Management Science

Publication details, including instructions for authors and subscription information:
http://pubsonline.informs.org

The Impact of Certain Communication Nets Upon Organization and Performance in Task-Oriented Groups

Harold Guetzkow, Herbert A. Simon,

THE IMPACT OF CERTAIN COMMUNICATION NETS UPON ORGANIZATION AND PERFORMANCE IN TASK-ORIENTED GROUPS*

HAROLD GUETZKOW AND HERBERT A. SIMON

Graduate School of Industrial Administration, Carnegie Institute of Technology, Pittsburgh, Pa.

Bavelas, Smith and Leavitt[1] have posed the problem: what effect do communication patterns have upon the operation of groups? To study this problem they designed a laboratory situation that is a prototype of those occurring in "natural" organizations existing in government and business. Each member of the group is given certain information. Their task is to assemble this information, use it to make a decision, and then issue orders based on the decision. This design provides a situation stripped of the complexities of large-scale social groups but retaining some essential characteristics of the organizational communication problem. In it we can examine how the communication net affects simultaneously (a) the development of the organization's internal structure, and (b) the group's performance of its operating task.

Leavitt made certain deductions from Bavelas' model of communication nets,[2] but his empirical studies[3] did not confirm the derivations. Leavitt explains the discrepancies in terms of such concepts as "different kinds of messages require very different clock times," and the failure of his subjects "to gravitate to the theoretically 'best' operating organization."[4] It is the purpose of this paper to present an alternative theory of these miniature organizations, and to test this theory by new empirical data and by comparison with Leavitt's original empirical findings.

The proposed explanation requires that a sharp distinction be made between: (a) the effects of communication restrictions upon performance of the operating task; and (b) the effects of the restrictions upon a group's ability to organize itself for such performance. That is, instead of regarding the group's problem as unitary, it appears essential to separate the operating or "substantive" task from the organizational or "procedural" problem. Our hypothesis may be stated thus: Imposition of certain restrictions on the communication channels available to a group affects the efficiency of the group's performance, *not directly* by limiting the potential efficiency of task performance with optimal organization in the

* This work was supported by a grant from the research funds of the Graduate School of Industrial Administration. Grateful thanks are due to Messrs. Wm. Dill, K. Hellfach, A. D. Martin, and F. Metzger, and to Mrs. Martha Pryor and Miss Anne Bowes for aid in the conduct of the investigation and help in analyzing its results.

[1] Bavelas, A., Communication patterns in task-oriented groups, *Jour. of Acoustical Soc. of Amer.*, 1950, 22, 725–730.

[2] Bavelas, A., A mathematical model for group structures, *Appl. Anthrop.*, 1948, 7, 16–30.

[3] Leavitt, H. J., Some effects of certain communication patterns on group performance, *Jour. of Abnorm. and Soc. Psychol.*, 1951, 46, 38–50.

[4] Leavitt, *ibid.*, p. 46–47.

given net, *but indirectly* by handicapping their ability to organize themselves for efficient task prformance.

Our empirical study involves basically a replication of Leavitt's work, but with essential modifications to permit us to study separately the group's performance of its operating task and its organizational task.

Each of 56 groups operated in the laboratory for about two hours, during which time the task was repeated twenty times. A fifteen minute pre-experimental training period was employed to reduce the task problem to a mere routine before the experiment with each group began. Each of the twenty task trial periods continued until the task was completed, the time required for completion varying from six minutes to less than one minute. Intertrial periods of not more than two minutes between successive trials provided the groups with an opportunity to solve the organizational problem. By a signalling arrangement, the subjects were allowed to terminate the intertrial periods at any time they wished before the end of the two minutes allowed them.

The alternation of task trials with interpolated intertrial periods was suggested by analogy with the traditional "trial-after-trial" design employed in learning experiments in individual psychology. In terms of this analogy, the intertrial periods may be interpreted as "learning" periods, during which the subjects may work on their organizational plans. The task trial periods are then "test" periods, in which the progress of the group is tested by measuring the speed and efficiency of task performance.

Except for the explicit separation of trial and intertrial periods, our procedures paralleled those used by Leavitt and Smith. As will be indicated later, our results substantially replicate their findings.

In Section I, we shall set forth the theory from which our central hypothesis is derived. In Section II, we shall test the hypothesis with the new empirical data we have obtained. In Section III, we shall compare our findings with those of Leavitt.

I. Separation of Operating Task from Organizational Problem: Theoretical Considerations

Description and Analysis of the Operating Task

Simon, Smithburg and Thompson argue that communication in a decision-making organization is two-fold:

> Communications must flow to the decision center to provide the basis for decision, and the decision must be communicated from the decision center in order to influence other members of the organizations whose cooperation must be secured to carry out the decision.[5]

The Bavelas-Leavitt-Smith problem requires both processes. In the operating task each person must record which one symbol of six is held in common by the

[5] Simon, H. A., Smithburg, D. W., and Thompson, V. A., *Public Administration*, 1950, New York: Knopf, p. 220.

five members of the group. The same six symbols are used on each trial. At the beginning of each trial, each person is given a card on which is printed five symbols; the other symbol is missing. Each individual is lacking a different symbol. The problem on a given trial is to have the group discover and record the one symbol that no one is lacking. The variation in distribution of the symbols from trial to trial in this investigation followed the schedule used by Leavitt.[6]

Note the two-fold communication process involved in this line task:

(a) Information Flow: At the beginning of a trial each participant knows only one of the missing symbols—his own. The participant need not know all of the missing symbols for solution of the problem. Each group member needs to know only the answer to record it, or to "carry out the decision." There must, however, be sufficient exchange of information so that one or more persons can form the solution, or "make the decision."

(b) Decision Flow: Once an answer is formed by one or more persons in the group, it must be communicated to those who are unable to, or do not, make the decision themselves.

Before proceeding with the analysis, let us explain the mechanics of the experiment.[7] The subjects, seated around a circular table, were separated from each other by five vertical wooden partitions (Figure 1). They were able to pass messages to each other through interconnecting slots. During the operating trials, they interchanged messages written on pre-coded cards which contained places for information and answers. During the intertrials the subjects were free to write to each other uncoded messages on blank cards about their organizational arrangements. This meant the group could determine who would send information to whom, who would make the problem-decision, who would send the decision-order to whom.

When a subject had recorded the problem-decision, this fact was immediately conveyed to the experimenter. When all five persons had recorded the solution, the trial automatically ended and the intertrial period began. The subjects were silent throughout the experiment, communicating only through pre-coded cards during the operating task trial and by written "free" messages during the intertrial periods. This enabled us to obtain a complete record of their communications.

Two hundred and eighty male freshmen engineering students at Carnegie Institute of Technology served as subjects for the experiment. The two hours devoted to the experiment were a required substitute for one class and an out-of-class assignment in a required freshman course. Most subjects were not very well acquainted with each other. Each group was composed of one man from each of the Carnegie Tech quintiles of the American Council on Education Psychological Examination; scores were available on all subjects. This insured an equating of groups with respect to intellective ability.

[6] Leavitt, *op. cit.*, Figure 2, p. 40.

[7] Further details about the procedures of the experiment are available, and can be obtained from the American Documentation Institute, 1719 N Street, N.W., Washington 6, D. C.

FIG. 1. Experimental Set-up

Given this task, how will a five-man group divide the labor involved in completing it? (1) It is possible either for everyone to *exchange information* with everyone else, or to have the missing symbol information collected by a single person. (2) It is possible either for everyone to *form the solution*, or to specialize to the extent that only one person forms the solution. (3) It is possible either to complete the problem without *circulation of answers* (since each may form the solution by himself), or to have the answer relayed from a single central source. But which organizational arrangement will be adopted? To what extent does the choice depend upon communication restrictions?

In replicating Leavitt's experiment, we have used two of his restrictions—those constituting his extreme cases: the "Wheel" and "Circle." In addition, we established groups that were entirely free of restrictions, using an "All-Channel" pattern. The three communication nets are illustrated in Figure 2. Our initial problem is to discover how the net restrictions imposed upon the various groups determined the organizational patterns used in performing the operating task.

Consider first the Wheel net: If the task is divided so that the "spokes" send their information to the "hub", the latter can make the decision and in turn return answers to the spokes. We will call this pattern a "two-level hierachy." Next, consider the Circle net: If two neighbors send their information to their opposite neighbors, who in turn relay this information with their own to the fifth member of the circle, this "keyman" can make the decision and relay the answer back through the "relayers" to the "endmen." We will call this pattern a "three-level hierachy." In the All-Channel nets, either one of these procedures —or others—may be used. It can be shown that the arrangements just described are the most efficient of those available. Although the use of the relays in the three-level hierarchy involves time delays, the minimum number of messages required by the two- and three-level hierarchies is the same—eight.

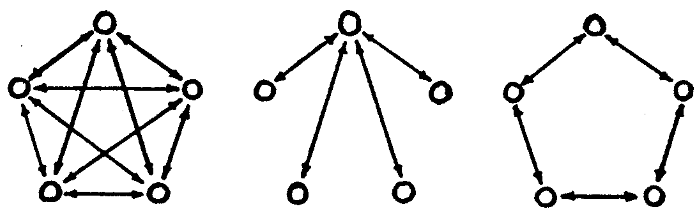

FIG. 2. Open Channels Used in the Three Nets

A channel-usage analysis, as suggested by Bavelas' model, misleads one into supposing that the two-level hierarchy is twice as efficient as the three-level hierarchy; for the two-level arrangement obviates the need for relaying, both when sending information and when sending answers. But the task is more than one of merely sending messages—messages must also be received, collated, and prepared. To compare efficiencies we need an estimate of the time required to perform *all* these task elements, and in proper sequence. To provide such a comparison of "limiting" efficiencies, of the two-level and three-level hierarchies, Hellfach made a methods-time measurement analysis of the task.

Methods-Time Measurement is a time-study procedure used widely in industry.[8] It involves identification of the basic motions that must be used to perform the operating task, and assignment of standard time values to these basic motions. Hellfach analysed each position in the five member group both when arranged as a two-level hierarchy and when arranged as a three-level hierarchy. Then he drew up a composite analysis of the operation for the two types of arrangement, making appropriate allowances for idle time required by the sequential nature of task elements (e.g., a "relayer" cannot transmit information until he has received it). His estimates are presented in Figure 3. He predicts

[8] Maynard, H. B., Stegmerten, G. J., Schwab, John L., *Methods-Time Measurement*, New York, McGraw-Hill, 1948.

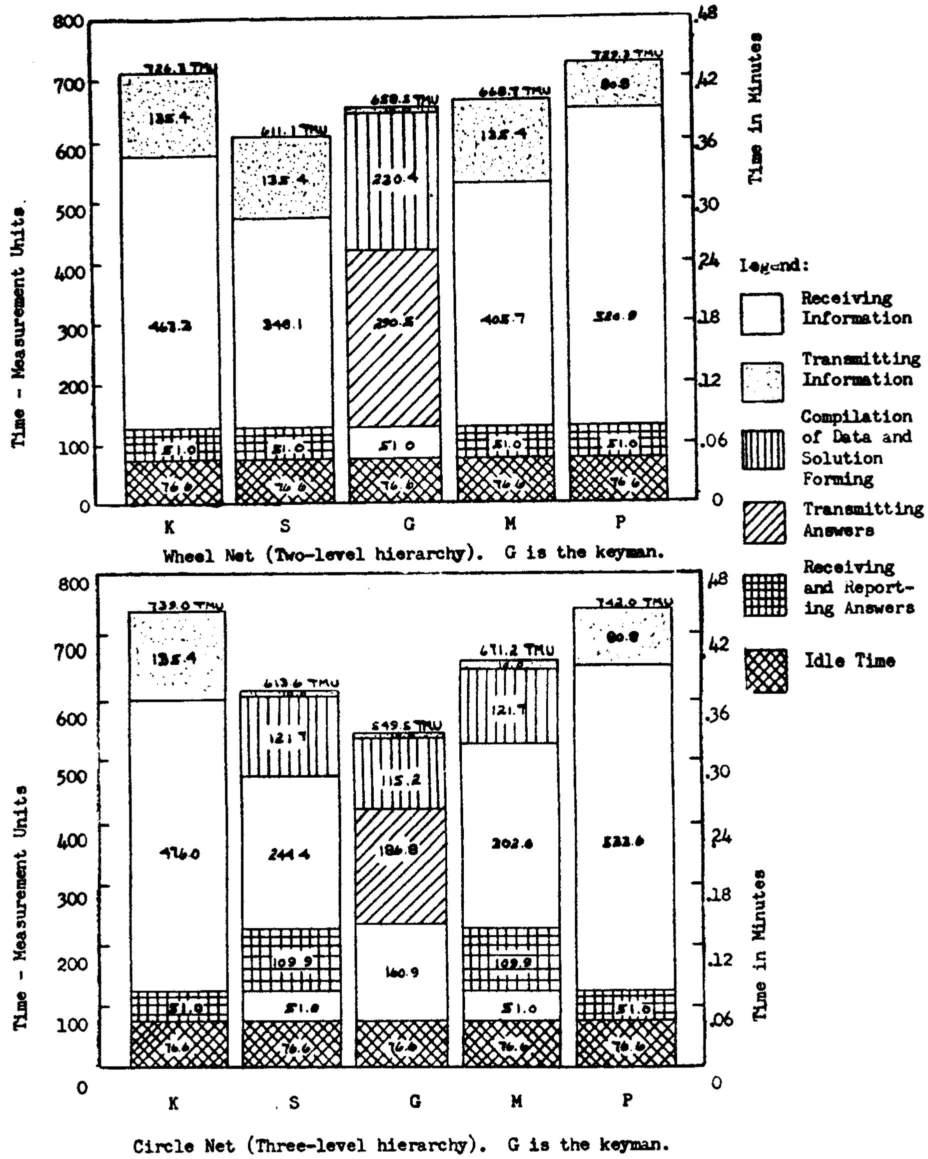

FIG. 3. Methods-Time Measurement Analysis

operating times for the two-level hierarchy of .445 minutes; and for the three-level hierarchy of .437. The difference between these times (which actually shows the three-level hierarchy to be slightly more efficient than the other!) is not consequential.

These theoretical considerations argue that, whatever effects the communication nets may have upon task performance, these effects cannot be traced to the objective limitations imposed by the net restrictions upon the groups. If a group can discover and use the optimal organizational pattern among those permitted it by the net restrictions, the minimum time achieved by a Circle group should be substantially the same as by a Wheel group. Even more interesting, the analysis leads to the conclusion that there is no difference in the limiting times for task performance between groups in the unrestricted net (the All-Channel groups) and those in the restricted nets (the Wheel and Circle groups).

Description and Analysis of the Organizational Problem

The theoretical discussion to this point supports our hypothesis that the communication restrictions affect the task performance of the groups not directly, but only indirectly by influencing the ability of the members to organize themselves for optimum performance in their line operation. Now let us examine in more detail the way in which the nets pose organizational problems.

Twenty of our 56 groups were allowed to operate without any imposed restrictions on their internal communication. The other groups operated within communication restrictions that reduced the number of channels for communication to approximately half of those available in the unrestricted groups. The two sets of restrictions differed from each other, however, in their effects upon the ease with which the groups might develop interaction patterns. The 15 wheel groups were restricted in such a way that their organizational problems should be minimal. The 20 circle groups were restricted with almost the same degree of severity (in terms of number of open channels), but in a way that made their organizing tasks comparatively difficult.

The three variations in the nets had different relationships to the organizational problem:

(a) *The "All-Channel" Net:* The organizational problem for an All-Channel group is not simple. The group has an advantage in that each member can communicate with the others, so that no relaying of messages through a "second party" is required. Yet the lack of communication restrictions means an open field with almost too many opportunities—a total of 20 one-way channels. Accordingly, each All-Channel group has the difficult job of developing its own restrictions—deciding that certain available channels will *not* be used. In addition, each of the members is equipotential with respect to his place in the communication net; no one member has initial advantages from his place in the net with respect to the functional requirements of the task.

(b) *The "Wheel" Net:* The Wheel groups are in a net in which the communication restrictions reduce the difficulty of the organizational problems to a minimum, yet hold the requirements of the operating problem constant. If the task is divided so that the spokes send their information to the hub, the latter can solve the problem and in turn send answers to the spokes. There would be no need for relay through a "second party." All the "unnecessary" channels have been blocked, so that their elimination is no longer part of the organizational problem. This reduces the number of open channels from 20 to 8, some 60 per cent. The existence of a hub means that the positions in the net are not equipotential—the four spokes are disadvantageously situated. Should a spoke attempt to become the solution former, he would need to depend upon the hub for relaying both information and answers. In addition, in such a situation, the organizational problem as to which of the four equipotential spokes would become problem-solver would need to be handled. But, if the hub becomes the solution-former, the wheel requires a minimum of organizing effort for solving the operating task.

(c) *The "Circle" Net:* This net retains the symmetry of the positions in the free situation but restricts drastically the number of communication opportunities. Simultaneously it makes imperative the use of a relay system, or three-level hierarchy, within the organization. No potential solution-former has immediate access to the other four missing symbols. His two neighbors need to relay their information and that of their other neighbors to him. Along with this impediment to organizing, there is the added difficulty that no one position is more or less advantageously situated for handling the solution-forming requirement. The reduction of available channels in this net is from 20 to 10, just 50 per cent.

A comparison of the way in which the three characteristics of the net differ from net to net is diagrammed in Table 1. From this display it is possible to make rough estimates of the difficulty of the organizational problem for groups in each type of net. The Wheel groups would have the least difficulty, for they have no channels to eliminate, no relays to establish, and already have one person occupying a dominant position in the net. The All-Channel groups would have the next grade of difficulty, since the elimination of excess channels and the evolution of one person as solution-former are both required, yet relays need not be established. The Circle groups should have the most difficulty, for they need both to establish relays and to evolve an asymmetrical arrangement among the positions. They also must do some eliminating of unneeded channels, although this last requirement is minimal. The difficulty of the organizational problem in the different nets varies as follows:

$$\text{Wheel} < \text{All-Channel} < \text{Circle}.$$

This analysis of the organizational difficulty yields a surprising outcome in indicating that an unrestricted net (All-Channel) in itself involves difficulties, and that restrictions in communication may be helpful (Wheel) or harmful (Circle) in the evolution of organizational structures, depending upon the nature of the relation of the restriction to the organizing and operating tasks.

TABLE 1

Comparison of the Three Nets

Characteristic differences among the three nets

Characteristics	All-Channel	Wheel	Circle
Number of Open Channels	20	*8*	*10*
Number of Symmetric Positions	5	*4*	5
Minimum Number of Relays Necessary	0	0	*2*

(The italic entries indicate the points at which the Wheel and Circle nets contrast with the All-Channel net.)

This concludes our theoretical analysis. It develops our basic hypothesis by arguing that the communication restrictions have no direct effect upon performance of the operating task. It argues that the communication pattern has important effects upon the difficulty the group will encounter in organizing itself—but that the restricted patterns do not necessarily make for more difficulties than the unrestricted patterns. Now let us examine the empirical data to determine whether they support or refute our theoretical analysis.

II. The Empirical Findings

Performance Times in Operating Task Trials

As far as the subjects were concerned, the time required for each trial was the central focus of the experiment. In the instructions they were told, "Your team is competing with the other five-man groups to see which group is fastest at getting the answer. The shorter the time, the better your team score."

The average time per trial for the three types of groups is presented in Figure 4. The Circle groups are clearly slower than the Wheel groups after the first trial.

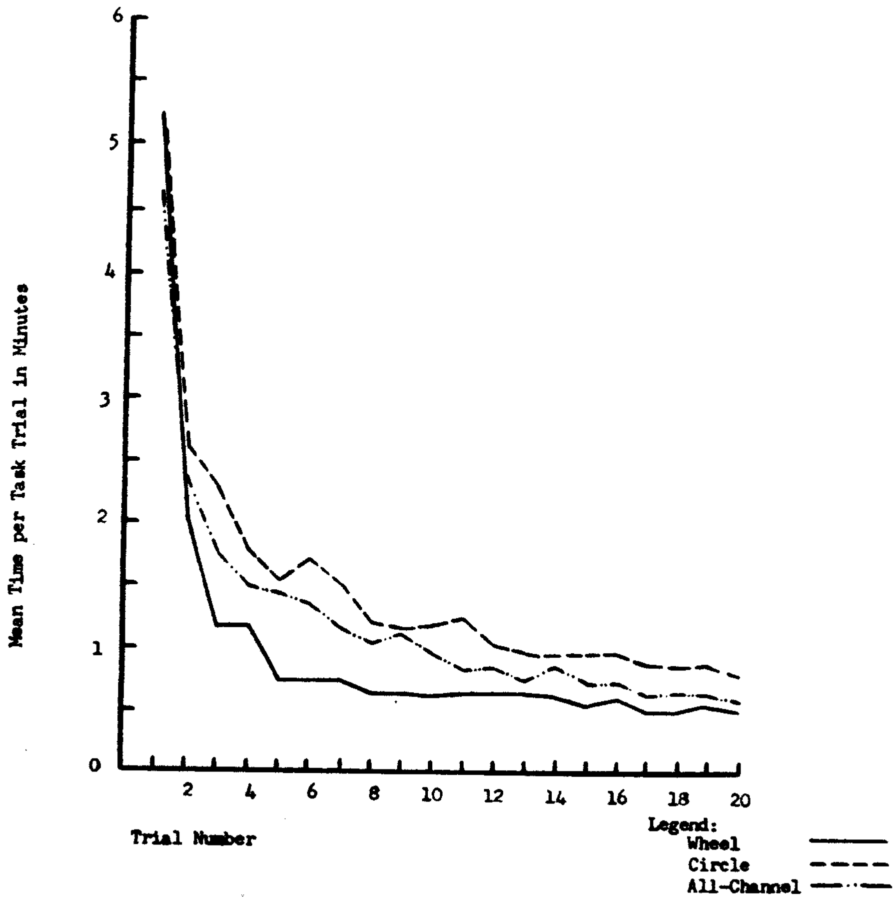

Fig. 4. Average Time per Group for Task Trials

TABLE 2

Time of Task Trials

(Minutes)

Net	Total Time		Average of the Three Fastest Trials	
	Mean	Standard Deviation	Mean	Standard Deviation
All-Channel ($n = 20$)	24.38	4.82	0.54	0.15
Wheel ($n = 15$)	19.12	3.09	0.46	0.08
Circle ($n = 21$)	29.45	5.08	0.73	0.15

Significance of Difference Between Nets

	Total Time	Average of the Three Fastest Trials
Wheel—All-Channel	$t = 3.06$ $p < .01$	t is not significant
Circle—All-Channel	$t = 3.17$ $p < .01$	$t = 3.96$ $p < .001$
Wheel—Circle	$t = 6.20$ $p < .001$	$t = 5.69$ $p < .001$

The All-Channel groups occupy an intermediate position. A statistical check of the differences between the types of groups was made on the cumulative time required for the 20 trials as shown in Table 2. This table also includes the averages for the three fastest trials within each type of group. Although the Circle groups are significantly different from the Wheel and All-Channel groups for both measures, there was a significant difference between the Wheel and All-Channel groups on only the "total time" measure.

The effects of the communication nets upon the time criteria were marked. During the 8th trial, the Wheel groups had already reached the levels eventually attained by the All-Channel groups in their last few trials. At the end of the 20 trials, the Circle groups were using some 60 per cent more time than the Wheel groups in performing their operations. During the course of the twenty trials, there were performance differences between the All-Channel and Wheel groups that eventually disappeared.

These findings hint that the Wheel groups, with the least difficult organizational problem, organized earliest; that the All-Channel groups, with a more difficult job, organized more slowly, but were eventually performing as well as the Wheel groups; that the Circle groups had difficulty in organizing, not reaching optimum performance within the 20 trials allowed. These differences correspond to the variations in organizational difficulty imposed by each net. The more difficult the organizational job, the less rapid was the evolution toward efficient task performance.

But are these differences actually due to the organizational arrangements, or are they (contrary to our theory) due to differences in task operation times in the optimal arrangements? An answer to this question requires an analysis of the organizational arrangement developed by each group. What are the message sending and receiving patterns that developed in the groups over the course of the twenty task trials? To examine the growth of miniature organizations, it is necessary first to determine whether there *is* a definite pattern; this is the *stability* problem. Then, if there is a pattern, we can examine how the message sending became differentiated into a particular *organizational arrangement.*

Organizational Stability

The *interaction pattern* is defined for a given trial in terms of whether or not one or more messages were sent from a particular person to another—that is, which of the open channels in the net were used, and in which direction, by the five persons constituting the group. Because a message card might have two or three units of information on it, the actual number of cards sent over a channel was of no literal significance.[9]

The *stability* of the interaction among the five persons is defined as the extent to which a given pattern persisted over a sequence of trials. An analysis was made of every trial for each group, contrasting the pattern of information messages with the pattern of answer messages. Then each sequence or "segment" of four trials within each group was classified as to stability of the pattern of channels used. The five segments chosen coincided with questionnaire periods: trials 1 to 4, 5 to 8, 9 to 12, 13 to 16, and 17 to 20. Information and answer messages were analyzed separately.

In making the analyses, we diagrammed the stability of the segment by using a solid arrow for those channels which were always used or never used, respectively, during the four trials constituting the segment. We employed a broken arrow for those channels which were used once, twice, or three times during the four trials. This notation is illustrated in the examples of Figure 5. Three degrees of stability were defined as follows:

1. Stable: A segment was termed "stable" with respect to its information or answer messages, if only one or two of the channels were used "intermittently," i.e., once or twice, or three times during the segment, regardless of the number of channels available. See the examples a, b, and c in Figure 5.
2. Semi-Stable: A segment was termed "semi-stable" with respect to its information or answer messages when three to one-half of the total open

[9] Because of our use of pre-coded message cards, it was easy for the senders to include more than one piece of information on each card. For example, a subject might have forwarded to his neighbor in a single message not only his own missing symbol but also information about what one, two, or three other persons were missing. Examination of the messages suggested we would lose little in the analysis by counting the number of message cards exchanged during the course of the experiment rather than tallying each item. A sample of the messages received by each of the 220 subjects during a single trial was checked for correspondence between the number of items of information and the number of messages cards involved. The sample was drawn evenly from all 20 trials for all three types of groups. The product-moment correlation between items and cards was +.84. This reliability was considered satisfactory, obviating the labor involved in a count of items.

channels were used intermittently. As noted previously, there were 20 open channels in the All-Channel, but only 8 in the Wheel and 10 in the Circle nets. See examples d, e, f, in Figure 5.

3. Unstable: A segment was termed "unstable" with respect to its information or answer messages when more than half of the open channels were used intermittently. See examples g, h, i in Figure 5.

These criteria were developed after considerable exploratory work with other ways of setting the boundaries between classes.

The results of the classification of the segments are presented in Table 3. The groups in All-Channel nets are significantly less stable than those placed in more restricted nets. The Wheel groups are more stable than the Circle groups.

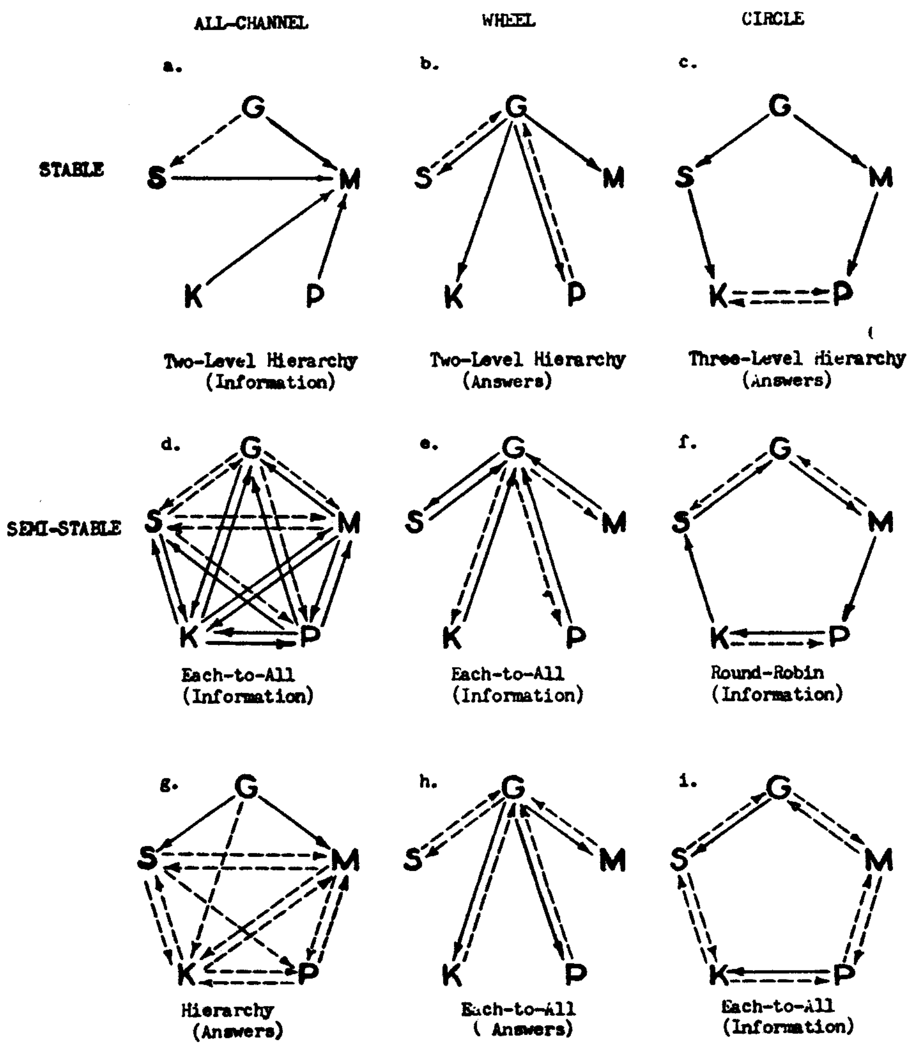

FIG. 5. Examples of Stability Classes of Interaction Patterns

TABLE 3

Percentage Distribution of Segments into Stability Classes

Net	Stability Classes	Information Exchange	Answer Exchange	Total Exchange
		%	%	%
All-Channel Segments (n = 200)				
	Stable	40	28	34
	Semi-Stable	45	37	41
	Unstable	15	35	25
Wheel Segments (n = 150)				
	Stable	90	91	91
	Semi-Stable	10	9	9
	Unstable	0	0	0
Circle Segments (n = 210)				
	Stable	81	21	51
	Semi-Stable	17	29	23
	Unstable	2	50	26

Significance of differences in stable vs. combined semi-stable and unstable segments between nets

	Information	Answer	Total
Wheel—All-Channel	$\chi^2 = 43.3$ $p < .001$	$\chi^2 = 68.7$ $p < .001$	$\chi^2 = 45.5$ $p < .001$
Circle—All-Channel	$\chi^2 = 36.2$ $p < .001$	χ^2 is not significant	$\chi^2 = 11.5$ $p < .01$
Wheel—Circle	$\chi^2 = 2.8$ $p < .10$	$\chi^2 = 85.1$ $p < .001$	$\chi^2 = 64.2$ $p < .001$

Thus, the more restrictions imposed on the communication channels, the more stable the groups. The stability level reflects the number of open channels (see Figure 2), although the difference between the All-Channel and Circle groups fails to approach a 20 to 10 ratio.

Organizational Arrangement

Now it is possible to characterize the organizational arrangements embodied in the semi-stabilized and fully stabilized interaction patterns. Qualitative analysis of the diagrams obtained from the stability analysis of the segments indicates that some groups operated without much division of labor or specialization of positions, utilizing all available channels. Others developed a more highly differentiated group structure.

1. *All-Channel groups.* These groups fell into two types of patterns in *exchanging information.* Three groups stabilized their information exchange with each person sending messages about his missing symbols to all others. Such an "each-to-all" pattern (semi-stable in this case) is illustrated in Figure 5-d. By

the end of the experiment, the other seventeen groups had clearly differentiated into two-level hierarchies, like the one illustrated in Figure 5-a.

The All-Channel groups displayed more variety in the organization of their *answer exchanges*. One group, in which each person had given information on his missing symbol to every other person, exchanged almost no answers. Another group developed an each-to-all pattern; still another developed a relatively unstable but clearly differentiated hierarchy in exchanging answers. Six groups developed quite stable 3-level hierarchies in exchanging answers. The remaining eleven groups used 2-level hierarchies, the inverse of the patterns they used in exchanging information.

In the All-Channel groups, taken as a whole, there is approximately the same kind of organization in the information exchanges as in the answer exchanges and both showed considerable differentiation.

2. *Wheel groups*. The imposition of the Wheel net resulted in the use of very stable two-level hierarchy patterns for information and answer exchanges after the first three or four trials.

During the initial trials in four Wheel groups, the *information exchanges* were of the "each-to-all" type, the person in the hub sending out information to all participants, as in Figure 5e. In the other eleven groups, the hubs during the initial trials sent information to only one or two persons, and ceased to send out any information about their own missing symbols after the fourth or fifth trial.

In *exchanging answers*, all of the fifteen groups very rapidly developed a 2-level hierarchy in which the person at the hub alone sent messages to the others in the group. Seven of the groups used this pattern for all twenty trials; another seven groups contained persons who sent answers to the hub during the early trials, as in Figure 5b. One group during its first four trials sent no answers back and forth, inasmuch as each person used his "information-received" to come to a solution independently.

There was early and very rapid development of the organizational arrangement in the Wheel groups, the information exchange being mirrored by the answer exchange.

3. *Circle groups*. The groups placed in Circle nets had much difficulty in organizing their structures. Although the groups *in toto* were not as unstable as the All-Channel groups there was still considerable variation in channel usage. The Circle groups tended to organize in the more "primitive," each-to-all patterns, as in Figure 5i.

The bulk of the Circle groups—13 out of the 21—used each-to-all patterns in exchanging their *information* messages. Eight groups used somewhat more differentiated patterns. A first step toward differentiation is found in four groups which evolved semi-stable "round-robins" in which information is passed around the circle, as illustrated in Figure 5i. A fifth group used a round-robin from trials 2 to 10, but in trial 11 one of the participants stopped forwarding his information, reconstituting the round-robin pattern into a chain. Three other groups developed the most specialized information exchange structures of all the Circle groups—ending their last three trials in three-level hierarchies.

TABLE 4

Development of Organizational Structures

(Percentage of Segments Differentiated)

Net	Type of Organization	Segment: Trials 1–4	Trials 5–8	Trials 9–12	Trials 12–16	Trials 17–20
		%	%	%	%	%
All-Channel Segments (n = 200)						
	Differentiated*	5	42	78	85	88
	Each-To-All	28	20	10	8	7
	Undiscernible	67	38	12	7	5
Wheel Segments (n = 150)						
	Differentiated*	77	100	100	100	100
	Each-To-All	23	0	0	0	0
	Undiscernible	0	0	0	0	0
Circle Segments (n = 210)						
	Differentiated*	14	26	33	48	48
	Each-To-All	52	40	33	38	36
	Undiscernible	34	34	34	14	16

* "Differentiated" means using such patterns as the 2- or 3-level hierarchy, round-robin, and chain.

The Circle groups differentiated more decidedly in their *answer exchange* patterns. Only one group remained in an each-to-all pattern. Ten of the 21 groups temporarily organized into special patterns, exhibiting much fluidity. Their answer exchange fluctuated from one form of a hierarchy to a semi-stable "each-to-all" to another form of hierarchy, often ending in a semi-stable each-to-all. The remaining ten groups differentiated into three-level hierarchy arrangements as in Figure 5c.

There was considerably more differentiation among the answer exchange patterns than among the information patterns. But by and large, there was a marked tendency for the Circle groups to remain primitive and undifferentiated. Almost half of the stability and semi-stability reported above (Table 3) for these Circle groups was gained by the consistent use of each-to-all patterns.

Table 4 displays the development of the differentiation throughout the course of the experiment for all three types of groups. The bulk of the organization of differentiated patterns is accomplished by the end of the 12th trial in the All-Channel groups. The imposed net helped the Wheel groups to achieve their organizations by the end of the 4th trial. The relative lack of differentiation in the Circle groups is vividly portrayed in Table 4; their high variability from one pattern to another is also reflected in the fluctuation of the percentage of differentiation from segment to segment.

The Critical Observations

We are now in a position to subject our central hypothesis to a clear-cut test. It follows from the hypothesis that groups placed in different nets will experiencc different degrees of difficulty in attaining an efficient organizational arrangement (say, a two-level or three-level hierarchy); further that the *speed of task performance will be approximately the same in all groups that do in fact attain an efficient arrangement, regardless of the net in which they are operating*. Finally, the average time required for task performance in the efficiently organized groups should, at least approximately, be that predicted by the M-T-M analysis.

Either a two-level hierarchy or a three-level hierarchy (or both) was a possible organizational arrangement within the nets studied. The empirical data indicate that three or more groups within each of the nets actually did organize themselves into one or the other type of hierarchy either for information exchange or answer exchange or both. *When the groups were so organized, they performed their operating tasks efficiently.*

The fifteen Wheel groups (all of which we may regard as "efficiently organized") averaged .46 minutes for their three fastest trials (cf. Table 2). This is almost identical with Hellfach's estimate of .45 minutes in his M-T-M analysis (*supra*, p. 237).[10]

The data for the organized Circle and All-Channel groups are decisive in confirming the hypothesis. The average speeds in the three fastest trials in the 17 All-Channel groups that developed 2- or 3-level hierarchies in both information and answer sending ranged from .34 to .68 with a mean of .489 minutes. The corresponding range for the three Circle Groups which developed a 3-level hierarchy was .40 to .52 minutes, with a mean of .472 minutes. The differences between the means of the organized All-Channel and Circle groups and Hellfach's estimate are not statistically significant; nor are the differences between the means of these groups and the mean of the Wheel groups.

The correctness of the other half of the hypothesis—the relative difficulty in achieving efficient organizational arrangement in different nets—follows immediately. Only groups working within the Wheel net were able to achieve a hierarchical organization with ease. As already reported, all fifteen such groups did so, and usually during early trials. Of the twenty All-Channel groups, seventeen did so, but generally later in the sequence of trials. Only three of the 21 Circle groups developed hierarchies. These findings confirm the theoretical analysis (*supra*, p. 240), which predicts that the difficulty in organizing will be greatest in the Circle groups, next in the All-Channel groups, and least in the Wheel groups.

[10] It is perhaps worth emphasizing that Hellfach's estimate does not in any way derive from the data of the experiment. The standard times he used for the task elements were derived from M-T-M tables drawn up from industrial time and motion studies. Although Hellfach was acquainted with the results of the experiment, his estimate was built up from data expressed in hundredths of hours, rather than minutes; he converted his totals to minutes as the last step. Hence, there was little opportunity for the experimental data to influence his estimate, even unconsciously.

Thus, both parts of our basic hypothesis are confirmed: The communication nets affected the efficiency with which the groups performed only through the influence they exerted upon the ability of the groups to develop adequate organizations.

III. Replication of Leavitt's Experiment

Our experimental procedure used the Wheel and Circle nets in common with Leavitt. We ran our groups 20 trials, in contrast with his 15 trials. He did not match his groups on the basis of intellective ability. In his experiment, the task and non-task messages were written contemporaneously during the operating trial itself, without benefit of a pre-coded task message card; we had the non-task messages written during an intertrial period.

Despite these differences, our empirical results in the main are a forthright confirmation of the work that was replicated. Leavitt found the fastest trial in his Wheel and Circle groups to average .53 and .83 minutes respectively.[11] His figures are comparable to those presented in Table 2. The Wheel groups in both his and our experiments took a little more than 60 per cent of the time taken by the Circle groups for completion of their fastest task runs. The absolute differences in times between the two experiments may be artifacts produced by apparatus dissimilarities and by the fact that Leavitt's data include the time used for sending non-task messages.

Leavitt's figures on volume of messages are comparable to the sum of our task *and* intertrial messages. In the Wheel nets our groups sent an average of 177 messages per group during the first 15 trials compared with Leavitt's 166, our average being about 7 per cent greater. In the Circle nets our groups sent an average of 389 messages over the first 15 trials and intertrials compared with Leavitt's 372, ours being about 2 per cent greater. These differences are not statistically significant. The ratio of information messages to answer messages in the two experiments is similar. Thus, our use of an intertrial period seems not to have disturbed the situation as originally designed by Bavelas, Leavitt, and Smith.

Despite our ability to replicate Leavitt's results as far as the time and volume of messages are concerned, there is a striking difference with regard to the extent to which our Circles organized. Leavitt says, "The *circle* showed no consistent operational organization. Most commonly messages were just sent in both directions until any *S*(ubject) received an answer or worked ont out."[12] Although our Circle groups were much less differentiated than groups in the other two nets, many consistent patterns evolved. The latter difference between our results and Leavitt's cannot be ascribed to the fact that we ran twenty rather than fifteen trials. At the end of the 15 trials, as Table 4 demonstrates, some 48 per cent of the segments had already differentiated into stable or semi-stable interaction structures. We cannot explain these differences.

[11] Leavitt, *op. cit.*, Table 2, p. 43.
[12] Leavitt, *op. cit.*, p. 42

Our results on the Wheel groups are identical with those obtained by Leavitt. All of his groups, like ours, used the same interaction structure, the information pattern being the inverse of the answer pattern. Like our groups, his evolved the organization by the fourth or fifty trials.

IV. Summary

This replication and extension of the work of Bavelas, Leavitt, and Smith on communication patterns in task-oriented groups enabled us to separate the effect of communication nets upon the performance of an operating task by the group, and upon the ability of the group to organize itself for this operating task. The particular nets we explored did not create differences among the groups with respect to the time needed for handling the operating task when an optimal organization was used. These same nets did introduce important differences in the organizing difficulties encountered. In this way we obtained an estimate, which can be refined through further experimentation, of the relative difficulties introduced by demanding the establishment of non-symmetric "keyman" roles, the organization of relay points, and the elimination of unnecessary channels.

The current management literature on the topic of communication leaves one with the expectation that certainly a reduction in communication restrictions should lead to a more adequately functioning organization. Yet, our findings in this experiment indicate that assertion of a one-to-one relationship between effective functioning and freedom in communication is unwarranted. Had our analysis not separated the organizational problem from the operating problem, it would have seemed paradoxical that complete freedom of communication is at times more limiting than restricted communication. The findings warn the practical communications expert working in industry or government that a change in communications structure may have quite different consequences for the efficiency of immediate day-to-day operations, and for the ability of the organization to handle changes in its own structure.