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Subject: the end of the list
From: "Linton C. FREEMAN" <LCFREEMA@uci.edu>
Date: Fri, 17 Sep 2004 14:12:25 -0700 (PDT)
To: pslazar@uci.edu

Dear Ms. La Zarr,

Here are the remaining nine fugitive items:

Fararo, T.J. 1973, Mathematical sociology. N.Y.:John Wiley, chapter on
equivalence.

Powell, W.W. 1990, "Neither market ..." Research in Organizational

17:227-241.

Freeman, L.C. et al. 1988, "On human ..." J. of social and biological
structures. 11:415-425.

Bavelas, A. 1950, "Communication patterns ..." J. of the acoustical
society of America. 22:725-730.

Seidman, S.B. et al. 1978, "A graph-theoretic ..." J. of mathematical
sociology. 6:139-154.

Iverson, G.J. et al. 1990, "Statistical issues ..." J. of quantitative
anthropology. 2:61-83.

Mazur, A. et al. 1989, "Dominance ..." J. of social and biological
structures. 12:87-99.


Thank you for your help.

Lin Freeman

---------------------------------------------
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guages have evolved toward some maximally efficient form, the maxima are certainly quite broad.

GROUP PROBLEM SOLVING

One final instance of psychological research and I am done. Dr. Bavelas has described his interesting experiments in group communication. Following his lead we have done some similar experiments over voice communication circuits and in the presence of an interfering masking noise. 3

We have tested only three-station nets. The five systems we used are shown in Fig. 3. The letters indicate the three members of the net, the arrows indicate the directions in which spoken messages could pass. These five nets permit every member to send information, either directly or indirectly, to the other two members. Note that as we proceed from left to right, net 1 has the greatest number of connections (six), and net 5 has the fewest (three).

If these three-man nets are given a problem to solve cooperatively, which net will obtain the solution most efficiently? The answer is that under good conditions it doesn't matter; one net is about as good as another. But when enough noise is introduced to make communication difficult, the loosely connected nets become far inferior to the well connected nets. This difference is shown in Fig. 4.

In this figure the number of words spoken during the solution of the problem and the time to finish are plotted for the five different nets. Three signal-to-noise ratios were tested, the levels in all channels were identical. At +6 db signal-to-noise ratio communication is good; at -2 db it is possible; at -10 db it is very poor. At the best signal-to-noise ratio, 6 db, all nets did equally well. At the poorest ratio, -10 db, net 1 was far superior to net 5.

In short, a communication system may look good while things are running smoothly, but break down completely when the pressure is on.

The story is not quite so simple, however. These data were obtained with a very mechanical kind of task. No thought and no decisions plagued the members. In Fig. 5 we have some results under identical conditions except that the problem was slightly revised to demand more ingenuity on the part of the group. Now net 3 is the best; in net 3 one man is central and coordinates the activity of the other two. For a more difficult problem, therefore, the group does better if one of the channels is completely removed; without that third channel the leader of the group is clearly appointed and the followers stop confusing each other.

It is not a general rule that the more communication channels the better; in some cases it looks as though too much uncoordinated flow of information can throw sand in the gears of group endeavor. The language engineer who tries to design communication procedures to be used in solving more practical problems should know that it is often as important to withhold information as it is to give it.

These three examples should be enough to make my point. The psychologist has an important place on the language engineering team. By interacting with the other members of the team the psychologist stands to learn a great deal in return. Until the team is created, however, Mr. Psychology can keep himself profitably employed trying to discover the basic scientific facts on which linguistic technology can be based. He still has a long way to go, and so it is appropriate to close this paper with that cliché so dear to every psychologist, "These results are suggestive, but more work needs to be done."

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Communication Patterns in Task-Oriented Groups

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(Received August 8, 1950)

GENERAL STATEMENT OF THE PROBLEM

When the nature of a task is such that it must be performed by a group rather than by a single individual, the problem of working relationships arises. One of the more important of these relationships is that of communication. Quite aside from a consideration of the effects of communication on what is generally called "morale," it may be easily demonstrated that for entire classes of tasks any hope of success depends upon an effective flow of information. On what principles may a pattern of communication be determined that will in fact be a fit one for effective and efficient human effort? Administrative thinking on this point commonly rests upon the assumption that optimum patterns of communications for a task-group may be derived from the specifications of the task to be performed. Students of organization, however, have pointed out repeatedly that working groups—even if one considers only communications relevant to the work being done—inevitably tend to depart from formal statements of the pattern to
be employed. One may take the view that this departure is due to the tendency of groups to adjust toward that class of communication patterns that will permit the easiest and most satisfying flow of ideas, information, decisions, etc. In groups that are free of outside direction and control, it is clear that the interaction patterns that emerge and stabilize are a product of social processes within the group. A group that exists as part of a larger organization, however, may have relatively little freedom to make such an adjustment. In military organizations, for example, the maintenance of the stated, presumably optimum, patterns of communication is regarded as a first principle of effective performance. It is easy to understand this tendency to inhibit changes in formal communication patterns if one considers how intimate the relation is among communication, control, and authority.

In such restrictive organizations the imposed patterns determine certain aspects of the group process; the group process does not completely determine the communication pattern. This situation raises questions about how a fixed communication pattern may affect the work and life of a group. Do some patterns have structural properties that limit group performance? It may be that among several communication patterns, all logically adequate for the successful completion of a specified task, one gives significantly better performance than another. What effects can pattern, as such, have upon the emergence of leadership, the development of organization, the degree of resistance to group disruption, the ability to adapt successfully to sudden changes in the working environment?

These questions have prompted a series of exploratory studies. The findings are incomplete at present, but are of some interest in their possible implications. This paper describes the areas of present experimental activity and the general direction that the work is taking.

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**Fig. 2.** The method of counting distances in pattern $B$ is:

- $a, b = 1$
- $b, c = 2$
- $c, a = 2$
- $d, e = 2$
- $e, d = 2$

The total of all distances in pattern $B$ is 10.

---

**Fig. 3.** Calculation of distances in pattern $D$:

- $a, e = 2$
- $b, d = 2$
- $c, e = 2$
- $d, e = 2$

Sum: 4

The total of all distances in pattern $D$ is 32.

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**Fig. 4.** Indices of relative centrality in three patterns. Index is the ratio of the sum of all distances within the group to the sum of the distances from a particular position.
COMMUNICATION PATTERNS

In Fig. 2 a method of counting is illustrated as it applies to pattern B. Counting in this way shows that the sum of all the internal distances in pattern B is 40 (Σ d₁₂ = 40). In a similar way we find that for pattern A, the sum is 30, and for pattern C, 32. Figure 3 shows the tabulation of distances in pattern C.

Now consider the differences among positions in the same pattern. It is clear that position b in Fig. 2 differs from position a in the same pattern. One aspect of this difference is shown by the tabulation of distances: d₁₂ = 10, whereas d₁₂ = 7. But what shall we say in comparing position b in Fig. 2 with position b in Fig. 3? In this case the distance from b to all the others does not differentiate between the two positions. Yet we cannot but feel that there is a difference. Since the two patterns have different total distances for all members, it may help if we express the distance "b to all others" in a relative manner. One way to do this is to calculate for each position the value of the ratio Σ d₁₂ / d₁₂. For position b in Fig. 2 the ratio is equal to 5.7; for position b in Fig. 3 the ratio is 4.6. In Fig. 4 the values of the ratio are given for all positions in patterns A, B, and C.

![Fig. 5. Two possible methods of operation in pattern B. Solid arrows represent the transmission of information about the cards held; dashed arrows represent the transmission of information about the card selection to be made.](image)

To summarize the preceding discussion, we can say that comparisons between two patterns might be made on the basis of "dispersion" (sum of internal distances); comparisons between positions might be made on the basis of "relative centrality" (ratio of sum of all internal distances to sum of distances from a particular position).

OPERATIONAL POSSIBILITIES OF PATTERNS

Let us turn now to the question of how these patterns might be used by a group. Any sensible discussion of "operation" must, of course, be in terms of some specified task. A simple but interesting one is the following: each of the five subjects is dealt five playing cards from a normal poker deck; the cards may not be passed around, but the subjects may communicate over the indicated channels by writing messages; the task is considered finished when each subject selects one of his five cards—the five selected cards to comprise the highest ranking poker hand that could be made with one card out of each group of five. (We assume that the subjects have a perfect knowledge of poker-hand ratings.)

![Fig. 6. Shortest time w. fewest messages (see text).](image)

It is clear that pattern B can be operated in a number of ways. Two of the possible operational patterns are shown in Fig. 5. Obviously, it is possible for this pattern to be so operated that any person in it will be the one to have all the necessary information first. Presumably this person will be the one to decide which card each individual should select. There are no linkage strictures that force a given method of operation. We can ask, however, whether there are differences in efficiency between different operational patterns. Two measures of efficiency come naturally to mind. One is the number of messages required for task completion. The second is the time required to complete the task.

It is possible to make a general statement about the number of messages required. In terms of the hypothetical task given above, one can say that each of the members has in his possession one-fifth of the information necessary for the solution. Also, all of the information must at some time be present at one position in the pattern. It can be shown that four messages are necessary and sufficient to accomplish this. Since all members must know the correct answer so that each one can select the proper card, an additional four messages are required. One may say that for any patterns with *symmetrical linkages* the number of messages required is equal to 2(n-1), where n is the number of members in the pattern. This requirement is completely independent of the linkage pattern as such.

We have a somewhat different situation with respect to the time it takes to reach a solution. We must, of course, for any general discussion of speed of solution, assume some standard unit of time to be associated with a message. This is not intended to exclude the possibility that in certain patterns morale effects will materially affect the speed with which an individual might perform. Let t equal the time it takes for information to go from one person to another when they are linked. A relation between t and the number of individuals in a group should be pointed out. If any linkage pattern is allowed, then it may be stated that the minimum time for solution has the following relation to the number of persons:

\[ t_{\text{min}} = n + 1, \quad \text{when} \quad 2^* n \leq 2 \times t. \]

This relation leads to some rather interesting conclusions. Let us consider two groups with unrestricted

![Fig. 7. Frequency of occurrence of recognized leaders at the different positions in patterns A and B (Smith, unpublished data).](image)
linkage. One group has nine members, the other sixteen. With a task such as the one described above the minimum time necessary for completion would be the same for both groups, although in the first we have nine individuals each possessing one-ninth of the information, and in the second we have sixteen individuals each with one-sixteenth of the information.

With 4 defined in this way it is easy to see that the operational pattern at the top of Fig. 5 requires eight units of time, whereas the lower operational pattern requires only five units of time. Obviously, when more than one message is sent in the same time unit, time is saved. However, if individual 4 sends a message simultaneously with individual c, as in Fig. 6, his message to 4 cannot possibly contain the information contained in the message from c. We can expect, therefore, that in certain patterns, time will be saved at the expense of messages, and that doing the task in the minimum number of messages will involve the use of more time units. This is nicely illustrated by pattern A in Fig. 1. In this pattern the problem can be done in as few as three time units, but to do this requires fourteen messages. If the problem is done in eight messages, the fewest possible, the number of time units required increases to five.

SOME EXPERIMENTS WITH SELECTED PATTERNS

Sidney Smith (unpublished data) has conducted an experiment with groups of college students arranged in patterns A and B shown in Fig. 1. He gave the groups a task that in its essentials was similar to the poker problem described above. Instead of playing cards, however, each subject was given a card upon which had been printed five symbols taken from a master set of six symbols. The symbols were a circle, a triangle, an asterisk, a square, a plus sign, and a diamond. Although each symbol appeared on some group of four of the five cards, only one symbol appeared on all five cards. The group's task was to find the common symbol in the shortest time possible.

In each subject's cubicle there was a box of six switches. Each switch was labeled with one of the six master symbols. The task was considered finished when each member of the group indicated that he knew the common symbol by throwing the appropriate switch. The switches operated a board of lights visible to a laboratory assistant who recorded individual and group times and errors (throwing an incorrect switch). The subjects communicated by writing messages that could be passed through slots in the walls of the cubicles. The slots were so arranged that any desired linkage pattern could be imposed. No restriction whatever was placed on the content of the messages. A subject who had the answer was at liberty to send it along. The cards on which the messages were written were coded so that a reconstruction of the communicatory activity could be made. Each experimental group worked on fifteen successive problems. The same six master symbols were used throughout, but the common symbol varied from trial to trial. Four groups worked in pattern A and four different groups worked in pattern B. No group worked in more than one pattern.

Only two of the findings will be reported here. These concern the number of errors and the emergence of recognized leaders. In order to study the emergence of recognized leadership, each subject answered a questionnaire immediately after the end of the fifteenth trial. One of the questions read, "Did your group have a leader? If so, who?" The answers are tabulated in Fig. 7. There was no clearly recognized leader in pattern A; the central position emerged as leader consistently in pattern B.

The errors are summarized in Table I. More errors occurred in pattern A than in pattern B. One-third of the problems were completed with at least one error in pattern A, but only one-tenth the problems were erroneously completed in pattern B.

No good theory has been formulated for the differences in number of errors, but the findings suggested that the individual occupying the most central position in a pattern was most likely to be recognized as the leader. Also, from observations of the subjects while they worked, it appeared that morale was better in pattern A than in pattern B. The morale of the individuals in the most peripheral positions of pattern B seemed poorest.

In order to explore these possibilities further, Leavitt3 conducted a more detailed study of the same two patterns plus two others. The four patterns tested are shown in Fig. 8. Leavitt used the same problems and the same

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Communication Patterns

Table II. Number of errors (incorrect switches thrown) and number of problems which on completion contained at least one error. (Leavitt, 1949).

<table>
<thead>
<tr>
<th>Error category</th>
<th>Pattern A</th>
<th>Pattern B</th>
<th>Pattern C</th>
<th>Pattern D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Av. total errors</td>
<td>17</td>
<td>10</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Av. incorrect completions of task</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

experimental setting used by Smith. He ran five groups in each pattern. The errors are summarized in Table II. The leadership recognitions are summarized in Fig. 8. Pattern D, at the bottom of Fig. 8, would have had far fewer errors had it not been for one of the five groups tested in pattern D. This one group became confused over the meaning of one member's method of reporting his information.

Leavitt's findings considerably strengthen the hypothesis that a recognized leader will most probably emerge (under the conditions of this experiment) at the position of highest centrality. Also, the findings lend some support to the hypothesis that errors may be related to pattern properties.

In addition to errors and leadership, Leavitt was interested in the question of morale differences between and within patterns. His subjects were asked two questions to which they responded by ratings from 0 (very unfavorable) to 10 (very favorable). The data are given in Table III as averages of all the ratings for all subjects in the same pattern. Pattern A seemed to have the best morale.

In order to check the hypothesis that morale differences exist within patterns and are related to centrality, the following analysis of the responses to the same to questions was made. The ratings of the men who occupied the most peripheral positions in patterns B, C, and D were averaged together; the ratings given by men in the most central positions of the same patterns were also averaged together. All ratings made by subjects in pattern A were omitted from these calculations for the obvious reason that no one is central or peripheral in that pattern. In response to the question, "How much did you like your job?" men in peripheral positions gave an average rating of 3.2 compared with an average rating of 8.8 by the men in the most central positions. In response to the question, "How satisfied are you with the job done?" the peripheral ratings averaged 4.6, the central, 7.8.

On the basis of a detailed study of all the data from his experiments, Leavitt makes the following comments:

"Pattern D operated as expected in all five cases. The peripheral men sent their information to the center where the answer was arrived at and sent out. This organization usually evolved by the fourth or fifth trial and was maintained unchanged throughout the remaining trials.

"Pattern C operated so that the most central man got all the information and sent out the answer. Organization evolved more slowly than in pattern D, but, once achieved, was just as stable.

"Pattern B was not as stable as patterns C and D. Although most of the times the answer was sent out by the individual in the most central position, this function was occasionally performed by one of the men on either side of him. Organization was slower to evolve than in patterns C and D.

"Pattern A showed no consistent pattern of organization. Subjects, for the most part, merely sent messages until they received or could work out the answer themselves."

A Proposed Experiment

In the experiment discussed above, the normal behavior of a subject in working toward a solution was to send to others a list of the five symbols appearing on his card. Occasionally, however, something quite different would occur. The subject would send, instead, the symbol out of the six that was not on his card. The advantages of this method in saving time and avoiding possible mistakes are obvious. In a sense, this procedure is a "detour" solution of the problem. The whole task situation was such as to suggest strongly the straightforward action of sending along the symbols one had, rather than the symbol one had not. Although the frequency of occurrence of this insight was fairly even in the groups, its adoption by the groups as a method of work was not. It was used by two of the five groups in pattern A, by one of the five groups in pattern B, and by none of the groups in patterns C and D. These differences cannot be demonstrated as significant, but they stimulate speculation. In individual psychology it has been shown repeatedly that an individual's frame of reference may be such as to effectively inhibit the solution of a problem involving a detour. With the groups in question the insight invariably occurred to some member or members. Why, then, did it not spread throughout the group in every case? Might it be that in certain communication patterns the probability of effective utilization of the insights that occur is greater than in others? It was felt that if a more suitable task could be devised, some relation between the occurrence and utilization of insights and the communication pattern might be uncovered.

A task has been constructed that seems to be a step in the right direction. Preliminary trials with it are encouraging. The task consists essentially of forming

Table III. Response to questions about morale (Leavitt, 1949).

<table>
<thead>
<tr>
<th>Question</th>
<th>Average rating by pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>How much did you like your job?</td>
<td>6.6</td>
</tr>
<tr>
<td>How satisfied are you with the job done?</td>
<td>8.0</td>
</tr>
</tbody>
</table>
squares from various geometric shapes. In Fig. 9 are shown the pieces that make up the puzzle and how they go together to form five squares.

Out of these shapes, squares may be made in many ways. Some of the possible combinations are: $CCAD$, $EAAAA$, $EAAG$, $FFAAAA$, $FFCA$, $FPGA$, $ICA$. However, if five squares must be constructed out of the fifteen pieces, there is only one arrangement that can succeed. In the experimental situation the pieces are distributed among five subjects. They are told that in order to succeed each member must have a square before him with no unused pieces. Messages and pieces may be passed along open channels.

The initial distribution of the pieces can be so arranged that the probability of “bad” squares being formed is increased. A possible distribution is given in Fig. 10. As can be seen, the pieces with which an individual starts may suggest very little and therefore be speedily traded. Examine the position $a$ in Fig. 10. The pieces $IHE$ do not readily combine. We may assume that the subject will pass one of the three to position $b$. At position $b$ the situation is quite different. The combinations $ACI$ or $AAAH$ or $ACE$ all form squares which, if completed and maintained, lead to group failure. Thus any piece $b$ receives from $a$ merely suggest possible “wrong” squares. In preliminary trials the wrong squares appear with great regularity. The point of the experiment is what happens once these failure “successes” occur. For an individual who has completed a square, it is understandably difficult to tear it apart. The ease with which he can take a course of action away from his goal should depend to some extent upon his perception of the total situation. In this regard, the pattern of communication should have well-defined effects.

A formal experiment using this task has not yet been done. Preliminary runs, concerned primarily with experimental method, show that the binding forces against restructuring are very great, and that with any considerable amount of restriction on communications a solution is improbable.

CONCLUDING REMARKS

If they do nothing more, these studies at least suggest that an experimental approach to certain aspects of social communication is possible and that, in all probability, it will be practically rewarding. Generalization at such an early stage of work is dangerous, but one is tempted to make a tentative step. It would seem that, under the conditions imposed by the experiments, differences between certain patterns very probably exist. The differences most clearly revealed are with respect to (a) the location in the pattern of recognized leadership, (b) the probability of errors in performance, and (c) the general satisfaction of group members.

Further, we note that in patterns with a high, localized centrality, organization evolves more quickly, is more stable, and errors in performance are less. At the same time, however, morale drops. It is inconceivable that morale should not, in the long run, affect stability and accuracy negatively. The experimental runs of fifteen trials, if extended to a larger number of trials, might well begin to show the effect.

More speculative is the question of the occurrence and utilization of insight. The preliminary trials with the “five squares” puzzle, while few, are dramatic. Every group succeeded in forming two, three, or four squares. But the ability to restructure the problem, to give up partial successes, varied widely from pattern to pattern. If the indications of the few experimental runs that have been made to date are any guide, both the occurrence and utilization of insight will be found to drop rapidly as centrality is more and more highly localized.