a brief synopsis of the primary impetus for network investigations by A. Bavelas, followed by brief reports of other network studies.

Consideration of the general area of communication networks was initiated by Bavelas. The paper that gave impulse to the great amount of experimental work that followed was "Communication Patterns in Task-Oriented Groups"[9] which was an outgrowth of the original paper by Bavelas: "A Mathematical Model for Group Structures"[10]. In the original paper, the concepts of distance between members, centrality and peripherality were introduced, having been translated from certain "topological" terminologies of Lewin applied to organizations. Major questions that stemmed from such a theoretical inquiry into the nature of communication in groups were: "In a given organization, where will the region of greatest centrality be? Who will be in it? Who will be the most peripheral?". It was the second paper, however, that directly led to communication experimentation. In this paper, the structure of communication networks was more specifically examined for experimental purposes. Indices

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[9] Alex Bavelas, "Communication Patterns in Task-Oriented Groups", Journal of the Accoustical Society of America, XXII (1950) 725-730

[10] Bavelas, "A Mathematical Model for Group Structures", Applied Anthropology, VII (1948) 16-30

of centrality were computed and became standard experimental arrangements for the network studies that were to follow. The measure of centrality was obtained by deriving a ratio of the sum of the distances of all positions to all others over the sum of the distances of a given position to all others. In this way an index of relative centrality for any position in any pattern could be computed.

The main question asked by Bavelas was: "Is it possible that among several communication patterns, all logically adequate for the successful completion of a specified task, one gives significantly better performance than another?" The studies involving communication networks can be roughly classified under one (or more) of the three headings which represent foci of such studies. For convenience, each of the following studies referred to will be put in the most appropriate category, even though it is understood that other categories may partially apply.

The three categories of research emphasis are: (1) Problem-Solving (2) Organization (3) Information Flow

(1) The category of Problem-Solving refers to those investigators such as Leavitt and Smith who have been primarily concerned with the direct relationships between kinds of networks and performance measures of members in such networks.

(2) The category of Organization includes researchers whose studies have centered on the kinds of organization that develop within networks, as such organizational developments would relate to problem-solving activities. Guetzkow, Simon, and Dill are among this group.

(3) The category of Information Flow refers to those investigators such as Shaw et al, Christie, Luce and Macy, Heise and Miller, whose researches have emphasized kind, distribution and clarity of information used by members of problem-solving groups.

The following material concerns investigations in the areas of communication networks in the order of the categories described above.

Category I: Investigations Emphasizing Problem-Solving Performances Relative to Communication Network Differences

Smith[11] studied the relationships between communication network and the adaptability of work-oriented groups, under a condition of change in task. Three kinds of networks were used: Circle, Chain and Wheel. Four groups were run in each network. The apparatus and the physical experimental conditions were the same as those in the Leavitt experiment, with the exception that the task of the groups was to determine what colored marble was held in common among all the members of the group for a particular trial. For the first fifteen trials, solid-colored marbles were used. After fifteen trials, mottled, less easily describable marbles were directly substituted for the more distinct, solid-colored ones. Measures were taken during all thirty trials on: (1) group time taken for problem-solving (2) errors made (3) morale (4) recognition of organizations.

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[11] Sidney Smith, "Communication Pattern and the Adaptability of Task-Oriented Groups" (Unpublished, M.I.T., 1950)

Results of analyses of the first fifteen trials agreed with those previously found by Leavitt[12]: the Wheel, Chain and Circle ranked in that order with respect to speed and stability of organization, frequency of recognition of and agreement on leadership. They rank in reverse order with respect to: time taken to solve problems, number of messages sent and the other variables being measured.

Results of analyses of the last fifteen trials indicated that: (a) the differences in time taken to solve problems between Wheel and the other patterns decreases to a non-significant level, even though the Wheel is slowed down less initially, after the introduction of ambiguity into the task (b) Circle groups decreased errors greatly and consistently; Chain groups decreased errors but less markedly than the Circle; Wheel did not show error decrease in the course of trials 16 to 30. (c) Observation of the groups showed that the subjects experienced some shock and temporary dismay when they were first faced with the new task requirement.

Smith suggests from such data that differences in communication patterns affect the adaptability of groups to changes made in their work-environment.

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[12] Harold J. Leavitt, "Some Effects of Certain Communication Patterns on Group Performance," Journal of Abnormal and Social Psychology, XLVIII (1951), 38-50

Leavitt, in the study "Some Effects of Certain Communication Patterns on Group Performance", used essentially the same physical arrangement and problem as Smith, with the modification of using four different 5-man structures (including the two used by Smith). Five groups were run in each of the structures: Circle, Chain, Y and Wheel.

The main findings concerning the patterns as units were as follows: The Wheel, Y, Chain and Circle rank, in that order, with respect to each of the following aspects:

a. Speed of development of organization for problem-solving. The Wheel, Y and Chain were stable once they were established. The Circle was inconsistent in organization, e.g. leadership and problem-solving procedure fluctuated.

b. Frequency with which the members name leaders

c. Agreement concerning who the leaders are

d. Rating of the group as a whole by the members

During the course of the fifteen trials all patterns showed a reduction in time to complete a trial. There were no clear differences in the average speed or in the learning rates of the various patterns as measured by time per trial. It was found, however, that: (a) the Circle pattern used more messages than any other pattern; (b) the Circle made more errors, but also corrected a greater proportion of them than any other pattern. Concerning differences in behaviors as related to position differences, it was found that: For a given pattern, the most central positions send the most messages, and the least central send the fewest. The most central positions enjoy their jobs more than the peripheral ones.

No position makes significantly more total errors than any other. The recognition of leaders in the group is related to differences in centrality of group members, i.e., the most central members are chosen as leaders.

The variables considered above in the Smith and Leavitt studies are the dependent variables found in the subsequent network studies. They fall into four classes:

a. Efficiency - number of errors, correct completions, speed of solution, number of messages

b. Leadership - positions named, agreement on leadership

c. Morale - rating of the group, rating of self

d. Organization - consistency, type

These dependent variables and the two independent variables (group structures and individual positions within any group structures) form the basis of the network studies.

Category II: Investigations Emphasizing the Development and Effects of Organization

Guetzkow and Simon[13], in their study "The Impact of Certain Communication Nets Upon Organization and Performance in Task-Oriented Groups", examined the distinctions between two classes of behavior in the group:

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[13] Harold Guetzkow and Herbert Simon, "The Impact of Certain Communication Nets Upon Organization and Performance in Task-Oriented Groups", Management Science, I (1955), 233-250

a. Direct problem-solving behavior such as relaying information, asking questions

b. Organizational behavior, such as assignment of roles and functions to team members

The authors set up a study to test the hypothesis that the effect of the communication restrictions in the networks is to complicate the organizational behavior rather than the direct problem-solving behavior. They used three 5-man groups: Circle, Wheel and All-channel. Their procedure differs from Leavitt's in that the group members could send only coded problem information during trials, but any kind of message during the inter-trial periods. The groups were differentiated with respect to the following: (a) number of open channels; (b) number of symmetric positions; (c) minimum number of relays necessary.

With respect to time per trial, it was found that the Wheel was highest in efficiency, the all-channel was intermediate, and the Circle least efficient. The same order of communication patterns was also true of the degree of difficulty involved in forming a stable organization. Concerning differences in organizational stability, it was found that the wheel was most stable, the circle next, and the all-channel least stable. Also, the greatest degree of differentiation was in the Wheel, next in the All-channel and least in the Circle.

In general, the results by Guetzkow and Simon with reference to the Wheel and Circle communication networks agree with those of Leavitt's (e.g. number of messages, time of fastest trial).

Guetzkow and Dill[14] further investigated some of their ideas with respect to the organizational effects of different communication networks. They analyzed the mechanisms by which task-oriented groups developed interaction structures for task performance. The following are the three major theoretical considerations that were developed on the basis of analysis of messages: (a) Severe restrictions on communication opportunities beyond the minimum required for task performance, tend to induce organizational development through a local learning mechanism. Freedom in communication tends to induce organizational development through insightful planning mechanisms. (b) Understanding of the kind of network by members is necessary but not sufficient for the establishment of differentiated, hierarchical structures. Also needed are specific proposals for arrangement of the organization, and promulgation of such proposals by members. Communication restrictions tend to restrict the planning and promulgation of such proposals. (c) The kind of communication not in use determines the extent to which members of the group are available for the required different role behaviors. Specifically, groups operating within a highly structured net (i.e., the Wheel) do not have the problem of role differentiation as much as other networks. The Concom (completely connected) on the other hand, is so arranged that there is complete interchangeability of parts and greater natural opportunity for

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[14] Harold Guetzkow and William Dill, "Factors in the Organizational Development of Task-Oriented Groups", Sociometry, XX (1957), 175-204

members to try out the developing roles and thus, theoretically at any rate, organized in the "best possible way". Circle groups, however, neither have the degree of structure of the Wheel, nor the degree of interchangeability of the Concom. Consequently, the organization for maximum performance by the circle is impeded.

The above study used twenty 5-man groups. The experimental procedures were the same as those of the original experiment[15] except that communication nets were alternated from task trial to inter-trial period. During the task trials, the net arrangement was the same that was used throughout both the task and inter-trial periods of the original experiment. During the inter-trial periods the communication restrictions were removed by opening all barred channels, making the pattern identical to one used throughout both task and intertrial periods by the All-Channel groups.

The above arrangement allowed the empirical test of the prediction that task performance in a restricted net will be equal to that in an unrestricted net if the restrictions are removed during the inter-trial period so that a relay system may be organized.

Category III: Studies Emphasizing Kind, Distribution and Clarity of Information

M. E. Shaw has extended the investigation of networks to include the effects of such variables as: amount and distribution of information, problem complexity and type of leadership. The following is a selection

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[15] Guetzkow and Simon, op. cit.

of studies in which Shaw et al have dealt with these variables:

Shaw[16] extended network investigation to 4-man groups. He states that the results of his work on 4-man groups, in general, support the differences which Leavitt found between the networks and sizes used by him, with respect to number of messages sent, satisfaction and nominations as a leader. Also, in this article, Shaw criticizes the use of the Centrality index, and suggests the concept of Independence as an alternative which, in terms of the measure constructed for it, fitted the data collected better than the curves obtained using Centrality as the operating concept. "The improvement of Independence over Centrality (when similarly fitted to the data with complex functions) is not given. If this is the case, then, it is unlikely that the neatness of fit can compensate for the greater simplicity of the earlier centrality measures".[17]

Shaw investigated the hypothesis that the distribution of information as well as centrality, is an important variable in the behavior of networks.[18] Shaw varied the amounts of information

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16 Marvin E. Shaw, "Group Structure and the Behavior of Individuals in Small Groups" , Journal of Psychology, XXXVIII (1954), 139-149

17 Murray Glanzer and Robert Glazer, "Techniques for the Study of Team Structure and Behavior", American Institute for Research, Pittsburgh, Pennsylvania, Part II, p. 16

18 Marvin E. Shaw, "Some Effects of Unequal Distribution of Information upon Group Performance in Various Communication Nets", Journal of Abnormal and Social Psychology, XLIX (1954), 547-553.

presented to positions within three networks. Three 4-man communication patterns were used: circle, wheel, and slash. Arithmetic problems were used. Each team member has some of the information necessary for solving the problem. In half of the teams, all members had the same amount of information. In the other teams, the information was unequally distributed in a specific way. Ninety teams were run, fifteen in each of the six combinations of experimental conditions (three communication networks and two types of information distribution).

Shaw summarized the results of the study as offering some evidence for the following: (1) time required for an individual in a position to complete an activity varies inversely with individual centrality. (2) Individual morale, number of items transmitted by an individual in a position and the probability that an individual in a given position will be chosen as a leader vary directly with individual centrality. (3) The emergence of leadership in a net varies inversely with the number of positions having the highest individual centrality index in that net, and directly with the maximum difference in individual centralities. (4) Increasing or decreasing the amount of information initially available to an individual in a given position has an effect similar to respectively increasing or decreasing the individual centrality index of that position or the number of channels available to that position.

In this subsequent study, Shaw tried to reconcile a difference in the relative problem-solving speed of the wheel and circle in his own and Leavitt's study.[19] Leavitt found that the wheel required less time to solve its problems than the circle. Shaw found the reverse. Shaw believed the difference in results was related to differences in task complexity. To test this belief, the standard Leavitt procedures were used with two types of problems: (a) simple problems (finding a common symbol) (b) more complex problems (arithmetic). Two 3-man networks were used: wheel and circle. Twelve groups were run in each network. Half of the groups in each pattern were given the simple task and the other half were given the complex task. Trend and higher order interaction analysis give support for Shaw's hypothesis.

Shaw and Rothschild investigated the effects of prolonged experience upon behaviors in several networks.[20] The subjects participated in twenty problems, two each day for ten days. Arithmetic problems were used. Three nets were used: wheel, slash and Concom (completely connected). Time scores, number of message

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[19] Marvin E. Shaw, "Some Effects of Problem Complexity upon Problem Solution Efficiency in Different Communication Nets", Journal of Experimental Psychology, XLVIII (1954), 211-217

[20] Marvin E: Shaw and Gerald H. Rothschild, "Some Effects of Prolonged Experienced in Communication Nets" , Journal of Applied Psychology, XL (1956), 281-286

units transmitted and satisfaction ratings showed improvement over successive days. Selection of positions as leaders was positively related to centrality. Day-to-day ratings of satisfaction were highest for the Concom and lowest for the wheel.

The studies by Christie, Luce and Macey[21] have been subjected to much more thorough mathematical analysis than the other network studies. The study cited in this section bears a close relationship to the Heise and Miller investigation (Problem-solving by Small Groups using various Communication Nets).[22] In this case, however, the nose arises from the ambiguity of the stimuli handles rather than being acoustic noise of the communication channels. The two main independent variables were: (a) group structure and (b) ambiguity of stimuli. The networks used were the 5-man circle, chain, wheel and pinwheel. An additional feedback variable was introduced by allowing some of the wheel groups to receive additional information concerning errors at the end of each trial. The task was for all the members of each group to determine the color of the one marbles used to those that were much less easily describable (used mottled marbles). Fifteen more trials were run with the latter ambiguous stimuli. The following were found:

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[21] Lee Christie, R. Duncan Luce, and Josiah Macy Jr., "Coding Noise in a Task-oriented Group", Journal of Abnormal and Social Psychology, XLVIII (1953), 401-409

[22] George A. Heise and George A. Miller, "Problem-solving by Small Groups Using Various Communication Nets," Journal of Abnormal and Social Psychology, XLVI (1951), 327-335.

a. The circle pattern which had error feedback, no highly central position and all symmetric channels learned fast and had good error reduction with respect to error performance.

b. The wheel, with no error feedback and with a highly central position and all symmetric channels showed no learning and no error reduction with respect to error performance.

c. The chain with slight error feedback and with a highly central position and all symmetric channels showed no learning and error reduction with respect to error performance.

d. The pinwheel with error feedback and no highly central position and no symmetric channels showed some initial learning and poor error reduction with respect to error performance.

e. The Wheel with error feedback and with a highly central position and with all symmetric channels showed slow learning and fair error reduction with respect to error performance.

One of the major conclusions drawn from the above study (and consistent with those of Heise and Miller, and Shaw) was that the nature of the group task is crucial in examination of the effects of different kinds of communication nets. Thus, for more complex tasks (as Heise and Miller, and Christie, Luce and Macey indicate) the order of efficiency going from wheel to Y to chain to circle may even be reversed.

Heise and Miller[23] introduced several new aspects into their study of problem-solving groups in different communication networks: (1) Communication took place over an intercom system. The subjects

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[23] Ibid.

could hear or speak to, simultaneously, as many of the other participants as the net allowed (2) the communication network was highly restricted. The subjects could only relay the words on lists. (3) the networks used included one-way as well as two-way channels. Five 3-person networks were used. Three experiments were conducted: (I) In this experiment the subjects had to reconstruct a master list of words on the basis of different incomplete lists given each of them. The results were as follows: (a) as noise increased, the number of words spoken, errors and the time required to complete the task increased for all networks (b) the differences between networks became greater with increased noise.

(II) In this experiment, the subjects had to reconstruct a twenty-five word sentence based on different parts given to each of them. The results were essentially the same as in Experiment (I) with the exception that the open chain was more efficient than the circle. Heise and Miller suggest that "The second type of problem was less rigidly structured and placed a higher premium on the coordination of the group activity." The open chain apparently allowed for better co-ordination.

(III) In this experiment the subjects were given anagram problems in which they had to form as many words as possible out of the letters of a given word. In this experiment the subjects would work independently. In contrast to the previous experiments, the results were as follows: (a) Intense noise decreased the number of words spoken (b) there was no systematic difference between the efficiency of the various nets.

Aside from the introduction of the one-way channel, these experiments indicate that it may be the case that there is no network that is best in all situations. Heise and Miller themselves suggest that the relative efficiency of a communication net depends upon the kind of problem the group is trying to solve. In particular, they suggest that the net differences are most apparent when the problem used requires successful communication for its completion.

IV. Change

Since this study deals directly with change in ongoing communication systems, it seems relevant to consider even briefly, the way it is being used in this study. Change is being used in this research in the following way: (a) the source of change conditions is the experimenter (b) the object of the change conditions is the communication network of a group of problem-solving subjects (c) the duration of the change is brief, lasting as long as the experimental conditions are operating (d) the level of the change is restricted to the problem-solving activities of the subjects (e) the breadth of the change is limited to changes in performance with respect to a specific kind of task within specific kinds of communication networks (f) the onset is of the kind where change is introduced sharply, without any gradual build-up or preparation for it (g) the process of introduction of the change is one of inposition, where the subjects are not aware of the change beforehand and have no choice in the rejection or acceptance of the changed conditions (h) the intent and direction of the change is one of learning under what conditions greater or less productivity will

develop (i) the change refers to imposed discontinuities in network programs rather than to modifications of operating levels of existing communication programs or networks.[24]

Change has been virtually neglected in communication experimentation, and has received an inappropriately small amount of attention in natural organizational settings. There are some good reasons why this is so, especially in the case of natural organizations. To introduce change in natural organizational settings requires considerable flexibility and faith on the part of management. Research on changes can easily be viewed by management as a threat to the ongoing efficiency of the organization. The kinds of rewards possible and probable, resulting from such research on changes are difficult to forsee or guarantee. Immediate positive applications of the results of such change investigations are likely to occur only infrequently.

From another viewpoint as well, experimental change studies in natural organizations are difficult to plan and execute. The variables that may be seen as important may neither be able to be clearly and operationally defined or controlled nor located or induced in such natural organizations in pure form as might be possible in a laboratory situation. The reasons for the paucity of laboratory experimental research on changes in communication do not appear to be as imposing or justifying. The most obvious impediment is the absence of theory adequate to generate testable propositions about change. As in most other areas of social psychological

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[24] March and Simon, op.cit., chap. vii

experimentation, the development of knowledge about communication networks in problem-solving groups may be characterized by little theoretical integration among studies and little consistency between investigators among the kinds of situations employed and variables used.

The following three studies, two in communication experimentation and one in a natural organizational setting, have dealt with change: (1) Smith[25] was concerned with effects of the introduction of ambiguity into the experimental task. Three 5-man networks were used: circle, chain and wheel. The groups were required to solve fifteen problems, each one concerned with the agreement of group members on the one common colored marble appearing in each of their boxes. After fifteen trials, ambiguity was introduced by substituting mottled marbles for the previous solid colored ones. The groups then had to solve fifteen problems using the modified task. Smith indicates the following: (a) in the first fifteen trials, the results were consistent with those of Leavitt[26]: the wheel, chain and circle rank in this order with respect to time taken to solve problems, errors made, etc. (b) in the second fifteen trials, the difference in time taken to solve problems between the wheel and the other nets ceases to be significant, even though the wheels are slowed up less at the sixteenth trial than the other nets.

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[25] Smith, op.cit.

[26] Leavitt, op.cit.

(c) Circle groups decreased their errors consistently (unitl, during the last five trials they were no greater than those made during the trials using solid-colored marbles); the chains showed a similar but small decrease in errors; the wheels making a great many errors in the mottled-marble trials. Specific analyses by Smith indicated evidence for the following conclusion: Differences in communication patterns may have marked effects on the adaptability of groups to environmental changes.

(2) Flament[27] has investigated certain effects of changes in communication networks on the performance of groups. All problem-solving groups (of five men each) were first subject to the following condition: subjects freely chose the central person and solved a series of problems in a very centralized network (where all members had to communicate directly with the central person). The groups having gone through such an identical experience, were assigned to four different experimental conditions: (a) the net remains centralized and the central person (freely chosed in the first condition) continues to be the central person (b) the net remains centralized, but the central person is replaced by a formerly peripheral person and becomes peripheral (c) the subjects are no longer restricted to such a centralized arrangement, e.g. no longer

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[27] Claude Flament, "Influence des Changements de Reseaux de Communications sur les Performances des Groupes", Communication a Societe Francaise de Psycholgie, Paris, 1955, p. 4-6

have to communicate to the central person, but the central person still retains a central position (d) the subjects are no longer restricted to such a centralized network, and where the centralized person has become peripheral and aperipheral person has become central.

Flament found: (1) Time taken to solve problems, number of messages and errors made, amount of disturbance and difficulty in working and cooperating, and morale were greater when networks were less centralized. (2) A stable, centralized person emerged and was recognized less frequently when the network was less centralized.

Flament also offers other, but less important generalizations about his results: novelty of positions leads to confusion between older and newer problem-solving possibilities. Such confusion manifests itself in the smaller degree to which the central person emerged and was recognized, more difficult adjustment to a task which requires a division of labor, lower efficiency in terms of time, errors and messages.

In summary, Flament seems to have suggested the following: When changes are made in the positions of subjects from one condition to another, and when the network is changed from a more to a less centralized one, at the same time, disorganization is increased and problem-solving efficiency lowered.

(3) Morse and Reimer[28] have investigated change in a natural

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[28] Nancy E. Morse and Everett Reimer, "The Experimental Change of a Major Organizational Variable," Journal of Abnormal and Social Psychology, January, 1956, p. 52.

organizational setting. This was a field experiment conducted in an industrial setting in order to test hypotheses concerning the relationship between the means by which organizational decisions are made and : (a) individual satisfaction, and (b) productivity. The following description is drawn from their report of the study: Using four parallel divisions of the clerical operations of an organization, two programs of changes were introduced. One program, the Autonomy program involving two of the divisions, was designed to increase the role of the rank-and-file employees in the decision-making processes of the organization. The other two divisions received a program designed to increase the role of upper management in the decision-making processes (the Hierarchically-controlled program). The phases of the experiment included: (a) before measurement, (b) training programs for supervisory personnel lasting approximately six months, (c) an operations period of a year for the two experimental programs, and (d) after measurement. In addition, certain measurements were taken during the training and operational phases of the experiment. Briefly, it was found that:

1. The experimental programs produced changes in decision-making allocations in the direction required for the testing of the hypotheses.

2. The individual satisfactions of the members of the work groups increased significantly in the Autonomous program and decreased significantly in the Hierarchically-controlled program.

3. Using one measure of productivity, both decision-making systems increased productivity, with the Hierarchically-controlled

program resulting in a greater increase.

The three studies of change have been suggestive of the following: the effects of modifications of the environment and structure of organizations, cannot be solely or even significantly predicted from knowledge of the properties of the changes alone. Rather, the elements needed for successful prediction of change effects are: (a) Knowledge of the particular environment and organizational structure, as well as (b) knowledge of the properties of the change.[29] The effects of changes introduced into ongoing work-systems are seen as developing out of what is being changed from and what is being changed to in such work-systems.

V. The Concept of Centrality and Its Major Role in the Study

Coordinated and cooperative action on the part of any group facing a common problem to solve requires the use of some kind of communication. The activities of such problem-solving groups have been shown to be directly related to the kinds of communication patterns used.[30] The differences between communication patterns themselves have been studied. These may vary among a variety of dimensions: number of connections, how much information is transmitted and who may communicate to whom.

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[29] Cf., p.19 (The way in which change is being used)

[30] Cf., Results of others, pp. 5-19

When communication patterns of problem-solving groups are varied, what is primarily being affected is 'who may communicate to whom'. When comparisons are made within a group or between groups with different 'who may communicate to whom' characteristics, the notion of 'distance' between members can be seen to be directly involved. For example, in a 5-man group where each of four of the five members has first to communicate to the fifth in order to communicate to any of the other members, it can be seen that the position of the fifth person is closer to the other four than is any other position. Closeness or distance is defined in terms of the number of steps needed for members of a group to communicate to other members.

Different communication patterns involve distinct differences in distances between members. The concept of Centrality directly describes the distance relationships between members in different communication patterns. Such distance relationships have been accurately computed and have served as the basis for comparisons between problem-solving groups, which have different communication patterns. It is believed that Centrality is the major determinant of behavior differences between groups because it reflects the extent to which member positions are strategically located relative to other positions. Distance between positions in a group is of strategic importance because it determines the accessibility to information for the positions. Therefore, it strongly influences the problem-solving behavior of the group. For example, a group member who is more central (less distance between him and other members)

will be in a better position, time-wise and step-wise, to receive and give information. Consequently, he will probably perceive himself and be perceived by others differently than someone who is less central (more distant from others) and consequently has less access to the receiving and giving of information. Differences in Centrality, then, can be seen to lead to role differentiations, including: differences in independence of action, responsibility and task interest. Such role differentiations should lead to differences in problem-solving behaviors of group members in terms of speed, accuracy and satisfaction, etc. Centrality, therefore, provides the major concept for exploring the effects on the problem-solving behaviors of groups when communication patterns are independently manipulated.

V. b. Variables to be Employed

Independent Variables

(1) Group Communication Structures (2) Individual Communication Positions Within Structures

Two 5-person communication patterns will be used:[31] (a) circle (b) wheel. These patterns are distinguished on the basis of Centrality measures: quantitative descriptions of the distance relationships between members in different communications patterns,

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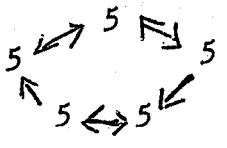
[31] H.J. Leavitt, "Some Effects of Certain Communication Patterns Group Performance", Journal of Abnormal and Social Psychology. XLVI (1951) 327-335

Figure 1.30

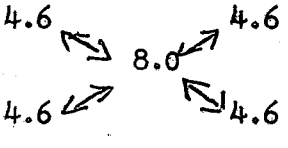
where distance is defined in terms of the minimum number of steps needed for members of a group to communicate to other members. On the basis of computed individual Centrality indices of members in the different communication patterns, group centrality measures were computed. The following is a diagram of the individual and group centrality measures, for the two kinds of communication patterns to be used:

Circle Pattern



Group 25

Wheel Pattern



Group 26.4

In the above illustration, the figures in the small circles represent the relative centrality measures[32] of the members. The numbers at the bottom of each diagrammed pattern represent the sums of the individual centrality measures from the respective patterns and are used as the centrality indices of the various conditions. It can be seen from the above illustration that the more central position occurs in the wheel pattern. Consequently, the wheel is

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[32] The index of Relative Centrality is the ratio of the sum of the distances of all positions to all others over the sum of the distances of a given position to all others. The relative centrality index of any position may be written as x where dxy is the distance from z to any other point.

considered to have a greater amount of centrality, in terms of individual member positions. Members of the respective patterns can communicate only through the use of channels designated by the arrows in the above illustration.

Dependent Variables

The following are the dependent variables to be measured: time taken to solve problems and number of correct trials. Both of those measures are taken directly from the data through the use of electrical recording apparatus.

VI. Three Possible Systems for Predicting Effects of Changes in Patterns

There are three logically possible ways of predicting the behaviors of groups which have had different communication patterns in the course of their functioning: (a) that the past conditions have little effect on the present conditions, which are most important; (b) that the past conditions have significant effects on the present conditions; (c) changes in and of themselves are the important factor and not the past nor the present conditions. To elaborate on the above three ways of predicting change effects:

(a) That the most important determinant operating on the groups is the present communication pattern. The previous communication patterns contribute only in a minor way to the present functioning of the groups. Thus, it would be predicted that the changes in the communication patterns would be important not because of the influences of the previous patterns, nor because of the present

to which the communication structure is changed.

(b) The most important determinants of behavior when changes occur in the communication patterns are the previous patterns of communication which influence the behaviors of the groups operating under the new communication patterns. In this case, what is critically effective is not primarily the changes in and of themselves, nor solely the nature of the present communication patterns, but rathe the interactions of the past communication patterns with the present patterns of the groups. This approach suggests that the order of change is the most important consideration, where the order of the changes contribute much to the present behavior of the groups.

(c) The most important determinants operating on the groups when there are imposed shifts in the communication patterns are those that develop as the result of the changes, in and of themselves. In this case, the amounts of changes that occur in the productivity of the group, for example when moving from one kind of communication pattern to another would be the same regardless of the order of the changes and the present communication pattern. All such changes would have significantly positive effects when introduced after group behaviors have become routinized and repetitive.

VII. Predictions Based on the Three Approaches

In the following section, specific predictions based on the three approaches will be made. They will be based on the concept of Centrality previously described in detail in Section V.

Approach One: The primary importance of the present communication pattern:

1. The behaviors of the groups (re the dependent variables being measured) should not be significantly different from each other, when the present communication pattern of the groups are the same, regardless of the differences in the past communication patterns of the respective groups under comparison. It follows then: (1.a) All circle groups should perform the same, i.e., regardless of the circle or wheel conditions that might have characterized the communication patterns of the Circle groups initially; (1.b) All wheel groups should perform the same (re the dependent variable being measured), i.e., regardless of the circle or wheel communication patterns that might have characterized the communication conditions of the wheel groups initially.

Summary for Approach One: This approach is based on the assumption that centrality differences between networks will lead to specific kinds of behavioral differences, consistently regardless of differential antecedent conditions. Based on such an assumption, groups in wheel conditions should perform similarly, regardless of differences in antecedent conditions. Groups in circle groups should perform the same regardless of differences in antecedent conditions.

2. All groups characterized by the same type of present communication pattern should be different from all the other groups characterized by different present communication patterns, in the same ways, regardless of the differences in antecedent communication patterns. It follows then: All circle groups will be different from all wheel groups, regardless of the fact that the circle groups might have had different antecedent communication conditions, and regardless of the fact that the wheel groups under comparison were anteceded by different conditions.

Approach Two: The primary importance of antecedent communication patterns in interaction with the present communication patterns.

1. The behaviors of a group characterized by a particular type of communication pattern will be influenced by the nature of the communication pattern(s) that anteceded it, in the direction of the behaviors characteristic of those antecedent patterns. Thus, when a given present pattern has been anteceded by a pattern with a higher centrality index than itself, it will lead to behaviors characteristic of a higher centrality index than itself, i.e., shorter time taken to solve problems; more correct trials. Also, when a pattern has been anteceded by a pattern with a centrality index lower than itself, it will lead to behaviors characteristic of a lower centrality index than itself, i.e., longer times taken to solve problems; more incorrect trials. It follows from the above approach that: (1..a) When a wheel arrangement has been changed from a circle arrangement, the behaviors of the wheel group will be more

similar to those of the circle pattern (take longer to solve problems, have more incorrect trials) than will the behaviors of a wheel pattern which has been anteceded by a wheel pattern. (1. b) A circle pattern that has been changed from a wheel pattern will exhibit behaviors that are characteristic of patterns with a higher centrality index than will a circle pattern that was anteceded by a circle pattern, e.g., will have fewer incorrect trials and take shorter time to solve problems.

Summary Statement of Predictions for Approach Two: Based on the fact that a Wheel pattern has a higher centrality index than a circle, the following is predicted: Whenever a present type of communication patterns has been anteceded by a pattern with a higher centrality index, the present pattern will lead to fewer incorrect trials, and less time taken to solve problems than if it had been anteceded by communication patterns of either the same or lower centrality indices. The higher the centrality index of the antecedent pattern, the more will the present pattern exhibit behaviors that are characteristic of higher centrality indices. The lower the centrality indices of the antecedent patterns the less will the present pattern exhibit behaviors that are characteristic of higher centrality indices. If the antecedent pattern has a centrality index lower than that of the present pattern, than the behaviors exhibited by the present pattern will be characteristic of centrality indices lower than its own (more incorrect trials and longer time taken to solve problems).

Approach Three: The primary importance of the Change itself; where neither the antecedent nor the present communication patterns contribute significantly to the changes in the behaviors that follow imposed changes in communication arrangements. It is the change of routinized behavior itself that is important. Consequently, after the behaviors of the circle or wheel have become repetitive, stabilized and routinized, it would be expected that changes in any of the arrangements to any of the arrangements will lead to more positive behaviors on the part of the members of the groups. The increase in positive behaviors, (i.e., as better performance on the dependent variables) will be the same for all communication-pattern changes. It follows then: the positive effects for the following changes will not be significantly different from each other: circle to wheel, wheel to circle.

It also follows, if it is the change itself that is of importance, i.e., that change has more positive effect than increased practice, then we can predict: (a) When a circle pattern is changed to a wheel arrangement, group behaviors will be more positively affected than when a wheel remains a wheel (increased practice); (b) When a wheel arrangement is changed to a circle pattern, group behaviors will be more positively affected than when a circle remains a circle.

Summary Statement of Approach 3: Approach Three suggests that change in and of itself will have positive effects on the behavior groups in communication networks regardless of the direction of the change.

VIII. Summary of Study Aims

The goal of this study is to examine the kinds of changes in behaviors that take place when the communication patterns of small problem-solving groups are altered. It is hoped that by establishing variations in conditions antecedent to the changes, that some important knowledge will be gained about the role that the history of organizations and groups plays in their operations and effectiveness. Further, a major aim in this project is to test the adequacy of three different approaches for integrating and predicting change phenomena, when such phenomena arise out of alterations in communication patterns.

IX. Significance of Research

As was stated in the section on Aims, this thesis is to be an attempt to simulate some important conditions of natural large scale organizations. Changes in communication and decision-making apparatus are imposed on the members of the organization. Changes are often involved in the job activities of the members of the organization which result from changes in the communication system of the organization. Changes in communication system involve changes in lines of authority and loci of decision-making, and consequently, changes in productivity and morale. It seems important, therefore, to be able to provide an account of the effects of such changes on the performances of problem-solving groups.

Since all organizations are continuously undergoing change, gradual or sharp, it would seem important to be able to understand, predict and consciously control for the effects of such changes. To accomplish the latter, requires some system of prediction and ordering of change effects. In this thesis, three logically possible systems are explored, each having different kinds of predictions and explanation systems for predicted change effects. Where evidence will be provided for the degree of adequacy of such systems for explaining, controlling and predicting change effects, there will be provided the beginning of a theoretical integration of some important organizational variables such as problem-solving ability through the examination of antecedent problem-solving conditions in the organization.

Procedure

Two hundred subjects, paid volunteers, drawn from undergraduate classes at Boston University, were randomly assigned to forty groups of five men each. Four experimental treatments were used involving all the combinations of Wheel with Circle communication arrangement. (A Wheel condition is one in which one member of the group, the central person, can send and receive from everyone else, but no one else can receive from or send to anyone other than the central person. A Circle condition is one in which each member can send to and receive from the member to his immediate left and the member to his immediate right).

The four treatments used were: (see page 40 for diagram of the experimental arrangement of communication change conditions)
(1) Circle-Circle (a no-change condition where the groups tried to solve a total of sixty problems in the Circle) (2) Circle-Wheel (where the groups tried to solve thirty problems in the Circle, and then had to try to solve thirty problems in the Wheel)
(3) Wheel-Circle (where the groups tried to solve thirty problems in the Wheel and then had to try to solve thirty problems in the Circle) (4) Wheel-Wheel (a no-change condition where the groups had to try to solve sixty problems in the Wheel network). The order of the running of experimental conditions was randomly determined.

Ten groups were run in each of the four experimental treatments. The subjects in each of the groups were randomly assigned to positions

Figure 2.2

DIAGRAM OF EXPERIMENTAL CONDITIONS

First Thirty Trials	Second Thirty Trials: C	Second Thirty Trials: W
C	10	10
W	10	10

10 Groups, 5 Subjects Each, In Each of Four Conditions:

CC, CW, WC, WW

C = Circle W = Wheel

in the communication network. The subjects were paid four dollars for their participation and were used only once. Each group spent from three to four hours in the experimental room. The subjects were allowed to smoke during the experiment and were made generally comfortable. No subjects were used who were color-blind or who had any admitted previous knowledge of the experiment.

Before the groups began to try to solve problems the following was told to them: "Gentlemen, this experiment is concerned with the ability of groups to work together in solving problems. This is important research. The Office of Naval Research has given us close to $35,000. to conduct this research over a two year period. In order for the results of this research to be meaningful, your full cooperation and sincere effort are required. Please follow the directions and do the best you can. If you do not, all this research, money, effort, and time will be wasted. Any questions you have regarding this study will be answered at the end of the experiment."

After the above, a complete list of instructions was read out loud by the experimenter. Each subject was instructed to silently read a copy of the instructions which he had in his booth, while the experimenter was reading them out loud. The following are the instructions that were used:

We've asked for your help today in an experiment on the ability of groups to solve problems. This question is a basic one for any groups organized for solving problems; for example, a research team, a management committee, a gun crew, and so on.

Now, before we get started, there is one general rule that needs to be followed, if the results of this experiment are to be worthwhile. Once we get under way, please do not talk to any members of your group. Any conversation will make the results of this experiment worthless.

Before starting the experiment, we want to get you used to the kind of problem you will be solving. So, we are going to have each of you do, alone at first, what you will be doing later, as a group.

Each one of you has five 4" x 5" cards. On each card will be five out of the following six possible symbols:
There is one symbol and only one symbol which appears on all five cards. Your job is to find out what the common symbol is. When you find the correct common symbol, Gently pull down One of the switches on your right, which has over it that symbol which you have decided is the common one.
Do you have any questions?
O.K. When I say "go", turn over the cards, find the common symbol, and when you have it, Gently pull down the One correct switch.

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Now we have come to the main problem. The task is the same. This time, however, instead of having five cards apiece, each of you will have only one card. Your job is to find out, with the help of others on your team, what the common symbol is.

You still may not talk to one another. Each of you can be identified by a different color. You are allowed to communicate, by writing only, on the narrow, message cards on your right (which are your own distinct color) and by passing them to other members, through the appropriate channels (open slots) in the apparatus. But, as you can see, certain channels (slots) may be blocked up. This means that you might not be allowed to send messages to every one, but only to those to whom you have open channels. Look in your booth,now, and see what channels are open. For every open channel (slot) through which you may pass messages to someone, there is an open channel through he may pass messages to you. This means that you may receive messages from anyone to whom you are allowed to send messages. The larger pieces of colored paper above and beside the channels (slots) indicate channels through which you may s end messages. The smaller pieces of colored paper above and below the channels (slots) indicate the channels through which you may receive messages. <u>You may send messages only through the channels marked "sending."</u> <u>You may receive messages only through the channels marked "receiving"</u>. The color of the paper beside and above the sending channels is the color identifying the person to whom you are sending a message. The color of the paper above and below the receiving channels is the color identifying the person from whom you are receiving a message.

You will find 4" x 5" cards with symbols on them, hanging on the left wall of your booth. On your right (below the switch box) there is a stack of your own colored cards, to be used by you for sending messages to other members of your group. You have enough cards to send as many messages as you want, to the men to whom you have open channels. Each of you, of course, will have a different symbol card, since there is only ONE common symbol. Your job as a team is to find the common symbol. You must not pass a message along on the same card which you receive from someone. You may copy any message you get and pass the copy along. The messages you send must be on your own colored cards. You may write any kind of a message you want. You have scrap paper which you may use for any purpose you want.

Your job is not done until everyone in your group has the answer. Then and only then, is the problem solved. When you have the answer, you may pass it along (on your own colored card). When anyone believes he has the answer, he should Gently pull down the appropriate switch, and then go on working. There is a switch for each of the six possible symbols that might appear on your symbol cards. When I see a light on my panel from each of the members of your group, I'll know the problem is solved. I will then say "stop".

You are allowed to change your mind about an answer as often as you want. But YOU MAY HAVE ONLY ONE SWITCH DOWN AT A TIME. So, if you change your mind about an answer, make sure that the

answer has been on for at least ten seconds, then, switch off the answer and switch on the new one.

Your team will be competing with other five-man teams to see how long it takes to get the right answers. The important thing is to get the answers in as short a time as possible. The shorter the time, the better will be your team's score. You will have a number of problems to solve. Each problem is called a trial. Each symbol card will represent one trial and will have the Trial Number on it.

Start when I give the signal, and stop when I give the stop signal. Start each trial by taking one symbol card off the hanging rock on the left wall of your booth, and trying by means of written messages, to find out what the common symbol is for that particular trial.

You and each trial by doing the following (after I have said "stop") : (a) place the symbol card used for the trial in the envelope attached to the left wall of your booth (b) fill out the questionnaire, answering every question completely (c) wrap the questionnaire, around the message cards you have received (d) put a rubber band around the questionnaire you have just filled out and the message cards you have received for that trial (e) drop the wrapped-up questionnaire and message cards in the container under your booth (f) When I tell you, turn switches back to off position, and be ready for another trial.

Raise your hand when you have done all of the above things.

After the Instructions had been read and the subjects had received answers (which were repetitions of the instructions) to questions that were raised, a practice problem was used. This practice problem was intended to allow the subjects to familiarize themselves with the task being used. Each subject was given five symbol cards, with different combinations of the six possible symbols that were used in the real trials. For each of the subjects there was only one symbol common to all the five cards that he had. When the subject recognized the common symbol, he pulled down the appropriate switch on the switch panel attached to the right wall of his booth. When all five subjects had correctly registered answers, the practice problem was ended, the instructions were completed and the real problems begun.

Every group was reminded once, for each of the first five trials only, of the following: " The important goal of your participation today is to solve the problems presented to you, correctly, as quickly as possible. Your job is not done until everyone in your group has answered. If you feel you have the answer pull the appropriate switch and continue working until everyone in your group has answered, at which time I will say stop and the trial will be ended."

Change was introduced after thirty trials, since previous research revealed that after thirty trials, within both Wheel and Circle conditions there were no significant differences in time taken to solve problems. (See appendix for results of previous

research, on the basis of which the thirtieth trial was selected as the point for the introduction of change.)

The physical change of communication channels was accomplished in the following manner. The apparatus itself allows for every person to send and receive messages from every one else., The original restrictions in communication channels were established by placing a piece of cardboard over all the sending and receiving channels in each booth such that only certain channels were available, (cut out), for use, e.g., those that the experimenter wanted the subject to use. The channels available were clearly marked regarding to whom and from whom the subjects could send and receive messages. The changes in communication channels were accomplished by removing the first card and replacing it with a second card with different communication channels available.

After thirty trials, each group whose network was changed was read the following announcement before beginning to try to solve problems in their new arrangement: " Until now, you have been using certain communication channels open to you for sending and receiving messages. Look in your booths now and see what channels are open. Some of the channels available to you for sending and receiving messages may be different from those used by you until now. When you have familiarized yourself with the open channels in your booths, raise your hands, and we will go on to solve more problems."

For a larger study (of which this thesis is a part) questionnaires were administered after each trial. The data collected in these questionnaires are not included in the analyses used in this thesis. (See p. , appendix for copies of questionnaires.)

The Experimental Task

(a) What it is: Since the major goal of the study is to examine the effects of antecedent conditions of different communication patterns on the behaviors of active, problem-solving groups, then the nature of the task is of considerable importance.

To each subject will be given a card, labeled by color and trial number, on which will appear a set of five (out of six possible) symbols. Each subject's card will be different from all the others in that the symbol lacking, the sixth one, will be a different symbol in each case. Thus, in any set of five cards there will be only one symbol in common. The problem will be for each member to find the common symbol. To accomplish this, each member will be allowed to communicate by means of written messages only, with those other members of the group to whom he will have an open channel. A subject who discovers the answer will be allowed to pass the answer along.

(b) Why it is used: The reasons for selection of the above-described task are two-fold: (1) There is sufficient evidence available to demonstrate the influence of the type of task used on the behaviors of groups with such tasks to solve. (Smith[33],

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[33] Sidney Smith, "Communication Pattern and the Adaptability of Task-Oriented Groups" (Unpublished, M.I.T., 1950)

Guetzkow and Dill[34], and Shaw[35]). The importance of knowing some of the differential effects of various tasks cannot be overestimated when the behaviors of problem-solving groups are examined. One major difficulty in the area of " Small Group Communication" experimentation is that there is not enough knowledge about the characteristics and properties of different types of problems that require solution. Thus it becomes almost impossible to relate clearly the kind of problem to the kind of communication pattern used to the kinds of behaviors that develop. What is known instead, is that for a given type of task, for a given kind of communication pattern certain kinds of group and individual behaviors will emerge. In short, what is being suggested is that since we are not able to classify properties of tasks and their ordered effects when specific communication patterns are involved, we must resort to the use of a task which has been shown to be related to specific kinds of behaviors, given specific kinds of communication patterns. This necessarily is done without our knowing what the properties of the task might be that actually do contribute to differences in behaviors of problem-solving groups using different communication patterns.

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[34] H. Guetzkow and W.R. Dill, "Factors in the Organizational Development of Task-Oriented Groups" (Carnegie Institute of Technology, Penn.)

[35] M.E.Shaw, "Some Effects of Unequal Distribution of Information Upon Group Performance in Various Communication Nets", Journal of Abnormal and Social Psychology, XLIX (1954), 537-553.

Secondly, since the predictions about the behaviors of problem-solving groups using different communication patterns are based either on direct extensions of the Centrality concept, then it would seem expedient to use as a task one which has been found to be consistently related to the types of communication patterns under consideration. Essentially, what is being suggested is that since the project, to a great extent, centers around certain extensions of the Centrality notion, and since specific results are available with respect to the effects of using this kind of task, then in order to examine such extensions experimentally, the same kind of task would need to be used.

The task described in the above section satisfied the previously discussed two criteria for problem selection: (1) It has been shown to operate in a given setting characterized by specific kinds of communication patterns. (2) It has also been used in the major study by Leavitt[36] dealing with the concept of Centrality.

Apparatus

(See page 51 for picture of experimental apparatus)

The subjects in each group will be seated around a circular table so that each will be separated from the next by a vertical partition from the center to six inches beyond the table's edge. The apparatus has slots permitting subjects to push written messages to the men

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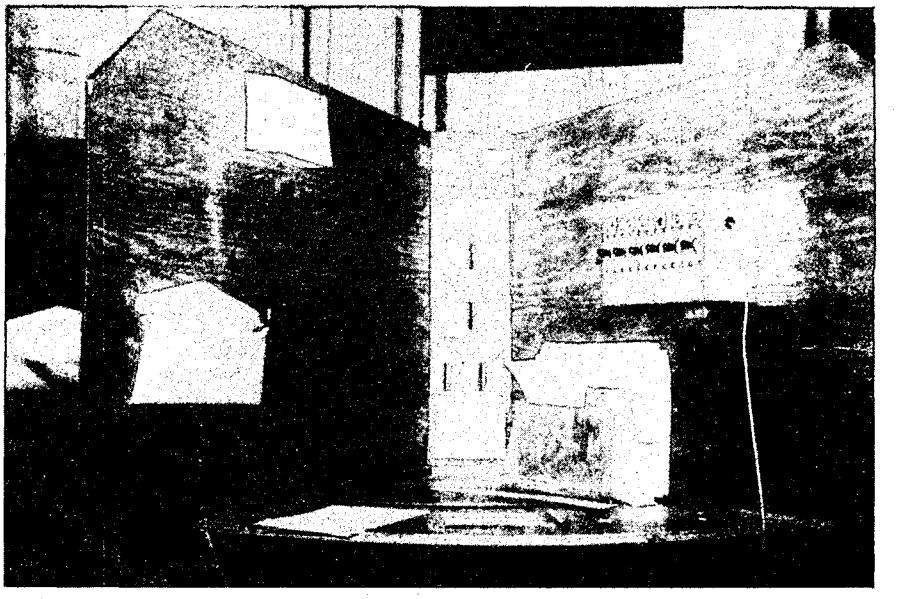
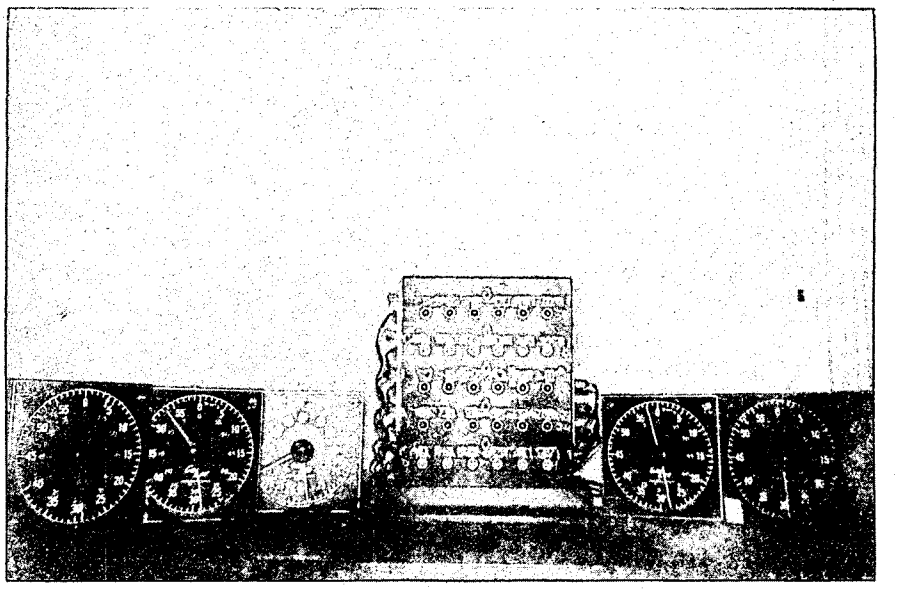
[36] Harold J. Leavitt, "Some Effects of Certain Communication Nets in Task-Oriented Groups", Op. cit.

Experimental Apparatus

Experimental Booth



Experimental Recording Apparatus



with whom they are allowed to communicate. A five-layered pentagonal box is located at the center of the table. The box will be placed so that the partitions will just touch each of the five points of the pentagon. Each of the five resulting wedge-shaped work spaces have been designated by a different color. The subjects are provided with blank message cards (the dimensions being 1 3/4" x 12 1/2") whose colors will match those of their respective work spaces. In order for any message to be sent from one booth to another it will have to be on a card whose color is that of the booth from which the message will be sent. On the left wall of each partition, large symbol cards (4" x 5") representing the trials, will be hung in loose-leaf fashion. The cards will be placed in order, with backs to the subjects. At the starting signal, the subjects will pull down the first card and begin the problem-solving. Also, each work space will be provided with a board on which will be mounted six switches. Above each switch will appear one of the symbols. When the subject will have registered an answer, he will throw the proper switch which will turn on an appropriate light on a master board of thirty lights in the experimenter's room and shut off a reaction timer wired to his booth. When five lights (whether or not they will have represented the correct symbol) representing the five different subjects will

have been lit, the trial will be ended by the experimenter. The experimenter will be able to tell by a glance at the light panel whether: (a) five different subjects have thrown their switches, i.e., what answer was decided on; (b) whether all five have decided on the same answer; (c) by later analysis, whether the answer decided on was right or wrong. The same detailed instructions will have been given to all subjects in all of the groups. The subjects will be made aware of the changes in communication patterns, at the times such changes will be made.

Measures of time taken for each person and for the groups as a whole were recorded (to the nearest second) together with all the responses of the subjects on a specially prepared data sheet. (See page and a description of the independent and dependent variables.) The answers to the problems were randomly assigned as well as the symbols missing from each of the member's cards for the trials. (See pages common symbols and the symbols missing from each member for any given trial.)

Questions to be Answered by the Experiment and Method for Answering Them

(A) The following question is the major one to be answered in this experiment: Do groups in the same communication arrangements exhibit differences in time taken to solve problems and number of correctly solved problems, when such groups differ with respect to initial communication arrangements? This question can be answered by comparing (separately for time taken and number of correctly solved problems): (a) C2 with C4 (b) W1 with W4.

If differences in antecedent communication conditions do not serve to distinguish between groups that work within the same present communication network, then it would be expected that:

(a) C2 would not be significantly different from C4 with respect to time taken to solve problems and number of problems correctly solved.

(b) W1 would not be significantly different from W4 with respect to time taken to solve problems and number of problems correctly solved.

If however, the kinds of differences in antecedent communication conditions do serve to distinguish between groups that work within the same present communication network, then the following would be expected:

(a) C4 would take significantly shorter time to solve problems and have a significantly greater number of correct trials than C2.

(b) W4 would take significantly shorter time to solve problems and have a significantly greater number of correct trials than W1.

If, however, it is not the kind of difference between antecedent and present communication conditions that serve to distinguish between groups in the same present communication arrangement, but simply differences between past and present patterns, then the following would be expected:

(a) W1 would take significantly shorter time to solve problems and have a significantly greater number of correct trials than W4.

(b) C4 would take significantly less time to solve problems and have a significantly greater number of correct trials than C2.

For any of the three approaches mentioned above to be supported in this study, all of the predictions within each approach will have had to be supported.

Table 2.18

Independent Variables

What They Are	How They Are Established	How and Why They Are Used
Two kinds of communication Patterns, Circle and Wheel, distinguished by different centrality indices.	Established by varying and limiting the 'who-may-communicate-to-whom' nature of the problem-solving groups.	Used to study differences in group behaviors (dependent variables) when the two kinds of communication patterns undergo changes

Dependent Variables

What They Are	How They Are Measured
Performance Measures 1.) Time taken to solve problems 2.) Number of problems correctly solved	Measured directly during ongoing problem-solving activities through the use of electrical recording apparatus.

Table 2.19

Six Symbols Used

TRIAL NUMBER	SYMBOL MISSING FROM: WHITE	RED	GREEN	YELLOW	BLUE	COMMON SYMBOL
1	△	◇	✱	○	□	+
2	◇	○	□	△	+	✱
3	+	✱	□	△	◇	○
4	□	◇	△	✱	+	○
5	○	✱	+	△	□	◇
6	△	○	□	✱	◇	+
7	□	+	○	◇	△	✱
8	◇	✱	□	+	○	△
9	✱	◇	□	△	○	+
10	+	○	□	✱	◇	△
11	○	+	△	◇	✱	□
12	✱	○	□	△	+	◇
13	△	○	◇	□	+	✱
14	□	◇	+	✱	△	○
15	+	○	□	◇	✱	△
16	○	+	△	✱	□	◇
17	✱	◇	+	○	△	□
18	+	◇	□	△	○	✱
19	△	+	◇	□	✱	○
20	○	□	△	◇	✱	+
21	+	○	□	✱	△	◇
22	○	△	◇	+	✱	□
23	△	○	+	□	◇	✱
24	◇	✱	△	○	□	+
25	✱	◇	+	□	○	△
26	○	△	◇	□	+	✱
27	□	◇	△	○	✱	+
28	+	✱	△	□	◇	○
29	◇	○	✱	+	□	△
30	✱	△	◇	+	○	□

Six Symbols Used

TRIAL NUMBER	SYMBOL MISSING FROM: WHITE	RED	GREEN	YELLOW	BLUE	COMMON SYMBOL
31	○	□	+	✳	△	◇
32	△	◇	+ ○	+	✳	□
33	+	○	✳	◇	□	△
34	△	+	□	✳	◇	○
35	○	✳	◇	△	○	+
36	◇	□	△	○	□	✳
37	△	○	+	□	+	◇
38	+	△	◇	□	✳	✳
39	✳	○	△	◇	○	+
40	□	◇	△	+	□	○
41	◇	□	✳	+	✳	△
42	✳	◇	○	△	○	□
43	+	✳	□	○	+	△
44	□	△	◇	✳	◇	○
45	○	□	◇	△	+	+
46	+	◇	△	□	✳	✳
47	✳	+	○	△	○	◇
48	□	○	△	✳	□	◇
49	+	✳	□	△	+	○
50	✳	△	◇	□	◇	+
51	+	○	△	□	○	✳
52	✳	△	+	◇	◇	○
53	□	△	○	✳	□	◇
54	○	◇	✳	□	+	△
55	◇	□	△	○	+	+
56	△	✳	○	+	✳	□
57	□	✳	△	◇	◇	+
58	□	◇	○	△	○	△
59	✳	+	+ □	✳	✳	◇
60	+	△	◇		□	○

Table 2.21

	Response 1	Response 2	Response 3	Response 4	Response 5	Response 6	Time
RED	+ ○ △ ✱ ○ □	+ ○ △ ✱ ◇ □	+ ○ △ ✱ ◇ □	+ ○ △ ✱ ◇ □	+ ○ △ ✱ ◇ □	+ ○ △ ✱ ◇ □	
YELLOW	+ ○ △ ✱ ◇ □	+ ○ △ ✱ ◇ □	+ ○ △ ✱ ◇ □	+ ○ △ ✱ ◇ □	+ ○ △ ✱ ◇ □	+ ○ △ ✱ ◇ □	
GREEN	+ ○ △ ✱ ◇ □	+ ○ △ ✱ ◇ □	+ ○ △ ✱ ◇ □	+ ○ △ ✱ ◇ □	+ ○ △ ✱ ◇ □	+ ○ △ ✱ ◇ □	
BLUE	+ ○ △ ✱ ◇ □	+ ○ △ ✱ ◇ □	+ ○ △ ✱ ◇ □	+ ○ △ ✱ ◇ □	+ ○ △ ✱ ◇ □	+ ○ △ ✱ ◇ □	
WHITE	+ ○ △ ✱ ◇ □	+ ○ △ ✱ ◇ □	+ ○ △ ✱ ◇ □	+ ○ △ ✱ ◇ □	+ ○ △ ✱ ◇ □	+ ○ △ ✱ ◇ □	

Trial Number

Results

This chapter is divided into two parts. Part I is confined to the analyses required to test the original predictions specified in the Methodology chapter. Results of such analyses indicated the need for further examination of the data. Part II includes such further analysis. The results in this part neither confirm nor disconfirm the original hypotheses. They do, however, provide evidence for the need to consider modifications of the original approaches when planning for later research.

Part I

In this part, the questions to be answered and methods used for answering them are:

(a) Will groups in the WC condition perform differently from groups in the CC condition for times taken to solve problems?

(b) Will groups in the CW condition perform differently from groups in the WW condition for times taken to solve problems?

(c) Will groups in the WC condition perform differently from groups in the CC condition for numbers of correct trials?

(d) Will groups in the CW condition perform differently from groups in the WW condition for number of correct trials?

All four questions are answered through the Analysis of Variance method for trials 31-60 (all trials after changes).

A graph corresponding to each of the tested sets of conditions follows the Analyses of Variance.

Following the presentation of the results in tabular and graphic forms, they will be examined to determine the extent to which each of the three prediction systems has been supported.

Table 3.3

(a) The results of the Analysis of Variance of the times taken to solve problems between the Circles that were changed from W heels (WC) and the Circles that were Circles (CC) throughout are included in the following table.[1]

Analysis of Variance of Time Scores of Two Conditions (WC and CC) with Ten Groups in Each Condition with Thirty Trials for Each Group

Source of Variation	Sum of Squares	df	Mean Square	F	
Total	244,904.29	599			
Total Between Groups	35,489.89	19			
Between Methods (WC and CC)	1,314.24	1	1,314.24	.692	
Between Groups Treated Alike	34,175.65	18	1,898.65		
Total Within Groups	209,414.40	580			
Between Trials	74,147.19	29	2,556.80	14.488	.01
Interaction: Trials x Methods	43,145.06	29	1,487.76	8.430	.01
Interaction: Pooled Groups x Trials	92,122.15	522	176.48		

The above results indicate that: (a) there was not a significant time difference between conditions WC and CC; (b) there were significant

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1. The F test on the raw time data indicated that the variances of WC and CC were significantly different. (11.485). Consequently, the data was transformed, logarithmically, and yielded an F of 4.833. The latter F was also significant, although much smaller than before transformation. To compensate for this heterogeneity of variances, the degrees of freedom used for the actual testing of the F ratios in the above table were halved.

differences in time scores over trials; (c) the differences over trials were different for the kind of condition.

(b) The results of the Analysis of Variance of the times taken to solve problems between the Wheels that were changed from Circles (CW) and the Wheels that were Wheels throughout (WW) are included in the following table.[2]

Analysis of Variance of Time Scores of Two Conditions (CW and WW) with Ten Groups in Each Condition with Thirty Trials for Each Group

Source of Variation	Sum of Squares	df	Mean Square	F	
Total	198,046.64	599			
Total Between Groups	84,806.44	19			
Between Methods CW and WW	7,462.43	1	7,462.43	1.737	
Between Groups Treated Alike	77,344.01	18	4,296.89		
Total Within Groups	113,240.20	580			
Between Trials	36,681.74	29	1,264.89	10.765	.01
Interaction: Trials x Methods	15,222.27	29	524.91	4.467	.01
Interaction: Pooled Groups x Trials	61,336.19	522	117.50		

The above results indicate that: (a) there was not a significant time difference between conditions WW and CW; (b) there were

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2. The F test on the raw time data indicated that the variances of CW and WW were significantly different (9.0087). Consequently, the data was transformed, logarithmically, and yielded an F of 3.4627. The latter F was also significant, although much smaller than before transformation. To compensate for this heterogeneity of variances, the degrees of freedom used for the actual testing of the F ratios in the above table were halved.

differences in time scores over trials; (c) the differences over trials were different for the kind of condition.

(c) The results of the Analysis of Variance of Number of Correct Trials in Blocks of five trials between the Circles that were changed from Wheels and the Circles that were Circles throughout are included in the following table.[1]

Analysis of Variance of Number of Correct Trials of Two Conditions (Wheel-Circle and Circle-Circle) with Ten Groups in Each Condition with Thirty Trials Collapsed into Six Blocks of Five Trials Each for Each Group

Source of Variation	Sum of Squares	df	Mean Square	F	
Total	118.37	119			
Total Between Groups	48.03	19			
Between Methods (WC and CC)	8.54	1	8.54	3.89	
Between Groups Treated Alike	39.49	18	2.19		
Total Within Groups	70.34	100			
Between Trial Blocks	10.17	5	2.03	3.12	.05
Interaction: Trial Blocks x Methods	1.66	5	.33	.50	
Interaction: Pooled Groups x Trial Blocks	58.51	90	.65		

The above results indicate that: (a) there was not a significant difference between WC and CC in number of correct trials in blocks of five

1. The F test on the variances of WC and CC conditions for number of correct trials in blocks of five revealed that the variances were homogeneous.
   F 5.3948/3.9334 1.3715.

(b) There were significant differences in number of correct trials over trial (c) the differences over trials were not dependent on conditions.

(d) The results of the Analysis of Variance of Number of Correct Trials in Blocks of five trials between the Circles that were changed to Wheels and the Wheels that were Wheels throughout are included in the following table.[1]

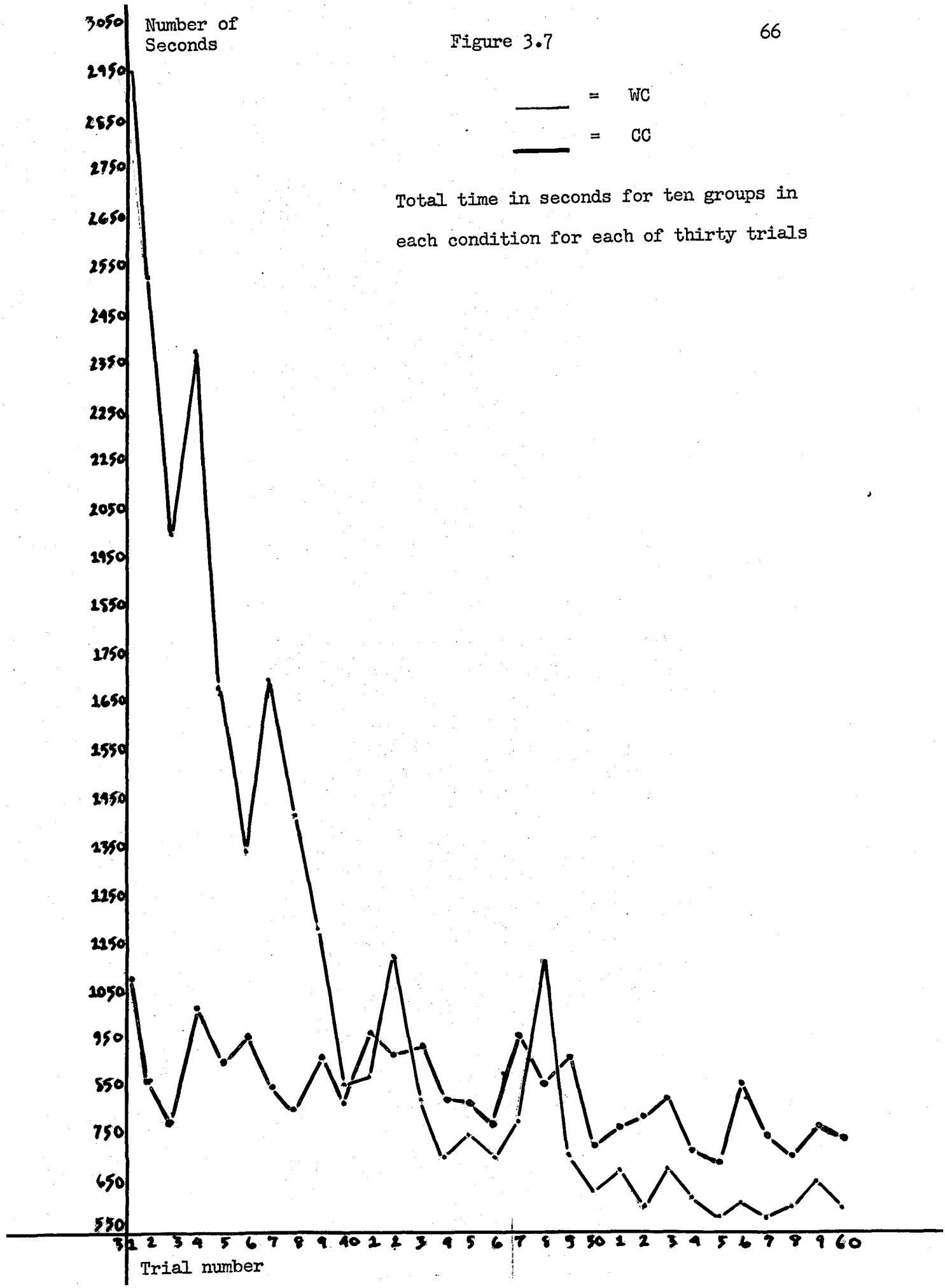
Analysis of Variance of Number of Correct Trials of Two Conditions (Circle-Wheel and Wheel-Wheel) with Ten Groups in Each Condition with Thirty Trials Collapsed into Six Blocks of Five Trials Each for Each Group

Source of Variation	Sum of Squares	df	Mean Square	F
Total	44.79	119		
Total Between Groups	11.29	19		
Between Methods WW and CW	.01	1	.010	.015
Between Groups Treated Alike	11.28	18	.626	
Total Within Groups	33.50	100		
Between Trial Blocks	5.84	5	1.168	4.141 Signif. .05
Interaction: Trial Blocks x Methods	2.24	5	.448	1.588
Interaction: Pooled Groups x Trial Blocks	25.42	90	.282	

The above results indicate that: (a) there was not a significant difference between CW and WW in number of correct trials in blocks of five (b) there were significant differences in number of correct trials over trials in blocks of five (c) the differences over trials were not dependent on conditions.

1. The F test on the variances of conditions CW and WW for number of correct trials in blocks of five revealed that the variances were heterogeneous (F .477/.281 1.697 significant at the .05). Because of this, the degrees of freedom used for testing the terms in the above Analysis of Variance Test were halved.

Figure 3.7

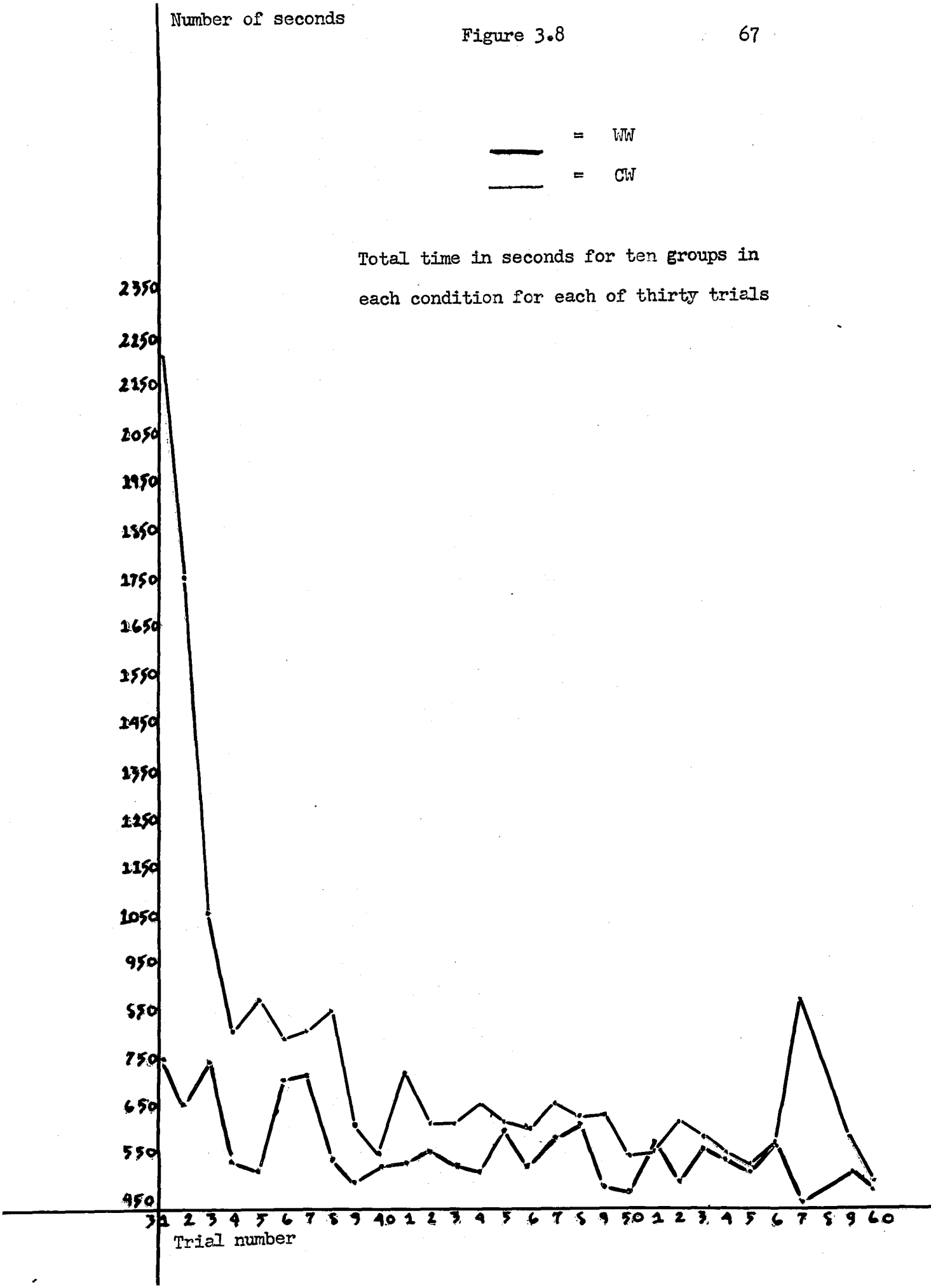


_____ = WC

_____ = CC

Total time in seconds for ten groups in each condition for each of thirty trials

Figure 3.8


= WW
= CW
Total time in seconds for ten groups in each condition for each of thirty trials
Number of seconds
2350
2250
2150
2050
1950
1850
1750
1650
1550
1450
1350
1250
1150
1050
950
850
750
650
550
450
1 2 3 4 5 6 7 8 9 10 1 2 3 4 5 6 7 8 9 50 1 2 3 4 5 6 7 8 9 60
Trial number

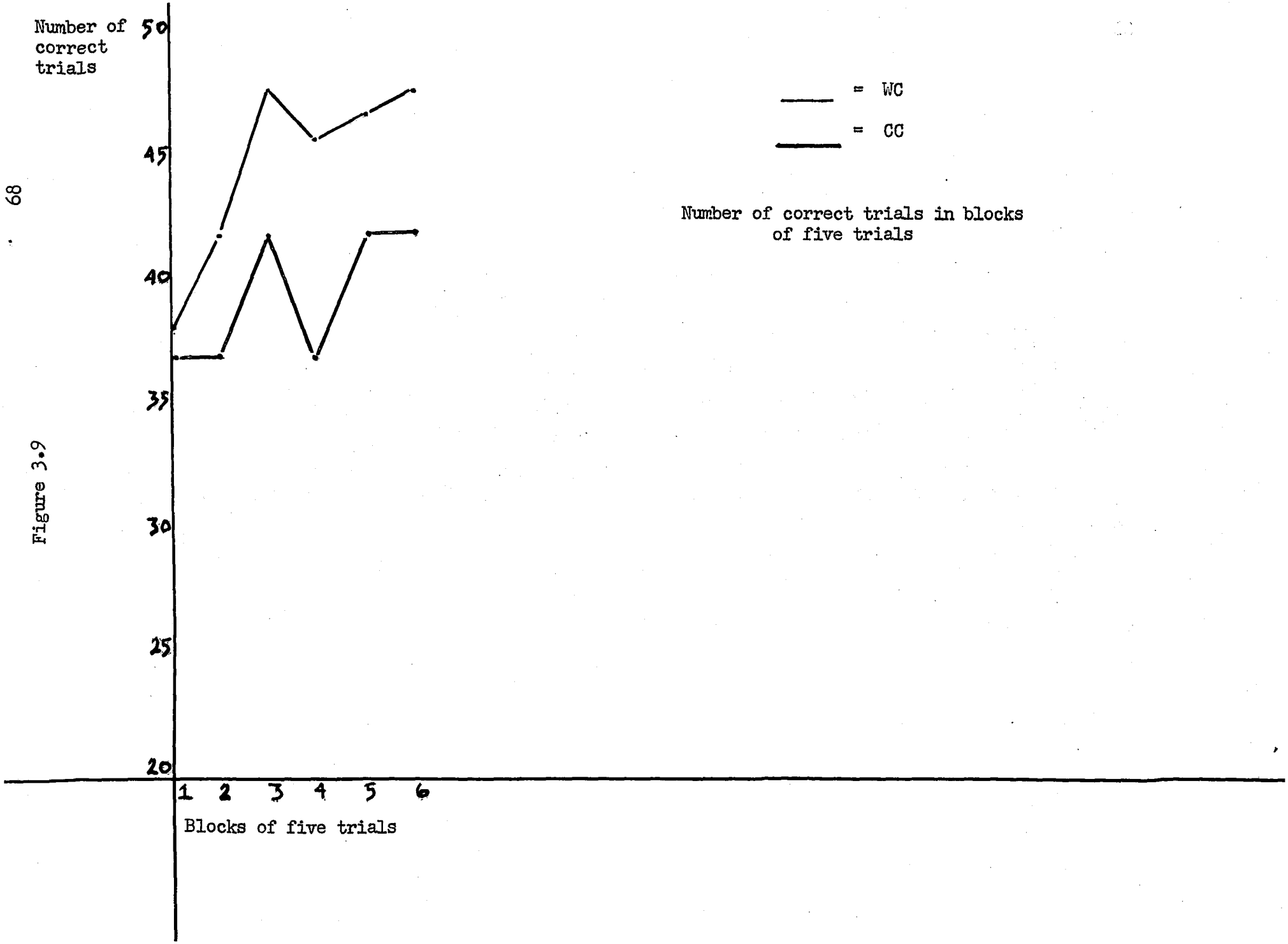

Number of correct trials
50
45
40
35
30
25
20
1
2
3
4
5
6
Blocks of five trials
= WC
= CC
Number of correct trials in blocks of five trials

Figure 3.9

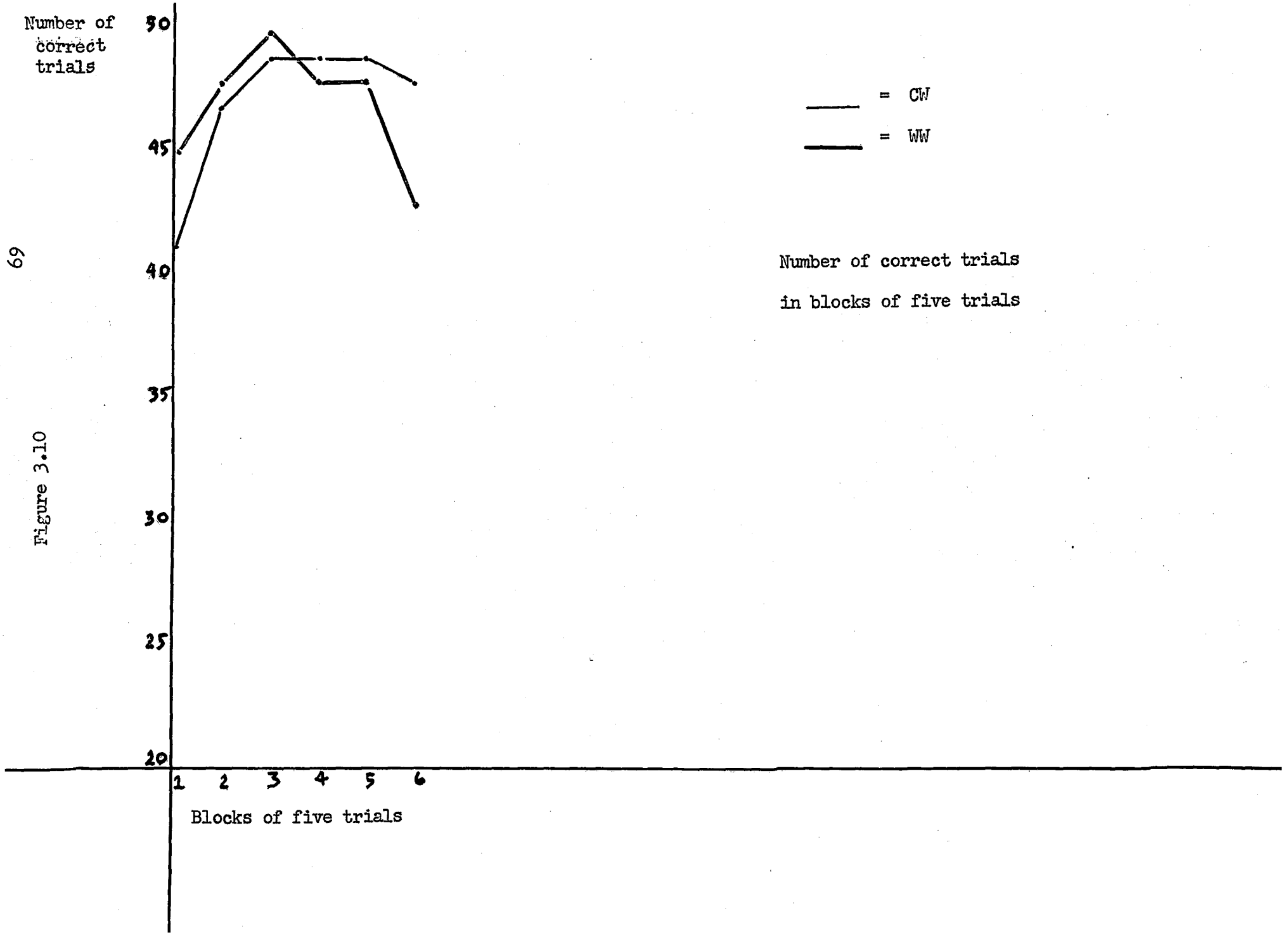

Number of correct trials
50
45
40
35
30
25
20
1
2
3
4
5
6
Blocks of five trials
= CW
= WW
Number of correct trials
in blocks of five trials

Figure 3.10

Inspection of the results indicates that one of the three approaches has been completely supported. The following table includes: (a) a description of the approach; (b) the expected results according to the approach; and (c) the reference to the part of the analysis that supports the expectation.

Approach	Expected Results	Reference
Differences in antecedent communication conditions do not serve to distinguish between groups that work within the same kind of communication network	(1) WW will not be significantly different from CW in time taken to solve problems.	The Between Methods Term page 65
	(2) WW will not be significantly different from CW in number of correct trials.	The Between Methods Term page 67
	(3) CC will not be significantly different from WC in time taken to solve problems.	The Between Methods Term page 64
	(4) CC will not be significantly different from WC in number of correct trials.	The Between Methods Term page 66

Evidence for the support of the above hypotheses was obtained by finding in the Analyses of Variance no significant time difference between WC and CC (p.64) and no significant time difference between CW and WW (p. 65) in their Between Methods terms, respectively. Evidence was also obtained by finding no overall significant difference between WC and CC (p.66) and between CW and WW (p.67) with regard to number of correct trials, in their respective Analysis of Variance tests.

Inspection of the other terms of the Analyses of Variance and the graphs of time and correct trials raises additional questions whose answers are needed to complete the findings of this study.

Part II

The Between Trials and Trials x Methods Interaction Terms in the Analyses of Variance of time taken to solve problems, for WC and CC as well as for CW and WW are significant (pages 64 and 65 respectively). The graph of the times taken to solve problems for WC and CC (p. 67) reveals that WC, with the exception of two trials has lower times than CC. It also indicates smaller variations in times among the last 15 or 20 trials than among the total 30 trials. The graph of the time taken to solve problems for CW and WW (p.68) indicates smaller variations in time scores among the last 15 or 20 trials than among the total 30 trials. With the exception of two trials in which the times are nearly identical, CW has longer times than WW.

The Between Trial Blocks Terms in the Analyses of Variance of number of correct trials for WC and CC as well as for CW and WW are significant (pages 63 and 64 respectively). The graph of the number of correct trials of WC and CC (p.69) indicates that much larger differences between WC and CC occur in the last 15 trials than in the trials before. The graph of the number of correct trials of CW and WW (p. 70) indicate that the number of correct trials is greater and more level in the last 15 trials than in the first 15 for CW. This graph also indicates that there is a trend of decreasing number of correct trials (three of the four blocks of trials are lower over trial blocks).

In view of the above results and indications, it seems justifiable to raise the question of whether or not sub-analyses of the experimental conditions over trials would provide evidence for modifying the research conclusions that would be based solely on the results of analyses in Part I.

The analyses included in Part II are intended to provide evidence for answering the above question.

In this part, the questions to be asked and methods for answering them are:

(a) Where if at all, does stabilization of times taken to solve problems take place for the WC condition? This is to be answered by Analysis of Variance and Tukey's Gap test.

(b) Do the groups in WC perform differently from those in CC after stabilization has taken place? A "t" test for trials 46-60 was used to answer this question.

(c) Where if at all, does stabilization of times taken to solve problems take place for the CW condition? This question was answered by Analysis of Variance and Tukey's Gap test.

(d) Do the groups in CW perform differently from those in WW after stabilization has taken place? A "t" test for trials 46-60 was used to answer this question.

(e) Do the groups in the CC condition perform differently on trials 31-45 than they do on trials 46-60 for number of correct trials? A " t " test was used to answer this question.

(f) Do the groups in the WC condition perform differently on trials 31-45 than they do on trials 46-60 for number of correct trials. A "t" test was used to answer this.

(g) A "t" test was used to answer the question of whether the performances of groups in the WC condition are different in trials 31-40 than they are in trials 41-60, for number of correct trials.

(h) Do groups in the CW condition perform differently on number of correct trials in trials 31-45 than in trials 46-60? This question was answered by a " t " test.

(i) Do groups in the WW condition perform differently in number of correct trials in trials 31-45 than in trials 46-60? This question was answered by a "t" test.

(j) Do the groups in WC perform differently on number of correct trials than those in CC for trials 46-60? This was answered by a "t" test.

(k) Do the groups in condition CW perform differently on number of correct trials than those in condition WW for trials 46-60. This was answered by a "t" test.

Following the presentation of the results of the above analyses, they will be summarized in table form.

(a) The following Analysis of Variance of times[1] taken to solve problems for the WC condition was done in order to obtain the appropriate error term needed in Tukey's Gap Test.[2]

Analysis of Variance of Time Scores of the WC Condition with Ten Groups with Thirty Trials for Each Group (Trials 31-60)

Source of Variation	Sum of Squares	df	Mean Square	F	
Total	198,332.67	299			
Between Groups	26,823.20	9	2,980.36		
Between Trials	111,670.47	29	3,850.71	16.796	.01
Interaction:					
Groups x Trials	59,839.00	261	229.27		

Tukey's Gap Test allows the differences between trial means that are significant to be located by comparing any trial mean with any other according to the least significant difference that would be required in order to consider such a difference as significant.

Tukey's Gap Test Applied to Trial Means

Trial	Mean time	Trial	Mean time	LSD	Least Significant Difference (LSD)
31	246.2	46	183.3		
32	233.9	47	188.1		
33	224.5	48	196.4		$\frac{1}{2}$
34	228.4	49	183.9	LSD	t 2 S
35	218.3	50	178.9		.05 m
36	211.6	51	182.3		
37	215.7	52	177.5		t
38	210.9	53	182.5		.05 with 18 df 2.1010
39	200.4	54	179.2		
40	191.1	55	176.7		$\frac{1}{2}$
41	191.1	56	178.1		2 1.4142
42	199.7	57	175.9		
43	191.4	58	177.4		S $\frac{229.27}{30}$ 2.7646
44	182.8	59	181.4		m
45	185.4	60	178.0	LSD	8.2143

1. The times used in this Analysis of Variance are the logarithmically transformed raw data multiplied by a constant of 1000 to remove the decimals.

2. Tukey, J.W. Comparing Individual Means in the Analysis of Variance, Biometrics, 5, 1949, pages 99-114.

With the exception of trial difference 48-49, there is no significant difference between any trial and the one following it, after trial difference 44-45. Also after trial 45, with the exception of trials 47 and 48, there is no significant difference between any one trial and any other.

(b) As the results of Tukey's Gap Test indicate, a levelling off of times taken to solve problems seems to have taken place after trial 45. For this reason the following "t" test was done in order to find out if the differences in times taken to solve problems between WC and CC are significant for trials 46-60.

"t" test on Times Taken to Solve Problems Between WC and CC Conditions with 10 Groups in Each Trial with 15 Trials in Each Condition (Trials 46-60)

	Condition WC		
Trial	Mean of 10 Groups	Condition Mean	Variance
46	183.3		
47	188.1		
48	196.4		
49	183.9		
50	178.9		
51	182.3		
52	177.5	181.3	28.4807
53	177.5		
54	179.2		
55	176.7		
56	178.1		
57	175.9		
58	177.4		
59	181.4		
60	178.0		

Condition CC

Trial	Mean of 10 Groups	Condition Mean	Variance
46	189.0		
47	199.1		
48	191.7		
49	195.3		
50	186.8		
51	188.2		
52	189.0	189.7	14.4957
53	191.6		
54	187.2		
55	185.7		
56	192.9		
57	187.4		
58	185.8		
59	189.4		
60	186.4		

F $\frac{S^2WC}{S^2CC}$ 24.4807 / 14.4957 = 1.9647 Not Significant. An F of 2.48 is needed to reject at the .05 level with 14,14 df.

"t" 7.0175 with 28 df is significant at less than the .01 level.

The above result indicates that there was a significant difference between WC and CC conditions with respect to mean number of correct trials for trials 46-60.

(c) The following Analysis of Variance of times[1] taken to solve problems for the CW condition was done in order to obtain the appropriate error term needed in Tukey's Gap Test.

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1. The times used in this Analysis of Variance are the logarithmically transformed raw data multiplied by a constant of 1000 to remove the decimals.

Table 3.18

Analysis of Variance of Time Scores of the CW Conditions with Ten Groups with Thirty Trials for Each Group (Trials 31-60)

Source of Variation	Sum of Squares	df	Mean Square	F	
Total	147,894.67	299			
Between Groups	64,578.07	9	7,175.34		
Between Trials	44,242.87	29	1,525.62	10.191	.01
Interaction: Groups x Trials	39,073.73	261	149.71		

Tukey's Gap Test Applied to Trial Means

Trial	Mean Trial Time	Trial	Mean Trial Time	LSD Least Significant Difference	
31	230.0	46	176.9		
32	212.1	47	180.0	$\frac{1}{2}$	
33	196.3	48	175.5	LSD $t_{.05}\ 2\ S_m$	
34	184.4	49	175.9		
35	189.8	50	172.8		
36	185.0	51	174.2	$t_{.05}$ with 18 df	2.1010
37	182.6	52	176.0		
38	186.9	53	177.8		
39	176.0	54	173.8	2 1.4142	
40	173.4	55	171.6		
41	181.2	56	175.1	S_m 149.71 / 30	2.2339
42	176.5	57	187.3		
43	178.1	58	183.3		
44	178.7	59	177.2	LSD 6.6374	
45	177.3	60	170.3		

With the exception of trial differences 56-57 and 59-60, there is no significant difference between any one trial and the one following it. Also, excluding trial 60, there is no significant difference between any one trial and any other, with the exception of trials 57 and 58, after trial 45.

(d) As the results of Tukey's Gap Test indicate, a levelling off of times taken to solve problems seems to have taken place after trial 45. For this reason, the following "t" test was one in order to find out if the differences in times taken to solve problems between CW and WW are significant for trials 46-60.

"t" Test on Times Taken to Solve Problems Between CW and WW Conditions with 10 Groups in Each Trial with 15 Trials in Each Condition (Trials 46-60)

Trial	Mean of 10 Groups	Condition Mean	Variance
		Condition CW	
46	176.9		
47	180.0		
48	175.5		
49	175.9		
50	172.8		
51	174.2		
52	176.0		
53	177.8	176.513	19.27
54	173.8		
55	171.6		
56	175.1		
57	187.3		
58	183.3		
59	177.2		
60	170.3		
		Condition WW	
46	172.6		
47	177.1		
48	180.9		
49	168.1		
50	168.5		
51	177.3		
52	171.6	172.967	16.99
53	176.1		
54	174.3		
55	172.4		
56	177.3		
57	166.5		
58	170.2		
59	172.2		
60	169.4		

F $\frac{S^2CW}{S^2WW}$ 19.27/16.99 1.1341 Not Significant. An F of 2.48 is needed to reject at the .05 level, with 14,14 df.

"t" 3.189 with 28 df is Significant at less than the .01 level.

The above result indicates that there was a significant difference between conditions CW and WW with respect to mean number of correct trials for trials 46-60.

(e) The following "t" test was done in order to find out if the groups in condition CC had mean numbers of correct trials in trials 31-45 and 46-60 that were significantly different from each other.

"t" Test on Number of Correct Trials for 10 Groups in Condition CC Between Trials 31-45 and Trials 46-60

Group	Trials 31-45	Trials 46-60	d	d - $\bar{d}$	$(d - \bar{d})^2$
1	15	13	2	2.5	06.25
2	13	14	1	0.5	00.25
3	12	14	2	1.5	02.25
4	6	8	2	1.5	02.25
5	12	9	3	3.5	12.25
6	12	12	0	1.5	00.25
7	10	15	5	4.5	20.25
8	9	10	1	0.5	00.25
9	13	13	0	0.5	00.25
10	14	13	1	1.5	02.25
	X 11.6	X 12.1	d 0.5	0	46.50

s^2 31-45 6.9333

s^2 46-60 5.4333

F 6.9333/5.4333 1.2760 Not Significant

"t" .6956 Not Significant (with 9 df a "t" of 2.262 is needed to reject at the .05.

The above result indicates that for condition CC there was no significant difference between trials 31-45 and trials 46-60 with respect to mean number of correct trials.

(f) The following "t" test was done in order to find out if the groups in condition WC had mean numbers of correct trials in trials 31-45 and 46-60 that were significantly different from each other.

"t" Test on Number of Correct Trials for 10 Groups in Condition WC Between Trials 31-45 and Trials 46-60.

Group	Trials 31-45	Trials 46-60	d	d - $\bar{d}$	$(d - \bar{d})^2$
1	14	15	1	0.3	0.09
2	12	15	3	1.7	2.89
3	14	15	1	0.3	0.09
4	13	12	1	2.3	5.29
5	14	14	0	1.3	1.69
6	11	15	4	2.7	7.29
7	15	15	0	1.3	1.69
8	11	10	1	2.3	5.29
9	13	15	2	0.7	0.49
10	11	15	4	2.7	7.29
	X 12.8	X 14.1	$\bar{d}$ 1.3	0	32.10

s^2_{31-45} 2.1777

s^2_{46-60} 2.9888

F 2.9888/2.1777 1.3724 Not Significant

"t" 2.1774 which is Not Significant at the .05 but is Significant at the .06 level. (A "t" of 2.262 is needed in order to reject at the .05 level.

In view of the above, and in view of the fact that inspection of the graph on page indicated that the largest block difference occurred between block 2 and block 3 (between trials 36-40 and trials 41-45); and in view of the fact that differences between trials blocks 3,4,5 and 6 seemed to be considerably smaller than the difference between trial blocks 1 and 2, it seemed important to find out if the mean number of correct trials for trials 31-40 was significantly greater than the mean number of correct trials for trial 41-60, for the condition WC.

(g) "t" Test on Mean Number of Correct Trials for 10 Groups in Condition WC Between Trials 31-40 and Trials 41-60

Group	Trials 31-40 (Mean x 10)	Trials 41-60 (Mean x 10)	d	d - d	$(d - d)^2$
1	9	10	1	0.45	0.203
2	7	10	3	1.55	2.403
3	9	10	1	0.45	0.203
4	8	8.5	.5	0.95	0.903
5	9	9.5	.5	0.95	0.903
6	7	9.5	2.5	1.05	1.103
7	6	10	4	2.55	6.503
8	9	7.5	1.5	2.95	8.703
9	6	10	4	2.55	6.503
10	10	9.5	.5	1.95	3.803
	X 8.0	X 9.45	d 1.45	0	31.230

S^2_{31-40} 2.00

S^2_{41-60} .69

F 2.00/.69 2.90 Not Significant

"t" 2.46 Significant at the .05 level

The above result indicates that the groups in the WC condition had a significantly greater mean number of correct trials in trials 41-60 than they did in trials 31-40.

(h) The following "t" test was done in order to find out if the Groups in condition CW had mean numbers of correct trials in trials 31-45 and trials 46-60 that were significantly different from each other.

"t" test on Number of Correct Trials for 10 Groups in Condition CW Between Trials 31-45 and Trials 46-60

Group	Trials 31-45	Trials 46-60	d	d -d	$(d - d)^2$
1	12	15	3	2.1	4.41
2	14	14	0	0.9	0.81
3	15	15	0	0.9	0.81
4	14	15	1	0.1	0.01
5	15	15	0	0.9	0.81
6	14	15	1	0.1	0.01
7	15	15	0	0.9	0.81
8	15	15	0	0.9	0.81
9	12	14	2	1.1	1.21
10	11	13	2	1.1	1.21
	X 13.7	X 14.6	d 0.9	0	10.90

s^2_{31-45} 2.2333

s^2_{46-60} .4888

F 2.2333/.4888 - 4.5689 Significant

"t" 2.5832 Significant at the .05 level

The above result indicates that the groups in the CW condition had a significantly greater mean number of correct trials in trials 46-60 than they had in trials 31-45.

(i) The following "t" test was done in order to find out if the groups in condition WW had mean number of correct trials in trials 31-45 and trials 46-60 that were significantly different from each other.

"t" Test on Number of Correct Trials for 10 Groups in Condition WW Between Trials 31-45 and Trials 46-60

Group	Trials 31-45	Trials 46-60	d	$d - \bar{d}$	$(d - \bar{d})^2$
1	15	15	0	0.4	0.16
2	14	15	1	1.4	1.96
3	15	14	1	0.6	0.36
4	14	15	1	1.4	1.96
5	13	14	1	1.4	1.96
6	15	15	0	1.4	0.16
7	13	11	2	1.6	2.56
8	15	14	1	0.6	0.36
9	14	13	1	0.6	0.36
10	15	13	2	1.6	2.56
	$\bar{X}$ 14.3	$\bar{X}$ 13.9	$\bar{d}$ 0.4	0	12.4

s^2_{31-45} .6777

s^2_{46-60} 1.6555

F 1.6555/.6777 2.4428 Not Significant

"t" 1.0775 Not Significant

The above result indicates that the groups in the WW condition did not show a significant difference in mean number of correct trials between trials 31-45 and trials 46-60.

(j) The following "t" test was done in order to find out if there was a significant difference in mean number of correct trials for trials 46-60 between conditions WC and CC.

"t" Test on Number of Correct Trials Between Conditions WC and CC with 10 Groups in Each Condition for Trials 46-60

Group	Sum Over Trials	Condition Mean	Variance
	Condition WC		
1	15		
2	15		
3	15		
4	12		
5	14	14.1	2.9888
6	15		
7	15		
8	10		
9	15		
10	15		
	Condition CC		
1	13		
2	14		
3	14		
4	8		
5	9	12.1	1.7666
6	12		
7	15		
8	10		
9	13		
10	13		

F 2.9888/1.7666 1.6918 Not Significant

"t" 4.1017 Significant at less than the .01 level.

The above result indicates that for trials 46-60, the groups in the WC condition had a significantly greater mean number of correct trials than the groups in condition CC.

(k) The following "t" test was done in order to find out if there was a significant difference in mean number of correct trials for trials 46-60 between conditions CW and WW.

"t" Test on Number of Correct Trials Between Conditions WW and CW with 10 Groups in Each Condition for Trials 46-60

Group	Sum Over Trials	Condition Mean	Variance
Condition CW			
1	15		
2	14		
3	15		
4	15		
5	15	14.6	.4888
6	15		
7	15		
8	15		
9	14		
10	13		
Condition WW			
1	15		
2	15		
3	14		
4	15		
5	14	13.9	1.6555
6	15		
7	11		
8	14		
9	13		
10	13		

F 1.6555/.4888 3.3868 Significant

"t" 1.5901 Not Significant. (with 18 df., a "t" of 2.101 is needed to reject at the .05 level).

The above result indicates that there was not a significant difference in mean number of correct trials between conditions CW and WW for trials 46-60.

Table 3.27

Summary Table

Part II Question Asked	Results Result	Reference
Are the differences in times taken to solve problems between WC and CC significant for trials 46-60?	CC Significantly longer than WC	"t" test page 77
Are the differences in times taken to solve problems between CW and WW significant for trials 46-60?	CW Significantly longer than WW	"t" test page 80
Do the groups in condition CC have mean numbers of correct trials in trials 31-45 and 46-60 that are significantly different from each other?	No Significant difference	"t" test page 81
Do the groups in condition WC have mean numbers of correct trials in trials 31-45 and 46-60 that are significantly different from each other?	Not Significant at the .05, but significant at .06.46-60 31-45	"t" test page 82
Do the groups in condition WC have mean numbers of correct trials in trials 31-40 and 41-60 that are significantly different from each other?	Significant: 41-60 31-40	"t" test page 83
Do the groups in condition WW have mean numbers of correct trials in trials 31-45 and trials 46-60 that are significantly different from each other?	No Significant difference	"t" test page 85
Do the groups in condition CW have mean numbers of correct trials in trials 31-45 and trials 46-60 that are significantly different from each other?	Significant: 46-60 31-45	"t" test page 84
Is there a significant difference in mean number of correct trials for trials 46-60 between conditions WC and CC?	Significant: WC CC	"t" test page 86
Is there a significant difference in mean number of correct trials for trials 46-60 between conditions CW and WW?	No Significant difference	"t" test page 87

Discussion of Results

(1) Comparison of Results of Parts I and II; Reformulation of Original Approaches

The results obtained in Part II, although not providing evidence for confirmation or disconfirmation of the original hypotheses, do provide evidence for the need to reconsider the formulations of these hypotheses. If the results of Part I were not interpreted with the qualifications obtained from the results of Part II, knowledge about what occurred in this research would have been incomplete.

The approach which was supported by the results in Part I suggested that it is the structure of the communication network that leads to differences in times taken to solve problems, and number of correct trials, and that, regardless of differences in antecedent conditions, groups in the same kind of present network would not exhibit significant differences with respect to these two variables. Support for this approach cmme from the Between Methods terms in the Analyses of Variance tests on times taken to solve problems, and number of correct trials. Such results, however, reflect the complete state of affairs only when all the trials after the change are grouped together in the analyses. It turns out, however, that the groups in the conditions that underwent change (CW and WC) performed differently in the beginning trials than they did in the end trials. As the result of grouping all the trials together,

trial differences between groups in conditions that underwent change and those that did not were obscured. The results of analyses that took into accountsuch trial differences, indicate support, with one exception, for an approach different from the one supported in Part I with the original hypotheses.

The approach that was supported by the results in Part II for the last 15 trials was the one that suggested that the behaviors of the groups in the same kind of communication pattern would be significantly different from each other if they had been anteceded by different communication patterns. The directions of such differences were suggested as the following:

(a) groups in a particular kind of communication network will perform better when they have had experience in a network with a higher centrality index than groups which have had experience with only the same kind of network.

(b) groups in a particular kind of communication network will perform less effectively when they have had experience in a network of a lower centrality index than groups which have been in the same kind of network throughout.

Specifically, the above approach predicted that: (a) Circles that were changed from Wheels would do better than Circles that were Circles thoughout, with respect to both times taken to solve problems and number of correct trials (b) Wheel that were changed from Circles would do worse thatnWheels that were Wheels throughout, with respect to times taken to solve problems and number of correct trials.

With the exception of the result that Wheels that were changed from Circles did not exhibit a significant difference in number of correct trials from Wheels that were Wheels throughout, the predictions specified above were supported.

The support of the above approach based on the results of Part II and applying to the performances of the groups after trial 45, points to the need for a reformulation which would include modifications on the approach supported by the results in Part I and that supported by the results of Part II. Such a reformulation can be stated as follows: The effects of changes that are made in the communication networks of problem-solving groups are manifest and significant only after measurable work periods following the changes. With the latter qualification of measurable work periods following changes, and with the exception of the one inconsistency in the results of Part II, the performances of groups in the same kind of communication networks can be differentiatied on the basis of their antecedent communication conditions.

The following section includes a proposed explanation of the above inconsistency and a design to be used for testing it.

(2) Explanation of an Inconsistent Finding in the Results of Part II and a Design for Testing It.

Wheels that were changed from Circles did not exhibit a significant difference in number of correct trials from Wheels that were Wheels throughout. This finding was inconsistent with the expectation based on the appraoch that was considered to have been supported by the Results obtained in Part II of the Results Chapter. This approach suggested that the behaviors of groups in the same kind of communication pattern would be significantly different from each other with respect to times taken to solve problems and number of correct trials, if they had been anteceded by different communication patterns. Analyses of the Wheel-Circle versus Circle-Circle conditions for both time and number of correct trials and Circle-Wheel versus Wheel-Wheel for time supported the approach. However, not only was the Wheel-Wheel condition not significantly different from the Circle-Wheel in number of correct trials, but also, the graph of the Wheel-Wheel condition for number of correct trials in blocks of five trials (page 9 of the Results chapter) indicated that there was a trend of decreasing number of correct trials.

It is possible to provide a plausible explanation of the above and to design an experiment that would provide evidence for confirmation or disconfirmation of it.

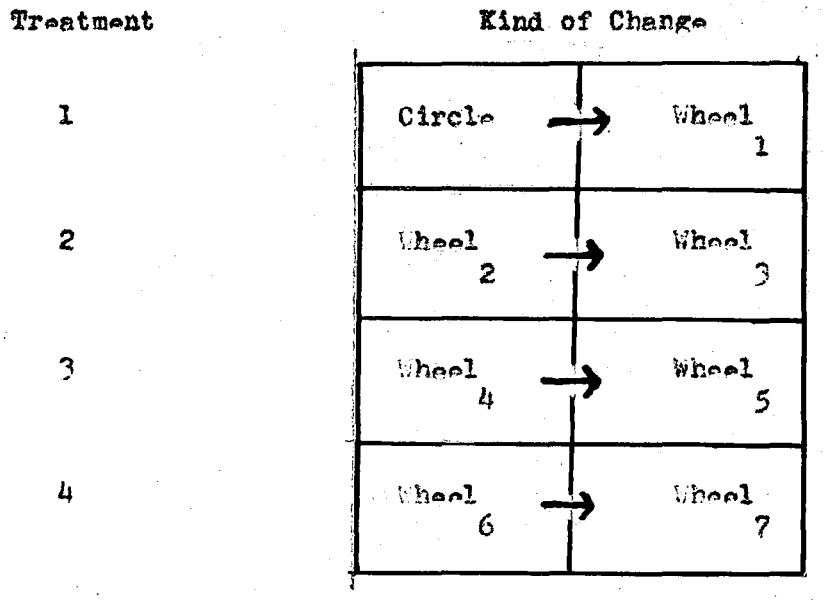
The decrease in number of correct trials in the Wheel-Wheel condition may be viewed as an effect of carelessness brought about by the absence of change within the Wheel-Wheel condition. The absence of change and the extended routinized behavior required in the Wheel-Wheel arrangement over such a great many trials may have been reponsible for such a decrease in quality of performance. If the latter is adequate as an explanation, then it would be expected that if change were to be introduced in a Wheel-Wheel arrangement without changing the structure of the network, the number of correct trials would not decrease. It would also be expected that groups in a Wheel-Wheel condition with such a change would have a significantly greater number of correct trials than would groups in a Circle-Wheel condition. If the latter predictions were to be supported, further evidence will have been provided for considering the past experiences of groups as affecting their present behaviors.

Three kinds of changes might affect number of correct trials: (a) changes in persons occupying the central positions (b) changes in the positions of peripheral members to other peripheral positions (c) changes which would include both (a) and (b).

Since there is no a priori reason to predict that any one of the above kinds of changes would be more effective than the others, an experiment designed to test the explanation suggested above would have to include all three kinds of changes.

The following is a suggested experimental design:

Figure 4.6



W_1 a wheel arrangement that has been changed from a Circle

W_3 a Wheel arrangement whose central member has been changed

W_5 a Wheel arrangement whose peripheral members have exchanged positions

W_7 a Wheel arrangement whose central members has been changed and whose three remaining peripheral members have exchanged positions.

The procedures, task and experimental apparatus will be the same for the above experiment as were used in this study.

(3) Limitations of Conclusions for Application to Other Network Studies

There are certain limitations to the conclusions that might be drawn from this research, for application to other experimental network studies. These limitations arise primarily from the specific conditions of the experimentation: (a) Each group used in this research had five members. It is not known how differences in group size would affect the behaviors of problem-solving groups in change conditions. Other investigators, in non-change experiments, have used groups of different sizes: (1) Heise and Miller[36] used three man groups (2) Shaw[37] has used four-man groups. No communication network study has used groups with fewer than three members or more than five. It is an open question as to whether, within a given kind of design, differences in size would lead to differences in performances of members. No research has been done to test the effects of size differences. Since this is the case, generalization of these results to similar kinds of networks but with different size groups would be uncertain.

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[36] Op. cit.

[37] Op. cit.

(b) the kind of task used in experiments has been shown to affect the behaviors of the problem-solving groups: (1) Heise and Miller indicate that it may be the case that there is no network that is best in all situations. They conclude from their research that the relative efficiency of a communication net depends upon the kind of problem the group is trying to solve. The latter conclusion has been pointed to by other investigators of communication nets: (2) Smith[38] (3) Guetzkow and Dill[39] and (4) Shaw[40].

The question that may be raised, when changes are introduced in a problem-solving situation, is whether or not such changes would have had different effects if the problems on which the groups were working were different.

(c) The way in which the communication network was established may turn out to be an important organizational variable. Of all the experiments on communication networks, there is none that tried to induce network arrangements rather than impose them. It may very well be that in problem-solving organization of the same communication structure, differences in behaviors of the members will be exhibited which are a function of the way in which the organization was originally established.

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38 Op. cit.

39 Op. cit.

40 Op. cit.

(d) The way in which the changes were introduced may be related to the effects of such changes. The changes in this research were made without the consent of the members, and without their knowledge beforehand. It is worthwhile to consider what might have occurred if: (1) the decisions to change were made by the members themselves (2) the subjects were to know about the changes beforehand (3) the subjects had experience in networks whose structures were established by them.

(e) The instructions to the subjects specified that they were to cooperate with each other so as to be able to get the answers as quickly as possible. From such instructions it can be seen that both speed and cooperation were stressed. The results of this research might have been different if the subjects were to have been told that they had to get the right answers but that the time they used in doing so was unimportant. Also, differences might have been obtained if the subjects had been advised to get the answers as individuals as quickly as possible, in which case, competition and not cooperation would have been stressed.

(f) The factor of motivation and involvement in the task is important to consider. While it was clear that the subjects were motivated enough by the promise of money to work on the problems throughout the experiment, it was not clear as to how much involved they were. The subjects knew that they were being paid for their participation in the reseafch and not for the quality of their performances.

It might have been the case that if the rewards were to have been contingent upon the quality of performance (shorter times taken to solve problems and number of problems correctly solved) the subjects would have behaved differently.

(g) There was no explicit feedback of results of time and correctness after each trial to the subjects. The only network study that has some evidence on the effects of feedback on performance was that done by Christie, Luce and Macy.[41] Besides other kinds of networks (where no feedback was involved), two kinds of Wheel conditions were studied: (1) A Wheel with no feedback (2) A Wheel with feedback. The Wheel with feedback about correctness of the trials after each trial, showed slow learning and fair error reduction, as opposed to the Wheel with no feedback which showed no learning and no error reduction. The latter result does reveal that under the specific experimental conditions used by Christie, Luce and Macy, feedback had definite effects on the performances of subjects in the Wheel conditions. It may be the case in situations of changes in networks, that knowledge of results would lead to different problem-solving behaviors than was the case under the condition of no explicit feedback.

(h) The kind of communication that was allowed in this experiment was non-verbal. Subjects were allowed to communicate only through means of written messages. The only study dealing with verbal

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[41] Op. cit.

communication was that done by Heise and Miller.[42] Communication took place over an intercom system. The communication networks used included one-way as well as two-way channels. The size of the groups used was three. The results of the study indicate the importance of the task in interaction with the type of network. The results were in agreement with those found by Shaw.[43] In change situations such as those used in this experiment, it might be the case that opportunity for verbal interaction would have different effects on performance as the result of influences on the psychological reactions of the members both to the network in which they worked and the changes made in it.

(4) Limitations of Conclusions for Application to Other Kinds of Groups

The limitations pointed to in the preceding section refer primarily to conclusions that might be generalized to other experimental studies of communication networks. There is another set of limitations that need to be considered as well. Such questions refer to the extent to which conclusions from this research are generalizable to other kinds of groups or team. The following section

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42 Op.cit.

43 Op.cit.

is intended to answer such questions by considering the special characteristics of this research and comparing them to natural work groups.

(a) In this research, as well as in other studies involving communication networks, restrictions on the availability of certain channels of communication to members are crucial, since it is from these restrictions that the structures of the networks are established. In natural work groups, the division of labor with its specifications of chains of command and lines of authority also restrict the channels of communication available to members. The major difference between the kind of restrictions in communication network investigations and that of natural work groups is that the former restrictions are physical and the members can not communicate to members to whom they do not have open channels, whereas the restrictions on communication in natural work groups are not physically determined but are the results of organizational rules of what should not be done.

(b) Related to restrictions on communication channels, is the fact that members of problem-solving groups in communication networks are also limited in the extent to which knowledge about the positions of others in the net was available to them initially. The uncertainty and ambiguity of role-relationships that might be expected to arise from such a lack of initial information, however, decreases as members become more certain of the positions of those to whom they can communicate and as they obtain more knowledge about the total work arrangement through second hand sources. It seems that the more

structured a network is the more likely is it that members tend to develop a completely accurate estimate of the total organization. Natural work groups, to a great extent, tend to approximate the above kinds of conditions. Even in work groups, where face-to-face contact is possible, and where no direct physical boundaries are placed on the positions of the members, analogous phenomena take place. When a work group is newly formed, members generally have a certain amount of information, but not enough, to be positive about the roles of the other members and themselves. Certain formal work requirements may be specified but many other and more-difficult-to-locate guidelines and clues have to be acquired. Also, in natural work groups, the more structured the work arrangements, the more likely will such further information be acquired earlier.

(c) The experimental conditions of this research and other network studies have made the participation of every member necessary to the successful solutions of the problems, in order for the problems to be solved accurately and with complete certainty and information. Even in such situations, however, it was possible for subjects to register correct answers without the information from or about some of the other members. Such procedures were contrary to instructions and could only have been accompanied by less than complete information and certainty. The likelihood of such responses being correct is smaller, the less a member relies on the information of others. In natural work groups it is much less the case that each member has information that others do not have. It is also less likely that

the certainty and accuracy of the group products would be as much affected by the absence of a given member. Of course, the degree to which the absence of the contribution of a given member would negatively affect a group product would depend at least on the position of the particular member in the work structure and on how much of his contribution would normally have been present in this product. In spite of the latter difference between problem-solving groups in natural and experimental network settings, it is nevertheless one of degree.

(d) The source of structural changes made in the arrangements of natural work groups is external. Promotions, demotions, changes in organizational units such as the integration or division of departments nearly always come from decisions made by those who are not actual working members of the units affected by the changes. Similarly, in this research on changes in networks, changes made in communication patterns came from outside the groups. The experimenter made the decisions and introduced the changes.

(e) Generally, when the sources of change lie outside the work-areas affected by the changes, the method of introduction of such changes is one of imposition. In the laboratory situation, the members of the groups had no choice in the acceptance or rejection of the changes. They could, however, work well or poorly within the new problem-solving arrangements. Similarly, in natural work groups, changes that are made generally take the form of having an external source and of imposition. Members of such groups, generally, have little voice in the acceptance or rejection of the formal changes.

Just as in the case of the laboratory network groups, however, the reactions of members to such changes can take the form of resistances which would be manifested in less productivity than would have been expected under the new arrangements. The introduction of technological changes in industrial organizations which lead to lower efficiency than would have been expected purely on a technological basis, would be a good example of the above phenomenon. Even in the cases where management seeks to gain the approval of the members for changes by using the various Human Relations techniques designed to create feelings of involvement and control over decisions, the above statements still hold. This is so, since the latter kind of management flexibility extends only to how the changes are going to be accepted, and not to whether or not the changes are going to be made.

(f) In this network research as well as in others, there was little opportunity for informal organizaions to develop. In part, this may be attributable to the short lengths of time that groups in network studies spend as members of work groups. Other major reasons seem to be that members of such groups have little opportunity to interact verbally, and to associate with each other outside the immediate working situation and then return to their jobs. Personality differences, so important to the development of any informal organization, have little opportunity to emerge and have effects in this way, due to the short life of the group, the lack of opportunity to interact verbally and to the absence of associations off the job during the life of the group. In such settings, personality characteristics emerge and have effects mostly in the area of job suitability: the extent to

which the demands of the position that a member has are congruent with his personality. Natural organizations differ considerably from network problem-solving groups in the above respect. The conditions specified above as tending to limit the development of informal organizations do not characterize natural work groups to the appreciable extent that they do in the case of laboratory network problem-solving groups.

(g) There are similarities, but also considerable differences between natural work groups and the problem-solving groups used in this research, in terms of motivational and reward systems. In this research, the primary motivation was the money that the subjects received for their participation in the study. Such a reward was not dependent on their performance in the group. The subjects knew that they would get paid regardless of the quality of their performance. The work that they did represented to them only a very small and probably very unimportant part of their lives. In natural work groups, although money is also a primary reward, the quality of the performances of the members is crucial to their being rewarded. The work that members do in natural organizations generally occupy a much more central place in their lives. Greater involvement with their jobs is to be expected more than in the case of work groups in the laboratory communication network investigations.

(5) The Need for a Program of Research

The previous sections (3 and 4) specified the major limitations of generalizations that might be made from this research to other experimental studies and to natural work groups. These limitations were in the form of variables that have not been explored either adequately or at all. There is no intrinsic reason why studies of changes in communication networks can not be designed to explore such variables. If usch were to be done, then generalizations to other studies and to other kinds of groups would be much more valuable and justifiable.

A program of research is needed in order to increase the applicability of the generalizations. Such a program of research would have to include the systematic study of the following variables: (a) Size of group (b) Kind of task (c) The method of establishing networks (d) The method of introduction of changes (e) The emphasis on quality as well as quantity (f) Level of motivation and involvement (g) Feedback of results (h) Verbal communication (i) Knowledge of positions of other members (j) The necessity of each member's contribution (k) Source of changes (l) Opportunity for informal organizations to develop (m) Opportunity for personality characteristics to affect performances.

(6) Centrality and the Effects of Changes

(a) The results of the research indicate the usefulness of the concept of centrality for understanding and predicting the effects of changes in communication networks on the behaviors of problem-solving groups. It has made possible the operational distinctions between communication structures, and consequently, has allowed changes in such structures to be clearly introduced and controlled.

(b) When changes in structure are introduced, a measurable work period is required before the effects of such changes become manifest and significant. This holds tru regardless of whether the changes are from higher structured arrangements to lower ones or vice-versa. Such work periods immediately following the changes are viewed as transition periods, during which groups learn how to operate within the new arrangements.

(c) Past communication experiences are believed to influence the operations which groups decide to use within the new arrangements. The behaviors of groups in a given network are viewed as the products of the interaction of the present and past communication structures. When a communication pattern has been anteceded by one with a higher centrality index, the performances of the groups in it are better than would have been the case if the antecedent pattern had the same centrality index. When a communication pattern has been anteceded by one with a lower centrality index, the performances of the groups in it are worse than if the antecedent had the same centrality index.

The Results in a Context of a Rational Approach to Planned Change

The Study of problem-solving groups has received a continuously increasing amount of attention from behavioral scientists. Much of the responsibility for such increased attention seems to have come from the growing interest of experimental organizational analysts in small-scale laboratory simulations of conditions that were previously considered to be treatable primarily in non-experimental and natural organizational settings. The increasing body of literature on communication arrangements in problem-solving groups illustrates such a trend. From the point of view of formally considering the structural properties of organizations as they relate to the effectiveness of their working parts, the study of communication structures is seen as a means of partially opening the black box of knowledge about the inner workings of larger organizations. To a great extent, one might justifiably suggest that the major focus or organizational analysis is or should be communication.

The work arrangement of positions in an organization may be viewed as a pattern of communicating parts whose collaboration leads to some product (s). Communication conditions among members can be viewed as either defining or reflecting chains of commands, lines of authority and responsibility, and contributions to the product that represents the work of the organization. Obviously there is an extremely large number of possible arrangements of positions. Such possible arrangements can be ordered in terms of the extent to which authority,

responsibility and contributions are distributed or concentrated among the parts. The more highly structured a work arrangement is, the more will authority, responsibility and major contributions to production be concentrated in fewer parts. Structure is considered to be directly related to the quality and quantity of production of physical goods and the psychological goods of the people occupying the parts in it: their feelings of satisfaction with their job, company, supervision and co-workers.

Demands for more equitable distributions of contributions and decision-making responsibilities of members of organizations have been increasing considerably in the last forty years. The increased education of workers, world events (wars) have given impulse to the development of a more democratic ideology in business organizations. The growing importance of a social technology that stresses shared leadership, together with many other factors has given prominence to organizational problems that center around the individuals occupying the parts of a work structure. The major question out of which such problems emerge is: How can an organization progress technologically and at the time provide for greater self-realization of its members through its work structure? The latter question of how to change is meaningless unless it is considered in a context of " there should be a change." The Philosophy of modern organizations would suggest that what exists, exists as temporary measures or stepping-stones for things to come.

A future-orientation has become normative for managers and leaders in large organizations. Change seems to be the order of the day. Tradition and the past seem to be more and more unimportant as determinants of the contemporary organizational scene. What seems to be happening is that change is becoming traditionalized, so that contemporary organizational guide-lines for action become rooted in a principle that things should be different from the past. If such a principle of difference from the past and such a tradition as change is for the good, are accepted and followed, then the problems of present-day organizational managers and students become sharply delimited and certain organizational issues become primary. Given change as the central theme, questions arise as:to:

(1) What the relative weightings of the various goals should be in planning for and instituting a change; e.g. profit, service to the community and benefits to the members of the organization?

(2) How should change be introduced, e.g. external imposition versus internal decision-making by members; gradual versus sudden; broad versus limited, and so on?

(3) What kind of change to introduce; e.g. what structural changes in organization would lead to what kind of effects on the performances of members?

(4) When should changes be introduced, e.g. when conditions are most stable or when they are least stable?

(5) What preparation for the effects of changes on those affected by them can be made; e.g. what are the human relations effects of such technological and structural changes?

The results of this research focus on aspects of question (3): When structural changes are made in the communication patterns of problem-solving groups, what effects are there on the performances of members?

In spite of the growing emphasis on change and the increased attention of small groups researchers to problems related to larger organizations, there has been very little effort invested in discovering the conditions that need to be considered when changes are to be planned. It remains, then, to consider how the results of this research relate to the present state of knowledge about communication and change in organizations, and how they might contribute to the discovery of such conditions.

Communication and change can be considered theoretically in terms of two different approaches to organizations: (1) the Rational Approach[44] (2) the Natural System Approach[45]. The kinds of communication and change problems differ in the two approaches. The Natural system approach would consider communication in terms of its functional aspects for the internal social system that develops out of the external system.[46] Communication would be treated as a dependent variable. It would be considered in terms of the adjustive and equilibrating tendencies of organizations in response to disturbances in their systems. Communication, in this context, would

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[44] Max Weber, "The Essentials of Bureaucratic Organization: An Ideal-Type Construction", Reader in Bureaucracy ed. by Robert K. Merton, Ailsa P. Gray, Barbara Hockey, and Hanan C. Levlin;(Illinois: Free Press, 1952).

[45] Philip Selznick, "A Theory of Organization Commitments", Ibid.

[46] George C. Homans, Op. cit.

serve such purposes as: (a) maintaining social control, setting and preserving standards of behavior, modifying either positively or negatively some of the behaviors expected solely on the basis of the formal organization, (b) providing acceptable and supportive outlets for feelings whose expression is not institutionalized formally, (c) providing information to members about things that are going on in parts of the organization with which they have little or no official contact, and which affect their membership in it: introduction of technological changes, layoffs, new incentive systems and so on.

In a general sense, the kinds of communication problems emphasized in the Natural system approach would be those that reflect inadequacies of the formal organization for maintaining social homeostasis. In this same context, change would be considered in terms of indicating dysfunctioning in the formal system. Change would be treated primarily in terms of unanticipated consequences of formal elements in organizations. Increased absenteeism and labor turnover following the introduction of new equipment in an organization, together with lower productivity than would be expected on an engineering basis, illustrate the kind of issue that would be likely to draw the attention of the Natural system approach.

The Rational approach concerns itself primarily with communication problems as they relate to the structural nature of organizations. Formal properties of the institutions are viewed in their relationships to planned expectations about communication issues such as:

(a) problems of delegation of authority (b) span of command (c) upward and downward communication channels for getting a job done (d) clarity of communications about contractual relationships such as role expectations. The latter include such elements as who-does-what-to-whom in the organization. The general focus in this approach is on the formal communication requirements of an organization for achieving pre-planned goals. Communication is used as an independent variable. As opposed to the Natural system treatment of changes as being unanticipated consequences and symptoms of disequilibrium, the Rational approach would view changes in either of two ways: (a) as human deviations from the ideal type, not reflecting disequilibrium, (b) in terms of planned adaptation to the demands of the external environment. In this approach, (a) would serve as the explanatory device for imperfections in the application of the pure model and (b) would serve as an explanation for the way bureaucratic organizations compensate for disequilibrium between themselves and the problem-solving requirements of their environments.

The Rational approach to problems of communication and change provide the more meaningful context for the results of this study. In order that change might be planned for most efficiently, with a maximum of control and predictability of effects, and with a minimum of unanticipated consequences, greater knowledge is required about the conditions or variables that need to be considered in planning. The results of this research indicate that the following kinds of conditions need to be taken into account: (a) the structural arrangement of positions which delimit the distribution of lines of

authority, responsibility and contributions to the group product, (b) the suitability of a given structural arrangement of communication positions for meeting the demands of the problems facing it, (c) a developmental model (which needs further elaboration and testing) that makes the following assumptions: (1) past experiences of people lead to selective modifications of later experiences and, responses to past experiences will tend to transfer over to later situations, (2) transfer will be greater, the more similar the later problem-solving experiences are to past ones and the more the past responses have become stabilized.

In this research information about all three conditions was utilized. The structural arrangement of positions was clearly understood and controlled for through the use of patterns which were established by controlling communication channels available to members. Knowledge about the suitability of the patterns used (Wheel and Circle) for the tasks required was obtained through the results of Leavitt's study[47] and through a preliminary study carried out with the primary purpose of increasing the certainty about the suitability of the patterns of communication used in the experiment. Finally, change was introduced after stabilization of times taken to solve problems had taken place. The post change experiences of members of the problem-solving groups were identical to the pre-change situations, with the intended exception of changes in the pattern arrangement of communication channels.

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[47] Harold J. Leavitt, Op. cit.

Taking into account the above information, it is possible, when planning changes of organizations, to make some predictions with more certainty than before about the planned effects of such changes on performance.

APPENDIX

Analysis of Variance of Times Taken to Solve Problems for the Circle Condition in the Summer Study

The following Analysis of Variance of Times Taken to Solve Problems for the Circle condition was done in order to obtain the appropriate error term needed for Tukey's Gap Test.

Analysis of Variance of Time Scores for the Circle Condition with 10 Groups with 40 Trials in Each Group

Source of Variation	Sum of Squares	df	Mean Square	F
Total	5,638,433.51	399		
Between Trials	3,653,660.31	39	93,683.60	.01
Between Groups	538,973.66	9	59,885.96	
Interaction: Trials x Groups	1,445,799.54	351	4,119.09	

The error term to be used in the Gap Test was obtained as follows:

$4,119.09/40 \quad 10.1488 \quad S_m$

Tukey's Gap Test Applied to Trial Means for the Circle Condition

The following test was done in order to locate differences between trial means that are significant when compared to the smallest difference between means that would be needed before such a difference would be considered significant.

Tukey's Gap Test Applied to Circle Trial Means

Trial	Mean Time	Trial	Mean Time	LSD	Least Significant Difference
1	626.6	21	112.4		
2	338.3	22	127.1		
3	274.2	23	110.7	LSD	$t_{.05} 2^{\frac{1}{2}} S_m$
4	213.5	24	104.6		
5	226.2	25	109.5		
6	182.3	26	98,1	$t_{.05}$	2.1010
7	240.4	27	97.8		
8	171.6	28	93.2		
9	182.0	29	93.9		
10	165.9	30	90.8	$2^{\frac{1}{2}}$	1.4142
11	172.5	31	108.5		
12	151.1	32	83.2	S_m	10.1488
13	133.7	33	93.8		
14	129.3	34	108.8		
15	120.3	35	81.9	LSD	30.1545
16	162.1	36	88.7		
17	127.1	37	86.6		
18	151.8	38	82.8		
19	115.5	39	75.4		
20	111.8	40	76.4		

The above result indicates that, with the exception of trials 31 and 34, there is no significant difference between any trial and any other one after trial 30. Also, after trial 30, there is no significant difference between any one trial and the one following it.

Analysis of Variance of Time Scores for the Wheel Condition in the Summer Study

The following Analysis of Variance Test was done in order to obtain the appropriate error term for times taken to solve problems for the Wheel condition needed to apply Tukey's Gap Test.

Analysis of Variance of Time Scores for the Wheel Condition with 10 Groups with 40 Trials in Each Group

Source of Variation	Sum of Squares	df	Mean Square	F
Total	5,318,208.96	399		
Between Trials	4,102,825.76	39	105,200.66	.01
Between Groups	114,628.41	9	12,736.49	
Interaction: Trials x Groups	1,100,754.79	351	3,136.05	

The error term to be used in the Gap Test was obtained as follows:

$3{,}136.05/40 \quad 8.8320 \quad S_m$

Tukey's Gap Test Applied to Trial Means for the Wheel Condition

The following test was done in order to locate differences between trial means that are significant when compared to the smallest difference between means that would be needed before difference could be considered significant.

Tukey's Gap Test Applied to Wheel Trial Means

Trial	Mean Time	Trial	Mean Time	LSD	Least Significant Differences
1	629.4	21	69.6		
2	307.3	22	70.8		$\frac{1}{2}$
3	294.6	23	76.3	LSD =	$t_{.05}$ $2^{\frac{1}{2}}$ S_m
4	190.8	24	57.9		
5	138.1	25	63.0		
6	115.6	26	54.2		$t_{.05}$ with 18 df. 2.1010
7	107.5	27	58.6		
8	104.7	28	59.7		
9	91.4	29	78.0		$2^{\frac{1}{2}}$ 1.41420
10	83.2	30	79.3		
11	90.6	31	72.7		
12	116.8	32	59.0		S_m 8.83200
13	65.4	33	59.6		
14	63.4	34	54.0		
15	63.7	35	52.6	LSD =	26.2419
16	84.4	36	55.3		
17	63.1	37	63.0		
18	68.3	38	55.8		
19	66.8	39	49.8		
20	68.7	40	56.6		

The above results indicate that, after trial 30, there is no significance between any one trial and the one following it. Also after trial 30, there is no significant difference between any one trial and any other.

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THE EFFECTS OF CHANGES IN PATTERNS OF COMMUNICATION ON THE BEHAVIORS OF PROBLEM-SOLVING GROUPS

Abstract of a Dissertation

Submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy

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The study of organizations in their natural state and problem-solving groups in the laboratory has received increased attention in recent years. Communication in particular has been the research concern of many investigators. Problems of changes in communication processes have been virtually ignored in experimental studies as well as in field investigations. The existence of disparate notions unsupported by empirical evidence about the effects of such changes provides somewhat confusing and conflicting references for making predictions.

There is, however, a growing body of evidence coming from laboratory experimentation about the relationship between communication networks and the performances of problem-solving groups in them. As well as providing such evidence, certain of these studies also make possible the establishment of operationally distinguishable communication structures and the introduction of rigorously controlled changes in them.

This is a laboratory study of the effects of changes in the patterns of communication of small problem-solving groups. These changes are in terms of who-can-communicate-to-whom. The overall question to be answered is: What effects do changes make in the communication patterns of problem-solving groups have on performance?

Two five-person communication patterns were used: (a) a Circle, in which every member could communicate to the persons on the immediate right and left, but to no one else. All members are equal with respect to the centrality indices[1] of their positions; (b) a Wheel, in which

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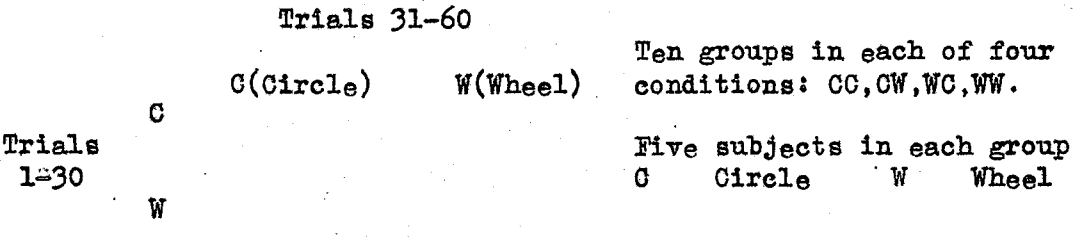
[1] Harold J. Leavitt, "Some Effects of Certain Communication Patterns on Group Performance", Journal of Abnormal and Social Psychology, XLVIII (1951), 38-50. Centrality is defined as the sum of the distances from all members to all members over the sum of the distances from a given position to all others.

each of the four members could communicate to the fifth, but to no one else. The fifth person could communicate to everyone. The centrality indices of the four members are equal but lower than that of the fifth or central person.

Four experimental conditions were used: (a) a change from a Circle to a Wheel (CW); (b) a change from a Wheel to a Circle pattern (WC); (c) a Wheel pattern throughout (WW); (d) a Circle pattern throughout (CC). Wheels have higher centrality indices than Circles. (A group centrality index is the sum of the centrality indices of the members.)

The task used was one that required members to find the common symbol from among six possible ones, through written communication only.

Diagram of Experimental Arrangement of Communication Conditions



By comparing the performances of CW with WW and WC with CC, it was possible to determine which of the following approaches was adequate for predicting the effects of changes on times taken to solve problems (t) and number of problems correctly solved (n).

Approach I...Groups in a Given kind of network will exhibit differences when their antecedent conditions have been different. The directions of such differences depend on the centrality indices of the antecedent conditions: (t) CW (t) WW (n) CW (n) WW (t) WC (t) CC (n) WC (n) CC

ApproachII...Changes in patterns of communication will lead to better performances regardless of the centrality indices of the antecedent conditions: (t) WC (t) CC (n) WC (n) CC (t) CW (t) WW (n) CW (n) WW

Approach III.It is the structures of the present communication that serve to distinguish between the performances of problem-solving groups, rather than antecedent conditions or the changes themselves. This approach would be considered supported if the following results were to be obtained: (t) WC (t) CC (t) CW (t) WW (n) WC (n) CC (n) CW (n) WW

(t) WC (t) CC (t) CW (t) WW
(n) WC (n) CC (n) CW (n) WW

Approach III was supported. For both kinds of communication patterns (C and W) the structures of the present patterns and neither the different antecedent conditions nor the changes themselves served to distinguish between the performances of groups in such patterns. Circles took longer times to solve problems and had fewer correct trials than Wheels.

Additional (t) and (n) analyses[2] were done for trials 46-60 (last fifteen trials) between WC and CC, and between CW and WW. The results were: (t) WC (t) CC; (n) WC (n) CC; (t) CW (t) WW; (n) CW (n) WW.

Speculation based on the results of the additional analyses suggests that a modified form of Approach I might be useful in further research on change: When changes in patterns of communication are introduced, a measurable work period is required before the effects of such changes emerge significantly. Such effects appear to be different for the (t) and (n) measures of performances. Considering (t) as the measure of performance, such a modification would suggest (for further testing) that for a given kind of network, differences in antecedent conditions would serve to distinguish between the performances of groups in the following way: When a communication pattern has been anteceded by one with a higher centrality index, performances of groups in it would be better than if the antecedent condition had had the same centrality index. When a communication pattern has been anteceded by one with a lower centrality index, the performances of groups in it would be worse than if the antecedent pattern had had the same centrality index.

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[2] Significant Trial x Network Interaction terms in the analyses of variance for (t) and (n) suggested the need for additional analysis.

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