SOME EFFECTS OF CERTAIN COMMUNICATION PATTERNS UPON GROUP PERFORMANCE

by

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ABSTRACT

Some Effects of Certain Communication Patterns Upon Group Performance

H. J. Leavitt
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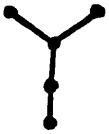
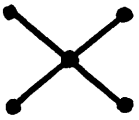
It is the purpose of this study to determine the effects of four different communication patterns on the task performance of small groups, and on the behavior of individual members of those groups. By communication pattern is meant the network of channels of communication linking the group members with one another.

Four different patterns were selected:  (Circle),  (Chain),  (Y),  (Wheel). These patterns differed from one another in both structural and operational characteristics.

The problem selected was one of simple collation of data. Each member was given a card with five symbols. Only one symbol was common to the cards of all five members. The task was for all the subjects to discover the common symbol, by means of written communications with one another. In all four patterns, this problem could be solved in a minimum of eight different messages.

Our procedure consisted, after a preliminary orientation period, of seating subjects around a circular table on which partitions were mounted. Subjects could not see one

another, but they could communicate by passing messages through appropriate slots in the apparatus. Any pattern could be set up by experimenter by blocking certain slots, and leaving others open. Each group of subjects solved fifteen different but similar problems. Five groups of undergraduates, five to a group, were run in each pattern.

Records were kept of speed of solution, errors, and numbers of messages sent. The content of the messages was analyzed. A questionnaire aimed at getting subjects' perceptions of their own roles, and of their groups was administered.

An analysis of the data collected showed pattern differences in behavior that most commonly fall in the order Circle, Chain, Y, Wheel. The Circle was erratic, active (message-wise), unorganized, and leaderless, but satisfying to its members. The Wheel was less erratic, required few messages, was well organized, and had a definite leader, but was less satisfying to most of its members. Positionally, the most central positions within patterns became the leader positions; the most peripheral ones the followers. Individuals in the central positions were most satisfied with their jobs; the peripheral ones were least satisfied. Other less definite differences occurred in self-correcting tendencies, origin of organization, and types of messages sent.

The behavioral results are correlated most clearly with centrality differences in and between patterns. The relationship between centrality and behavior is discussed. It is proposed that centrality effects behavior through the medium of the limitations that low centrality places on the independence of action of certain members. These independence-dependence differences are felt to account for differences in accuracy, satisfaction, activity, and differences in other dimensions of behavior among the four test patterns.

Acknowledgments

This work owes both its origin and its completion to the thinking of Professor Alex Bavelas of the Industrial Relations Section at the Massachusetts Institute of Technology.

In addition the members of Professor Bavelas' seminar in Advanced Experimental Psychology are the source of most of the mathematical concepts and of many of the methodological ones. The help of Sydney L. Smith should be particularly noted in this regard.

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I. The Problem

Cooperative action by a group of individuals having a common objective requires, as a necessary condition, a certain minimum of communication. This does not mean that the individuals must have communication with one another.* It is enough, in some cases, if they are each touched by some part of a network of communication which also touches each of the others at some point. The ways in which the members of a group may be linked are infinite; very possibly only a few of the possible ways have any usefulness in terms of effective performance. Which of all feasible patterns are "good" patterns from this point of view? Will different patterns give different results in the performance of group tasks?

In a free group, the kind of network that evolves may be determined by a multitude of variables. The job to be done by the group may be a determinant, or the particular abilities or social ranks of the group members, or other cultural factors may be involved.

Even in a group in which some parent organization defines the network of communication, as in most military or industrial situations, the networks themselves may differ along a variety of dimensions. There may be differences in

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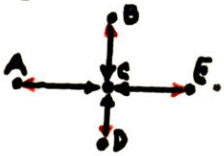
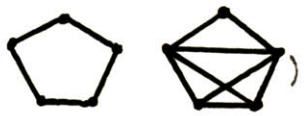
*Some current, as yet unpublished, research by Skinner and Bavelas indicates that groups with no direct communication between members but with a common goal may achieve a kind of functional role taking, and may improve their performance as a group.

number of connections, in the symmetry of the pattern of connections, in "channel capacity" (how much and what kind of information may be carried through any connection), in the direction of flow of information, and in a multitude of other ways.

Consider, for example, a five-man group whose task it is to keep a daily record of production in five manufacturing departments of a plant. Suppose, too, that each of the five men, one responsible for each department, needs to know the production records of the other four departments. There are several possible patterns of communication for doing this kind of job. Let's select one. The superintendent sends a memo to each of the five, A, B, C, D, and E. The memo reads, "Henceforth at the end of each day, A, B, D, and E will send their production figures to C. C will collate them with his own, and return a copy of the full report to A, B, D, and E." The superintendent then has set up this pattern of communication, 

. He has set up four channels. He has made C the central figure, and he has determined that the channels be used toward C at time 1 and away from C at time 2. He has determined, too, that several channels may be used simultaneously. There are, however, twenty-one other patterns of communication (all with two-way linkages) from which the superintendent could have chosen. (Examples: 
)

Has the superintendent chosen the "best" one?

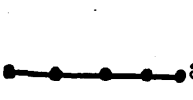
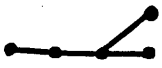
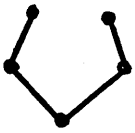
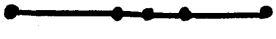
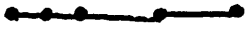
As often as not, the problem is not so clear cut. Individuals are simply placed in organizational positions from which they can communicate with a limited number of other positions. How to use the available channels, whether or not to use all of them, when to use them, all these are usually left to the discretion of the individual occupying the position. Even in the most rigid formal organization, there is considerable leeway in the way in which individuals may make use of the communication network. The members of the organization, in other words, are given a structural communication pattern, but not necessarily an operational one.

It is the purpose of this investigation to explore experimentally the relationship between the behavior of a small group and the pattern of communication in which the group operates. It is our further purpose to test some hypotheses about the psychological conditions that result from various communication patterns, and the effects of these conditions on the organization and the behavior of its members. We shall seek to do this for small groups of a constant size, using two-way written communication, and a task that requires the simple collation of information.

II. Some Characteristics of Communication Structures

The stimulus for this research lies primarily in Bavelas' "A Mathematical Model for Group Structures"(1) in

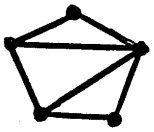
which is considered the problem of defining some variables which describe certain dimensions of group structures. In that study, the structures analyzed consist of cells connected to one another. If we correlate persons to "cells" and communication channels to "connections," we find that some of the dimensions which he defines are directly applicable to the description of communication patterns of the sort with which we are concerned. Thus, one way in which communication patterns vary can be described in terms of the sum of the neighbors that each individual member of the group has, neighbors being defined as individuals with whom a member has a direct connecting link. So too the concepts of "distance" and "centrality" as defined by Bavelas are of value in describing differences between structures and differences between positions within structures.

Unfortunately, the dimensions we have mentioned, sum of neighbors, sum of distances, and centrality, do not in themselves uniquely define a pattern. What defines a pattern is the way the cells are connected, regardless of how they are represented on paper. Thus  and  and  are the same, while  is different. Moreover  and  are the same, and  and  are the same. When the patterns get more complicated, it sometimes gets a little difficult to decide whether they are

the same or different.  and  , for instance, are the same pattern. Essentially, our criterion is this: if it is possible to "bend" one pattern into the shape of another, the two are not different. If they cannot be twisted (without breaking a link) into the same shape, they are different patterns. A more precise definition of unique patterns requires the use of elaborate topological concepts.

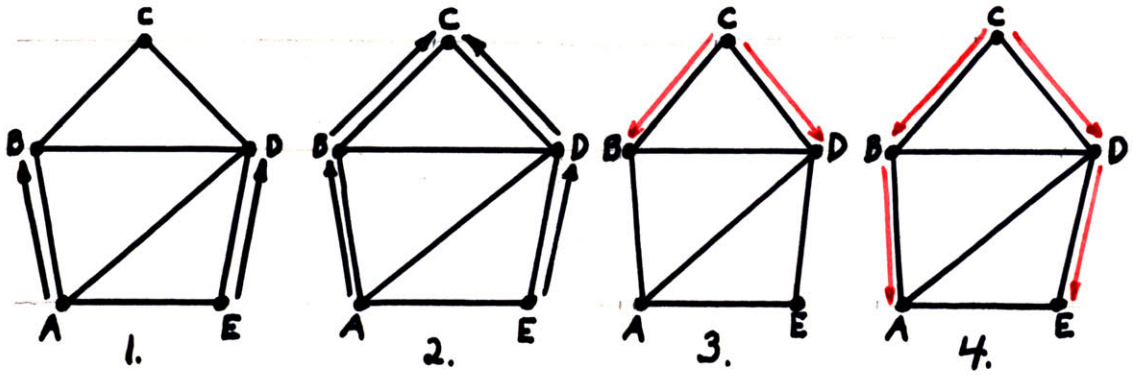
We have, then, among the structural characteristics of given patterns of communication, the concepts described by Bavelas(1) plus two dimensional "pictures" of the patterns. It is one of the purposes of this paper to determine experimentally how certain of these structural characteristics are related to the manner in which a particular problem is worked out in a particular pattern, and to other aspects of the behavior of the group members.

III. Some Operational Characteristics of Communication Structures

In the preceding section, we concerned ourselves briefly with structural characteristics of communication patterns. As we approach the problem of trying to predict and measure the behavior of a group operating in any pattern, another set of problems arises. Consider, for example, the pattern (A)  . If (1) at each cell we place a person; if (2) each link represents a two-way channel for written communications;

and if (3) we assign to the five participants a task of the kind mentioned earlier, (a task requiring that <u>every</u> member get an answer to a problem which can be solved if one or more members collate the segments of information originally held by each member) then we are faced with the task of determining what <u>possible</u> methods of solution exist.

1. <u>Pattern Flexibility</u>: We note first that the subjects need not always use all the channels available to them in order to reach an adequate solution. They could, for instance, decide to solve the problem in the pattern (A) structure this way:



Step 1: A and E send their information to B and D.

Step 2: B and D send their own plus A's and E's information to C.

Step 3: C collates all the information, arrives at an answer, and sends the answer to B and then to D.

Step 4: B and D send the answer to A and E respectively.

If the problem is solved this way, three of the seven open communication channels are ignored, and the minimum number, four, is used. The problem could also be solved using five, six, or seven channels.

Moreover, our original seven link pattern can be used as a four link pattern in different ways. That is, included in (A)  , in addition to the four link pattern  , is the four link pattern  , and the four link pattern  , all of which are adequate for the solution of the problem.

2. Operational Flexibility: Not only can structures with more than minimum linkage be converted into patterns with fewer links, but with the specification that X links must be used, any pattern can be operated in a variety of ways. Thus the pattern  (which has no pattern flexibility) can be used as described above (1)  (information funnelled in to C, and the answer sent out from C). It is also possible to use it this way: (2)  (E is the key), or this way: (3)  (D is the key). These are operational differences that apparently can be best characterized in terms of the roles taken by the various members. Thus in (1), C is the decision making member. In (2), it is E (or A, depending on which way communication starts), and in (3), D is the key man. (A mirror image of (3) with B as the key man is, of course, also possible.)

Unfortunately, the use of the term "key" man is often not very helpful, since some patterns may be so operated

that more than one, or even all members, independently make the decision about the right answer.

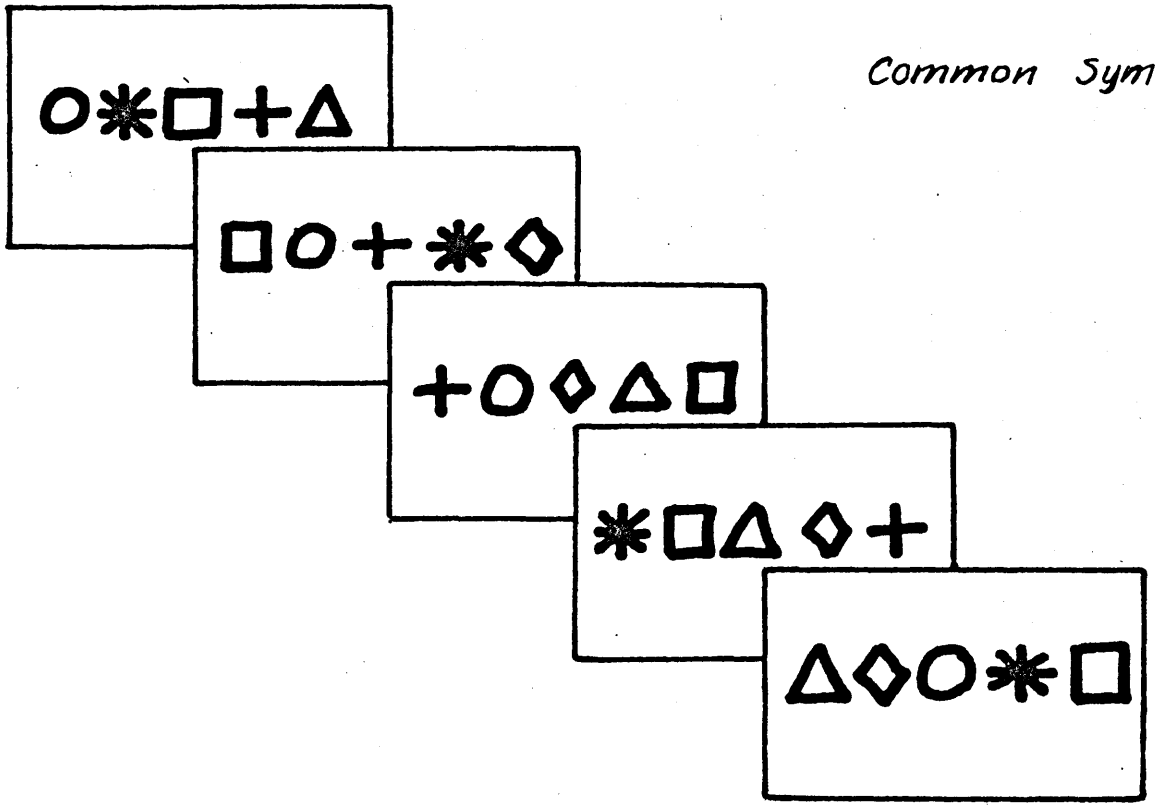
IV. The Definition of Maximum Theoretical Efficiency

Before going further it seems wise to state specifically the problem which we gave to our subjects. To each subject was given a card on which there appears a set of five symbols selected from six arbitrarily adopted ones (see Figure 1). Each subject's card was different from all the others in that the symbol lacking (the "sixth" one) was a different one in each case. In any set of five cards there was one and only one symbol in common. The problem was to find the common symbol. To accomplish this each member was allowed to communicate, by means of written messages, with those other members of the group to whom he had an open channel (a link in our diagrams). The problem was not solved until every subject knew the common symbol. Every separate written communication from one subject (A) to another (B) was considered one message, whether it was a transmission of the answer, of A's symbols, of A's plus C's symbols, or anything else. A subject who had deduced the answer was allowed to pass the answer along.

With an awareness of some of the characteristics of these simple communicational patterns, it is possible to begin to concern ourselves with the question: how can the methods by

A Sample Set of Symbol Cards

Figure 1.



which any pattern can be operated be characterized? We established six major criteria: (1) speed of solution, (2) number of communications used for solution, (3) frequency of wrong solutions, (4) kind of organization, (5) emergence of a leader, and (6) satisfaction of members with their jobs.

In considering these criteria, it became clear that pre-experimentally it would be possible to deduce something about the limits which the communication pattern must set on any group. Though this could not be done with all the criteria, it was certainly possible to determine the minimum number of communications necessary for solving the problem. And the same seemed possible for speed, if we adopted an arbitrary time unit. We therefore set about to determine the theoretically minimum number of messages, and the theoretically minimum time necessary to solve our problem in any communicational pattern.

1. Minimum Number of Communications: For any pattern of n members, the minimum number of communications, E, is given by $E = 2(n-1)$.

Thus, no matter what the pattern, a five-man group cannot solve the problem in less than eight communications; no six-man pattern in less than ten.

The logic for this statement lies in the fact that it requires at least n-1 messages to accumulate the necessary information at one point. Moreover, it is not possible to

accumulate all necessary information at more than one point in n-1 messages. It also requires n-1 messages to distribute the answer from one point. Hence, 2(n-1) gives total minimum messages. Therefore, in any pattern of n subjects, the experimental problem can be solved in 2(n-1) messages, and cannot be solved in fewer messages.

Theoretically, then, with number of messages as the sole criterion, any pattern of n subjects is as efficient as any other n-sized pattern, no matter what its number of links, and no matter how the links are distributed.*

2. The Time Criterion: If we assume "standard" subjects, all of whom work, think, and write at the same speed, it is possible to calculate the limit set by the communication pattern on the speed with which the problem can be solved. Toward this end, we arbitrarily defined a time unit t as the time required to complete any message, from its inception by any subject to its reception by any other. We were aware of the fact that different kinds of messages required different clock times for transmission, and, hence, that our t units were not "really" equal to one another.

We then set about calculating the time units necessary to solve our problem for any pattern. To the extent that we succeeded in generalizing our findings, we noted the following:

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*It is interesting to note here that with a message, rather than a time incentive, both the circle and chain patterns are solved in the fewest messages possible. The data on time versus message incentives may be found in a manuscript, yet unpublished, by Smith and Leavitt.

1. For any n, not a power of 2, with unrestricted linkage, when $2^x<n<2^{x+1}$, and x is a power of 2, x+1 equals the minimum possible time units for solution of the problem. Thus for a five-man group we have $2^x<5<2^{x+1}$ becoming $2^2<5<2^3$, and x+1=3 time units. No five-man pattern can be done in less than three time units, although several require more than three. When n is an even power of 2, the formula $2^x=n$ holds, and x=minimum t.*

To illustrate, two examples of the determination of minimum t are these:

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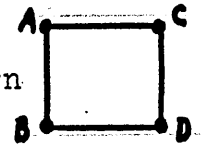
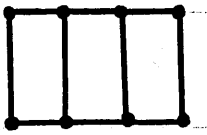
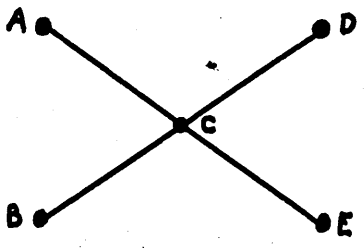
*This is an empirical generalization derived chiefly from an analysis of a four-man square pattern 

. In such a pattern, A and B, and C and D may swap information in t_1. Then A and C, and B and D may swap in t_2 to yield a complete solution. For an eight-man pattern  , the same simultaneous swapping process yields a minimum t. For the intervening n's, at least "part" of a t unit is required in addition to the minimum t for the four-man pattern. A detailed account of this analysis may be found in an as yet unpublished paper by J. P. Macy, Jr.

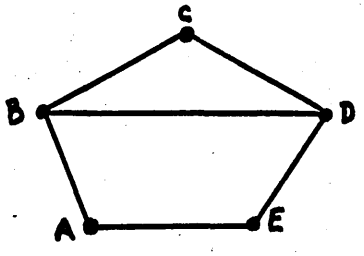
Example A



Method:	Time Units				
	t_1	t_2	t_3	t_4	t_5
A sends to	C				
B " "	C				
D " "	C				
E " "	C*				
C waits then sends to		A* then to B* then to D* then to E*			

* answer — total 5t; 8 messages

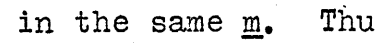
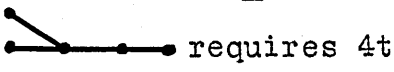
Example B



Method:	Time Units				
	t_1	t_2	t_3	t_4	t_5
A sends to	E	then to B			
B " "	D	waits, then to	C*		
C " "	D	then to B*			
D " "	B	" " E*			
E " "	A	" " D*	then to A*		

* answer — total 3t; 11 messages

2. It will be noted that although example B above requires fewer t units than example A, it requires more message (m) units. A can be done in 5t and 8m. B can be done in 3t but requires 11m. This phenomenon, effectively the generalization that it requires increased messages to save t units, holds

for all the patterns we have examined. It is, however, true that certain patterns requiring different t's can be solved in the same m. Thus  requires 5t for 8m, while  requires 4t for 8m.

With this information, plus a considerable amount of empirical exploration, we are in a position to determine for patterns of small n's, the minimum messages and minimum theoretical times required for solution. Since any pattern could be done in 2(n-1) messages, we decided to use t as an independent criterion of theoretical efficiency, and to call upon messages only when t units were equal.

V. Some Hypotheses About the Psychological Effects of Various Patterns on the Performance of Participants

Up to this point, we have concerned ourselves with the mechanical possibilities of patterns of communication. The subjects we have talked about have been idealized and standardized automatons, both rational and imperturbable. If we could locate such subjects, we should expect them immediately to achieve the theoretical minimum time in the minimum messages possible for that time. And we should expect errorless performance, without fatigue or complaint.

There are two general kinds of reasons which dictate against perfect performance from real people. The first of these is the obvious one, that people are not standardized, that individual differences exist in intelligence, reaction

time, and frustration tolerance. These, however, are the differences commonly faced in psychological research, and commonly met by using large numbers of subjects and appropriate experimental designs.

There is, however, a second set of forces more or less peculiar to this situation, that may prevent subjects from working even at their individually maximum efficiencies. These are the forces set up by the patterns themselves. Consider, for example, the feelings of an individual in A's position in the pattern:

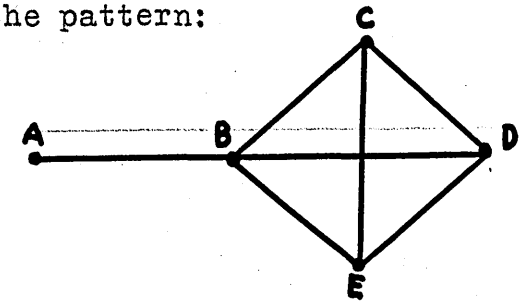


Figure 2

Trial after trial, A is likely immediately to send his information to B, and then wait for the great unknown to grind out an answer. All the important activity, all the decision making occurs away from him. His participation in the problem is minimal. His opportunities to satisfy his needs for recognition, cognizance, activity are extremely limited. For him, the situation is not likely to be a satisfying one.

In seeking, then, to predict behavioral differences among these patterns, particularly with respect to the psychological satisfaction they permit, we were forced into a

reconsideration of some basic views on human behavior. In what way should we expect members of different pattern groups to behave? We turned chiefly to the point of view expressed by McGregor(4), who, in turn, derived it from a variety of sources(3,5).

The most relevant considerations about human behavior and our derivations from them are these:

1. Behavior is directed, not random, and it is directed toward the satisfaction of needs.

2. Frustration of goal directed behavior leads to "negative" behavior.

3. In the experimental situation to which our subjects will be exposed, opportunities for need satisfaction will vary (as between A and B in Figure 2). Some positions in some patterns will limit independent opportunities to satisfy needs for activity, cognizance, dominance. Others allow for considerable independence.

"Independence" here refers to the extent of the subject's range of activity and the extent of his control over the ranges of activity of the rest of the group.

4. In general, the <u>differences</u> between patterns in total opportunities for need satisfaction can be held to derive from differences between positions within patterns. These differences between positions are differences in the extent to which position limits independence. Position limits, for any subject, the extent to which the experimental situation can

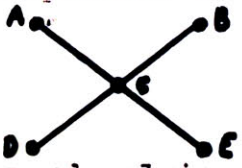
be a means to satisfactions over and above the satisfactions that might derive from pleasing the experimenter or from the experiment's "educational" value.

5. Though opportunities for need satisfaction may exist, individuals may not be able adequately to utilize them. They may fail in our test situation because of limitations in their own individual capacities, or because the rest of the group, on whom every individual is dependent, may fail to behave in a way which permits the utilization of available means to need satisfaction. They may fail to achieve certain satisfactions, in other words, because of the way they do or do not organize.

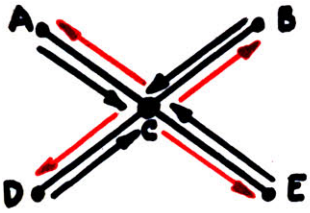
6. Differences in independence are probably determined, we suggest, by positional differences. Which characteristic of particular positions is most involved in limiting independence, we cannot with certainty say. It may be centrality; it may be number of neighbors.

Out of these considerations, there emerged some general hypotheses, from which specific predictions might be derived.

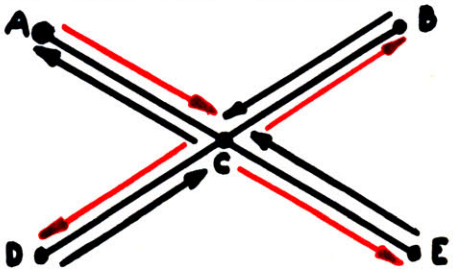
Hypothesis 1: The enjoyment of any subject of his position in a pattern will depend, first, on the opportunities for satisfaction that position offers. (a) Where the opportunities are least, the possibilities of enjoyment will be least. (b) Where opportunities are most, satisfaction will vary to the extent that the individual can organize himself and the group to use those opportunities effectively.

To some degree, opportunities for participation are determined by the static pattern independent of how that pattern is operationally used. Thus, in 

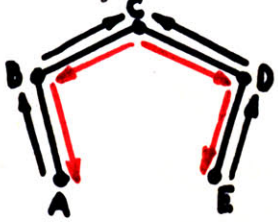
it is almost impossible for C to do as little toward solving the problem as at least three other subjects. If the pattern is used,



C is the key, and C clearly sends, receives, and decides more than any of the others. If the pattern is used thus, so that all information is funnelled to A,



then A is the decision-making member. Nevertheless, C still participates more than B, D, and E, and, depending on our weighting of sending, receiving and deciding acts, probably still more than A.

Although positions in a pattern do, in a sense, set a maximum limit on opportunities for participation, the opportunities are chiefly a function of how the pattern is used. Thus the pattern  appears to give each person equal opportunity. But if that pattern evolves operationally into 

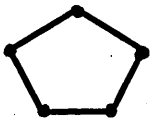
so that information is funnelled into

C and out again, then clearly opportunities differ. Any predictions we may make about individual satisfaction, therefore, must be predicated on a particular operational method, rather than on the pattern itself. The operational methods available are limited at the upper end by the pattern itself and at the lower end by minimum possible linkage (n-1).

Even, however, if the circular pattern is used in a way which permits effective equality of opportunity to all participants, and even if the opportunities are equal relative to total time required for solution, subjects may still feel dissatisfied. The opportunities may not be used fully, and the subjects may know (or feel) that those opportunities are not being used fully. If the subjects cannot "organize" and systematize their procedure; if the answer comes, they know not how and from whom, a residue of unresolved tensions may remain. And in a circular pattern particularly, where no "key" position exists to serve as a nucleus for organization, organization and hence satisfaction may be hard to come by.

Hypothesis 2: Those methods of operation for any pattern which least evenly distribute opportunities for participation among the members, will be least generally satisfactory and least durable. Those methods with most even distribution may be either satisfactory or unsatisfactory depending on whether or not an organization emerges.

The bases for this extension of the first hypothesis are two: first, any subject's level of aspiration will primarily be set relative to the other members of the group; and second, the belief that even if one of the members of a pattern becomes much more dissatisfied than the rest, that pattern cannot long be operated (i.e., there will be a tendency for modification of the pattern).

Again, an estimate of the distribution of opportunities for participation can only be partially made from a consideration of the pattern per se. Most of the answer lies in the operational method used. Thus, the pattern  permits fairly equal distribution of opportunities, but it may be used in a way which puts the burden of sending, receiving, and deciding on one or two individuals.

Hypothesis 3: The operational organization most likely to emerge from the range of possible systems will be one in which the most central individuals occupy "key" positions, i.e., act as points for the accumulation of all information, and make decisions about the answer. In effect, we are suggesting that where personality factors are constant, "leadership" is determined by advantageous position in the pattern. In this case at least, we feel centrality is the characteristic of position that is most relevant in determining behavior. Where no individual is more central than any other, a clear organization should not readily emerge.

The phrase "not readily" in the sentence above is used because personality differences may well, in the long run, result in the creation of a leader where positional differences do not. With standardized subjects, however, we should not expect a permanent "key" man where no differences in centrality exist.

Hypothesis 4: Speed of operation of any pattern will be limited by the structure of that pattern.

With subjects of equal skill, intelligence, writing speed, etc., a pattern with a theoretical minimum t of 3 should be operated more rapidly than a pattern with a theoretical minimum t of 5.

This hypothesis has been implicit in our discussion to date. It requires some qualification, however. First, we shall not seek directly to correlate t with clock time. Were it not for two problems we might attempt to predict a rank order of operational clock speeds to match our rank order of theoretical t. The first problem is that although the structural pattern sets a limit on theoretical t, the psychological forces at play during the operation of any pattern may be such as either to enhance or inhibit the attainment of that theoretical limit. The second danger lies in the t unit itself and its reflection of reality (i.e., clock time). Clearly, the time required to collate four pieces of information, decide on an answer, and send the answer out is different from the time required to write down one's own information and pass

it along. Moreover, if an individual is in a position to send out the answer to more than one other person, the time required to send the answer to person one may be much different from that required to send the answer to person two. The two may, in fact, be done effectively simultaneously by writing two messages and sending with two hands. Despite these weaknesses, we feel that some degree of relationship may exist between theoretical time, even as poorly defined as it is, and clock time taken as a mean for several groups. Particularly, we should expect a relationship between t units required for one man to get an answer and clock time. We expect this because the great differences in time measured in seconds seem to be between information messages and answer messages. The former can be expected to be fairly constant, while the time required to send answers will vary greatly with number of channels open to the individual disbursing the answer.

A simultaneous consideration of these hypotheses leads to a sort of multivariate theory of the behavior that will be elicited by various patterns. On the one hand, we have our theoretical t for any operational pattern on the basis of which very roughly to predict operational speed. But our prediction of speed must be qualified to take into account our hypotheses about the psychological effectiveness of that particular pattern. It is possible that the psychological weaknesses of a

pattern may adversely effect its operational speed. On the other hand, the fact that a particular pattern can be operated rapidly may partially compensate for the dissatisfaction resultant from its structure.

With these general considerations in mind, we may turn to the specific conditions of our experiments.

VI. Method

1. The problems to be solved: By using six symbols, □○△◊+✳, it is possible to make up five cards, each having five symbols, all of which have only one symbol in common. The square, for example, may be the symbol to appear on all five cards, while each of the other five symbols appears on only four cards. (See Figure 1)

To each member of a five-man group one of these cards was presented. Each member's card contained just one symbol that also appeared on all the other four cards. Subjects were asked to find the common symbol by communicating with one another under the conditions described below. When all five men indicated that they knew the common symbol, the trial was ended. Another set of cards, with another common symbol was then given to the subjects, and another trial was begun.

Each group of subjects was given fifteen consecutive trials. The composition of the standard sets of cards, used

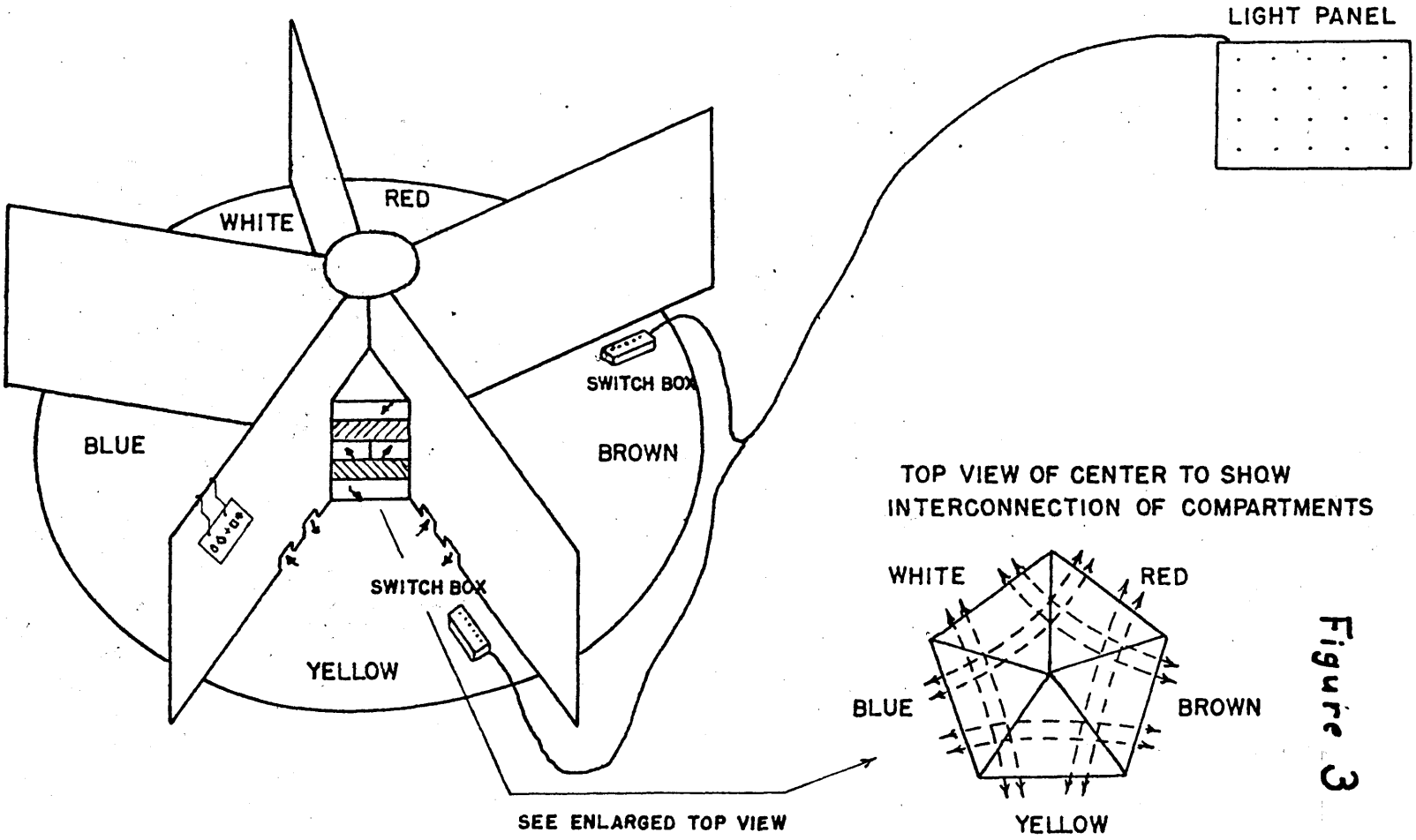

LIGHT PANEL
WHITE
RED
BLUE
BROWN
YELLOW
SWITCH BOX
SWITCH BOX
SEE ENLARGED TOP VIEW
TOP VIEW OF CENTER TO SHOW
INTERCONNECTION OF COMPARTMENTS
WHITE
RED
BLUE
BROWN
YELLOW

Figure 3

Symbol Distribution per Trial

Six Symbols Used: ○ △ ◇ □ + ✱

Table 1.

Trial No.	Symbol Missing From: White	Red	Brown	Yellow	Blue	Common Symbol
1	△	◇	✱	○	□	+
2	◇	○	□	△	+	✱
3	+	✱	□	△	◇	○
4	□	◇	△	✱	+	○
5	○	✱	+	△	□	◇
6	△	○	□	✱	◇	+
7	□	+	○	◇	△	✱
8	◇	✱	□	+	○	△
9	✱	◇	□	△	○	+
10	+	○	□	✱	◇	△
11	○	+	△	◇	✱	□
12	✱	○	□	△	+	◇
13	△	○	◇	□	+	✱
14	□	◇	+	✱	△	○
15	+	○	□	◇	✱	△

for all groups, is indicated in Table 1. The table indicates the symbol not on each person's card for each trial. By referring this missing symbol to the set of six symbols at the top, the reader may reconstruct the symbols actually on each man's card. The common symbol (the right answer) is also shown in Table 1.

2. The Apparatus: The subjects were seated around a circular table (Figure 3) so that each was separated from the next by a vertical partition from the center to six inches beyond the table's edge. The partitions had slots permitting subjects to push written message cards to the men on either side of them.

To allow for communication to the other men in the group, a five-layered pentagonal box was built and placed at the center of the table. The box was placed so that the partitions just touched each of the five points of the pentagon. Thus, each subject was left to work in a wedge-shaped enclosure.

Each of the wedge-shaped work spaces was then painted a different color. Subjects were supplied with blank message cards that matched the colors of their work spaces, thus permitting ready identification of the source of any message. On the left wall of each partition, sixteen large symbol cards, representing sixteen trials, were hung, in loose-leaf fashion. The cards were placed with blank backs to the subject, and were arranged in the proper order for every subject. At the starting signal, the subject could pull down the first card and go to work.

In addition, each work space was provided with a board on which were mounted six switches, above each of which appeared one of the six symbols. When the subject got an answer to the problem, he was to throw the proper switch, which would turn on an appropriate light on a master board of thirty lights in the observer's room. When five lights (whether or not they were under the correct symbol), representing five different subjects, were lit, the observer called a halt to the trial. The board was arranged in rows and columns, the rows representing symbols, the columns subjects. The observer could, therefore, tell at a glance whether (1) five different subjects had thrown their switches, (2) whether all five had decided on the same answer, and (3) with the aid of a key, whether the answer decided on was right or wrong. The detailed instructions given to all subjects may be found in Appendix 1.

It will be noted that a preliminary series of four problems, in which subjects were given all the information required for solution, were used. This was done to familiarize the subject with the tasks, and to note the extent of differences between subjects in solving such problems by themselves.

3. The Procedure: One hundred M.I.T. undergraduates, drawn from various classes at the Institute, served as subjects for these experiments. These one hundred were split up into twenty groups of five men each. These twenty groups were then further subdivided, so that five groups could be tested on each

of our four experimental communication patterns:

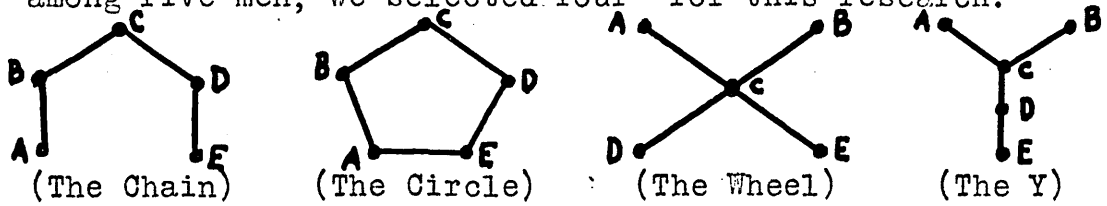
Patterns: 				Total
5 groups (25 people)	5 groups (25 people)	5 groups (25 people)	5 groups (25 people)	20 groups (100 people)

Each group was given fifteen consecutive trials on one pattern, a process which required one session of about fifty minutes. These subjects were not used again. We also randomized the order in which we used our patterns, so that if one group had been run on pattern B, the next was run on one of the other patterns. One additional precaution was taken. Just in case the color or geographical position of one's workspace might effect his behavior, we shifted positions for each group. For pattern A, for example, position C was the blue booth for one group, the red booth for the next, and so on.

After a group had completed its fifteen trials, and before they were permitted to talk with one another, each member was given a questionnaire (Appendix 2).

4. The Patterns Selected: As indicated earlier, we settled upon an n of five for our experimental groups. Patterns of five offer a wide variety of characteristics, and, at the same time, remain simple enough to be handled experimentally.

From the many different communication patterns possible among five men, we selected four* for this research:



*Research on other patterns was being carried out concurrently by other members of the staff.

Our selection of these four stemmed from a variety of considerations. They represented extremes in centrality (as in the circle vs. the wheel), as well as considerable differences in sum of neighbors and total distances. In theoretical t units they varied from 3 to 5. In minimum message units, they were, of course, the same, except that the circle required 14 m for 3 t. They could offer considerable differences in opportunities for participation, and possibilities for organization. And, in addition to all this, they looked, on an intuitive basis, as though they might yield behavioral differences.

On the accompanying table (Table 2), will be found some of the relevant characteristics of the four patterns.

Table 2

Pattern Characteristics

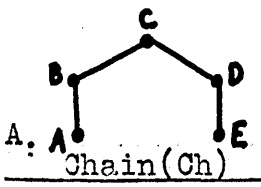
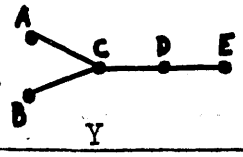
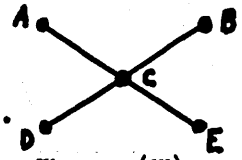
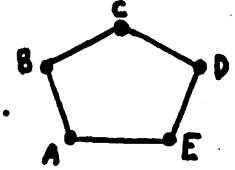
	Linkage	Most Central	Sum of Neighbors	Sum of Distances	Min. T.	Min. M.
A.  Chain(Ch)	4	C 6.7	8	40	5(8m)	8(5t)
B.  Y	4	C 7.2	8	36	4(8m)	8(4t)
C.  Wheel(W)	4	C 8.0	8	32	5(8m)	8(5t)
D.  Circle(O)	5	all 5.0	10	30	3(14m) 4(11m) 5(8m)	8(5t)

Table 2 (cont.)

Participation Pattern (for Min. t) (See Text)

	A	B	C	D	E	
	1	2	2	2	1	Send
Chain	1	2	2	2	1	Receive
			1			Decide

	A	B	C	D	E	
	1	2	3	1	1	Send
Y	1	2	3	1	1	Receive
		1	1			Decide

	A	B	C	D	E	
	1	1	4	1	1	Send
Wheel	1	1	4	1	1	Receive
			6			Decide

	A	B	C	D	E		
	3	3	2	3	3	Send	) Positions
Circle	3	3	2	3	3	Receive	) Interchange-
	1	1	1	1	1	Decide	) able

Linkage refers to the total number of connecting channels. By most central position in a pattern, is meant that position from which the total distance to all other positions is least (See Bavelas(1)). Sum of neighbors and of distances have also been defined by Bavelas. The parentheses after each minimum t figure show the minimum messages possible at that t, while the parentheses after minimum messages refer to the minimum t for that m.

The second section of the table shows "opportunities for participation" that would be available to persons operating from each position of each pattern if that pattern is operated so as to yield a minimum t. Thus in the Chain, operated 

, people in positions A and E get one chance to send a message, one chance to receive one, and

no chance to make a decision from accumulated information. In the case of the Circle, it is not necessary that any person should so behave. The O may be operated thus:

During t_1, E and D swap, B and C swap, A sends to E.

During t_2, D and C swap, A and B swap, E sends to A. At this point A has the answer.

During t_3, D and E swap, B and C swap, and everyone has the answer.

Presuming the use of "most efficient" methods, we have arbitrarily assigned equal weights to sending, receiving, and deciding operations.

VII. Results

The data which we have accumulated from running twenty-five groups of subjects are many and complicated. In seeking to make them as orderly and meaningful as possible, we decided to break them down into two large classes, (a) a total pattern analysis, and (b) a positional analysis. By total pattern analysis, we mean a breakdown of gross differences between total behavior in one pattern and total behavior in another. By positional analysis, we mean a breakdown of

differences between different positions within a single pattern (and to some extent a breakdown of differences between positions in different patterns). In effect, we are asking two different questions. First, does behavior in one pattern differ in general from behavior in another pattern? And second, does behavior of people in certain positions within a pattern characteristically differ from behavior in other positions of the same or other patterns?

A. Differences between Patterns:

Before going into our quantitative measures, it seems wise to mention some overall observations about how the patterns were actually operated by the subjects. This seems particularly important in the light of the emphasis we placed on operational method in developing our hypotheses.

Although our data do not permit precise, quantitative characterizations of the operational methods used, we did get a good picture of what actually happened from (1) direct observation, (2) post-experimental analysis of messages, and (3) post-experimental talks with subjects. These three sources pointed to the following characterizations of the operation of our four test patterns.

1. The Wheel operated as expected in all five cases. The peripheral men funnelled information to the center where an answer decision was made and the answer was sent out. This organization had usually evolved by the fourth or fifth trial and remained in use throughout the remaining trials.

2. The Y operated so as to give the most central position, (C), complete decision making authority. The next-most-central position, (D), served only as a transmitter of information and of answers to and from C. In at least one case, C transmitted answers first to A and B and only then to D. Y's organization evolved a little more slowly than the Wheel's, but, once achieved, it was just as stable.

3. The Chain, although used as expected for the most part, produced some unexpected results. Usually information was funnelled in from both ends to C, where the answer was worked out, and then sent out in both directions. There were several cases, however, even during the last few trials, when B or D reached an answer decision and passed it to C. The organization was slower in emerging than the Y's or the Wheel's, but consistent once reached.

4. The Circle showed no consistent operational organization. Most commonly, subjects reported that they just sent messages until they received or could work out an answer. In every case, all available links were used at sometime during the course of each trial.

More detailed information about operational patterns may be gleaned from the sections that follow. It is probably of some use, however, to keep in mind the discrepancies between the ideal operational organization, on the basis of which our

hypotheses were designed, and the organizations actually used by subjects in the test situation. Only the Wheel really behaved in the theoretically "ideal" way.

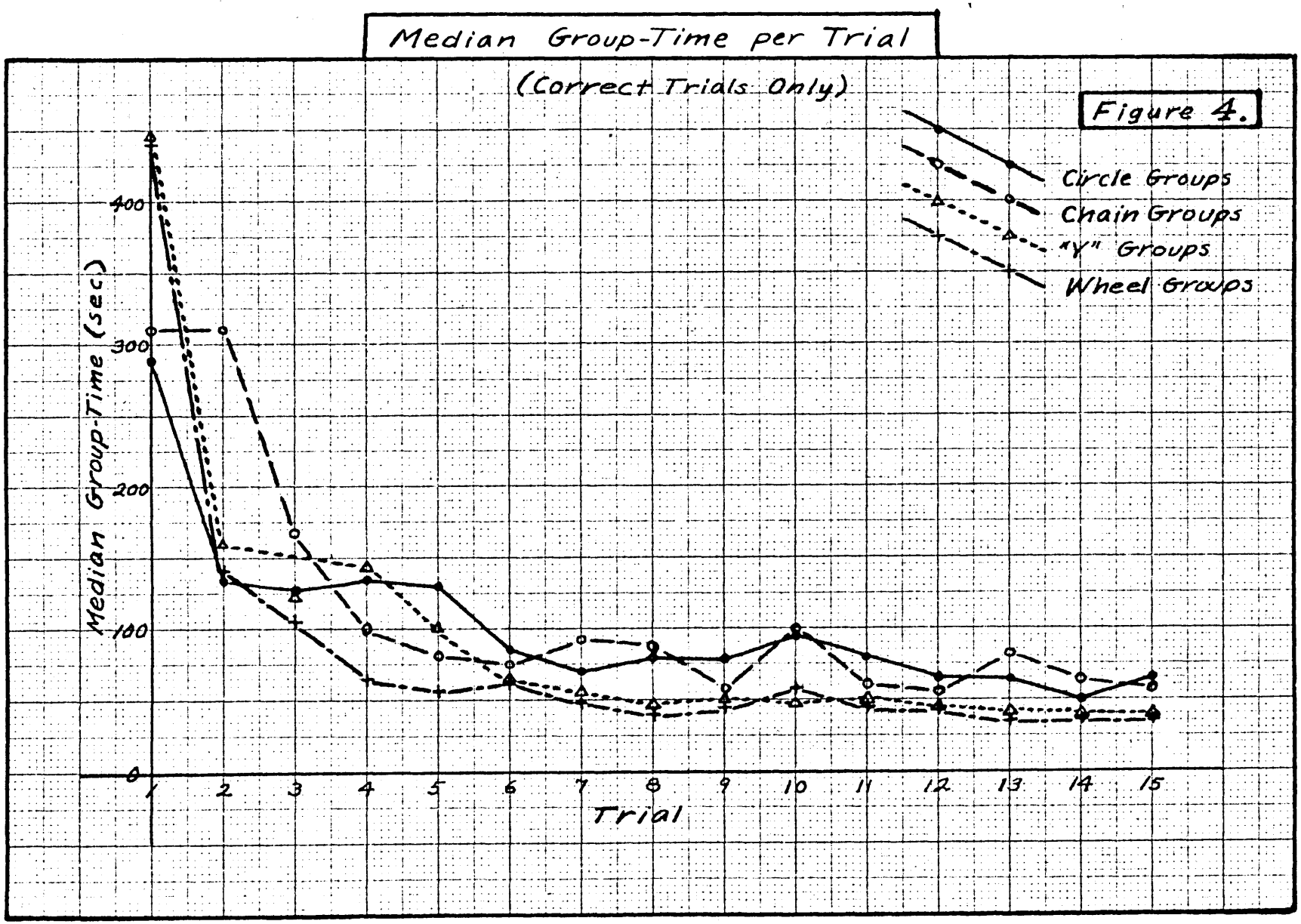
Direct Measures of Total Pattern Differences: Time, Messages, Errors.

Three things we sought to measure directly were time required for a solution to the problem, the number of messages used, and the number of errors made.

1. Time: One of the duties the experimenter assigned to himself was to clock the time required for each group to complete each trial. A trial was considered completed, it will be recalled, when each subject had thrown a switch to indicate that he believed he had a correct answer. Sometimes the five switches thrown were not in agreement, sometimes they were in agreement but all wrong.

The curves in Figure 4 are for correct trials only: that is, for trials in which all five switches represented the correct common symbols. Each point on each curve is the median time in seconds for that trial — taking only the time in seconds for the groups that correctly answered during that trial. In most cases, the medians are for distributions of five groups, but in no case do they represent less than three groups.

The variability of the distributions, represented by these medians, is considerable. For example, in the fifteenth trial, the distribution for the O has a range of 50-96 seconds; for the Ch, 28-220 seconds; for the Y, 24-52 seconds; and for the W, 21-46 seconds.


Median Group-Time per Trial
(Correct Trials Only)
Figure 4.
Circle Groups
Chain Groups
"Y" Groups
Wheel Groups
Median Group-Time (sec)
400
300
200
100
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Trial

With these very variable results, we can only feel that we have not really tested patterns for differences in speed, particularly since so much of the time that went to make up each trial was a constant consisting of writing and passing time. Any differences attributable to pattern would be a small fraction of this large constant, and would be easily obscured by accidents of misplacing or dropping of messages.

Despite all these factors, one measure of speed did give statistically significant differences. That measure was of fastest single trial of any group.

If we take the mean of the fastest trials (again only correct trials) for each group in each pattern, and compare the means of all four patterns, we find that the Wheel was considerably faster (at its fastest) than the Circle (at its fastest). The difference between these two patterns is significant at the 1% level.

Table 3

Fastest Single Correct Trial

	Circle	Chain	Y	Wheel	P. Values*	
Mean	50.4	53.2	35.4	32.0	O-W	$p < .01$
Median	55.0	57.0	32.0	36.0	Ch-W	$p < .10$
Range	44-59	19-87	22-53	20-41	O-Y	$p < .05$
					Ch-Y	$p < .20$

*Significance of differences between means were measured throughout by t tests. The P. values are based on distributions of t which include both tails of the distribution (see Freeman(2)). Where differences are between proportions, p. is derived from the usual measure of significance of differences between proportions.

2. Messages: All the messages, that each subject received during one trial, were collected and labelled. From a tally of these messages, Figure 5 was constructed. The medians, here again, are for the most part medians of a five-group distribution. We simply counted the number of messages sent by each group during a given trial and plotted the median number for the five groups working under each pattern. Again, we ignored trials in which the answers were incorrect. It seems clear that the Circle pattern used more messages to solve the problem than the others.

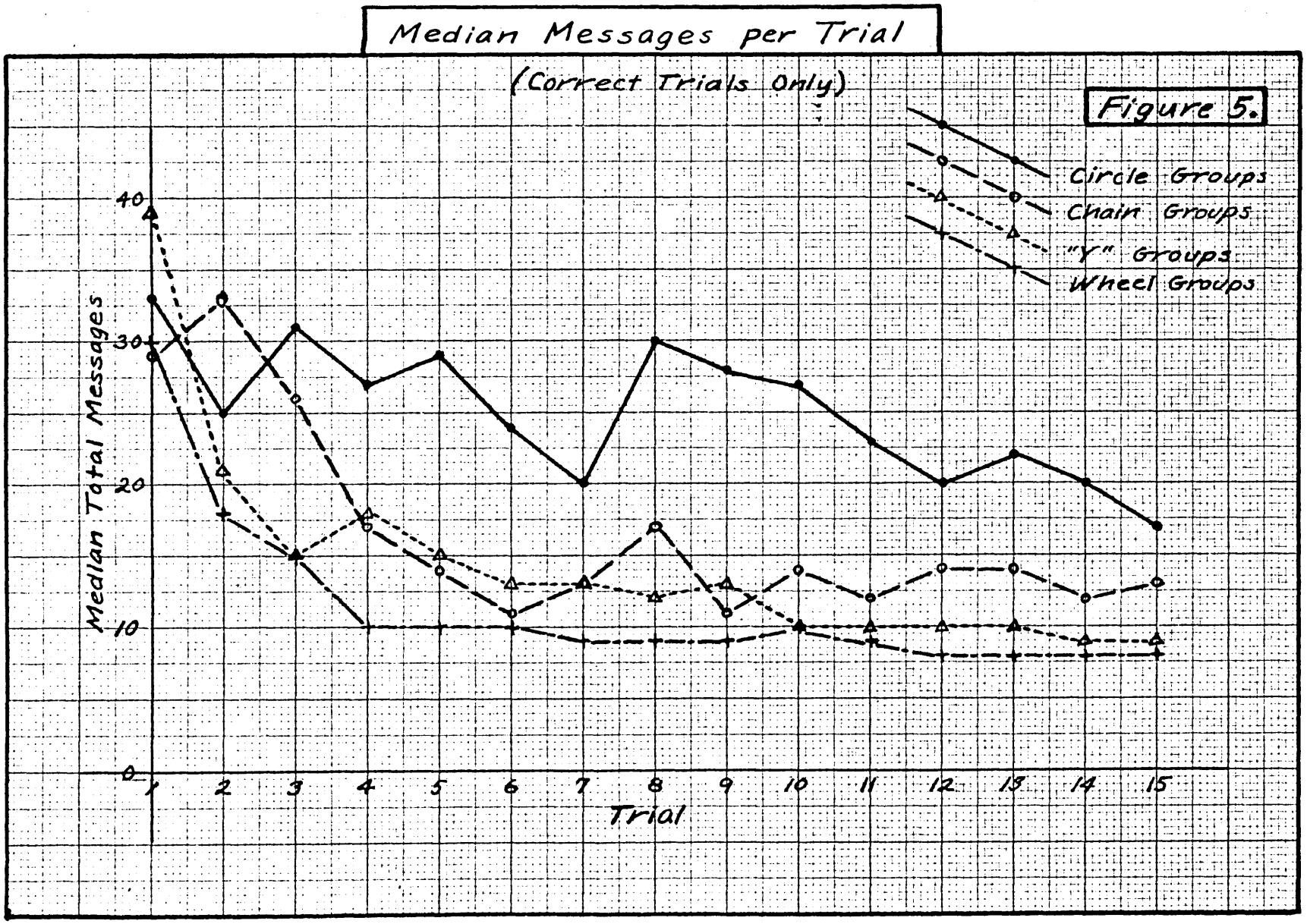
The difference is perhaps more striking if we consider (Table 4) only the "best" (fewest messages) trials for each group, and combine the "best" trials for all the groups in each pattern.

Table 4

Fewest Messages (correct trials only)

	Circle	Chain	Y	Wheel	P.	Values
Mean	19.6	11.2	9.8	8.0	O-W	$p < .01$
Median	18.0	11.0	9.0	8.0	O-Y	$p < .01$
Range	16-27	8-16	8-13	8-8	Ch-W	$p < .05$
					Ch-O	$p < .02$

3. Errors: A third measure we were able to make directly was of "errors." An error was defined as any turning on of a wrong switch by a subject during a trial. From his view of the master board of lights, the experimenter could tabulate the number of times each subject threw a switch that did not represent the correct common symbol. These errors were tabulated whether or not they were subsequently corrected during the trial. Errors that were not


Median Messages per Trial
(Correct Trials Only)
Figure 5.
Circle Groups
Chain Groups
"Y" Groups
Wheel Groups
Median Total Messages
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Trial

corrected are labelled "final errors," the others are referred to as "corrected errors."

It can be seen from Table 5 that there are differences between patterns in the number of errors made. It should be pointed out, however, that the error figures for the Wheel are distorted by the peculiar behavior of one of the five Wheel groups. In contrast to the rest of the Wheel groups, this particular group got completely bogged down in the early trials. The source of the difficulty seemed to be the failure of the center man to catch on to the idea of sending the missing symbol rather than the five symbols on one's card, an idea which many subjects evolved early in the fifteen trials. As a consequence of this misinterpretation, the center man apparently took the messages which he received to be <u>answers</u> rather than simple information, and, in addition to throwing his own switch, passed the information on <u>as an answer</u>. This difficulty was cleared up after a few trials, and the figures for the last eight trials are probably more representative than the figures for the full fifteen trials.

As in the preceding tables, each figure in Table 5 represents the five groups which worked in each pattern.

Again, some of the differences seem to be real, and, again, the Circle stands at one extreme.

Another, it seems to us, significant factor in these error data, is the proportion of total errors that were

Table 5

Errors

Total Errors (15 trials)

	Circle	Chain	Y	Wheel	P. Values
Mean	16.6	9.8	2.6	9.8	O-Y $p < .02$
Median	14.0	5.0	1.0	4.0	
Range	9-33	3-19	1-8	0-34	

Total Errors (last 8 trials)

	Circle	Chain	Y	Wheel	P. Values
Mean	7.6	2.8	0	.6	
Median	4.0	1.0	0	0	---------
Range	1-18	0-11	0	0-2	

Final Errors

	Circle	Chain	Y	Wheel	P. Values
Mean	6.4	6.2	1.6	2.2	
Median	6.0	4.0	1.0	1.0	----------
Range	2-14	1-19	0-5	0-7	

Number of Trials with at Least 1 Final Error

	Circle	Chain	Y	Wheel	P. Values
Mean	3.4	1.8	.8	1.2	
Median	4.0	1.0	1.0	1.0	---------

Uniform Final Errors

Circle	Chain	Y	Wheel	P. Values
1	4	1	1	---------

corrected. Although more errors were made in the Circle pattern than any other, a greater proportion of them (61.4%) were corrected than in any other pattern. Too, the frequency of unanimous five man final errors is lower for the Circle pattern, both absolutely and percentage-wise, than for the Chain. Comparison with the other patterns is prohibited because of the small number of errors that occurred in the other patterns.

Questionnaire Results

The reader will recall that a questionnaire (Appendix 2) was given each subject immediately upon the completion of a group's fifteen trials. The questionnaire consisted of twelve questions. Some of the questions evoked significantly different answers from members of different pattern groups. Many more of the questions were not discriminating. Nevertheless, each of the questions is considered below.

Question 1: "How confident are you that your group got the answers right?"

In answer to this question, subjects were asked to draw a curve roughly representing their confidence during the progress of the fifteen trials.

No differences in the early trials were apparent. If we consider only the level of confidence at the fifteenth trial, we find that only members of the Circle pattern show

anything less than almost perfect confidence (a numerical value of 5 represents maximum confidence).

Table 6

Question #1: Confidence Level at 15th Trial

	Circle	Chain	Y	Wheel	P. Values
Mean	3.9	4.6	4.9	4.8	O-W $p < .20$
Median	4.0	5.0	5.0	5.0	

The only difference approaching significance in question 1 is the difference between the Circle and Wheel groups. Nevertheless, it is interesting to notice that high participation (as in the Circle) does not result in more confidence than low participation (as in the Wheel).

Question 2: "Describe briefly the organization of your group?"

It became clear, as we read through the answers to this question, that the word "organization" was ambiguous. Some of the subjects took the word to mean pattern of communication, while others equated "organization" with one's own duties, or with status differences. These differences in interpretation were not random, however. If we consider only answers in which organization is taken to mean communication pattern, we find almost no one in the Circle group completely reproducing the actual pattern, while sixteen of the twenty Wheel subjects describe the Wheel pattern accurately.

Table 7

Question #2: The Organization of the Group

(Complete Recognition of Pattern)

	Circle	Chain	Y	Wheel
Total	1	11	8	16

(Answers not Involving Pattern)

	Circle	Chain	Y	Wheel
Total	14	8	3	4

On the other hand, many more Circle members refer to other aspects of organization than pattern. Answers not involving pattern usually concerned leadership, value judgments, inadequacies of other people and so on.

Question 3: "Did your group have a leader? If so, who?"

The differences between patterns on this question were striking. Only thirteen of twenty people who worked in the Circle named a leader, and those named were scattered among all the positions in the Circle pattern. For all patterns, the total frequency of people named increased in the order Circle, Chain, Y, Wheel. Similarly, the unanimity of opinion increased in the same order, so that, for the Wheel pattern, all twenty-three members who recognized any leader agreed that position C was that leader.

Table 8

Question #3: Positions Recognized as Leader

	A	B	C	D	E	other	P.*	Values
Circle	2	6	1	2	3	12	O-Ch	$p < .05$
Chain	0	4	12	2	0	8	O-Y	$p < .01$
Y	1	1	17	1	0	5	O-W	$p < .01$
Wheel	0	0	23	0	0	2	Ch-W	$p < .01$

Question 4: "Was there anything, at any time, that kept your group from performing at its best? If so, what?"

We received a great variety of answers to this question. The answers were categorized as far as possible into the classes listed in Table 9.

Table 9

Question #4: What Held the Group Back

	Circle	Chain	Y	Wheel
Knowledge	1	5	6	8
Organization	4	1	2	5
Extra Messages	1	1	1	2
People	4	4	2	2
Nothing	0	3	3	4
Writing Clarity	0	1	1	2
Elimination	0	2	3	1
Miscellaneous	15	8	7	3

There appear to be no large differences between patterns. The fact that none of the Circle members feel that nothing can be done to improve their group is suggestive.

- -

*Determined from differences between proportions. Circle positions were averaged, and compared with the number of selections of the most frequently selected position in the other patterns.

So, too, is the finding that knowledge of the pattern does not appear as an obstacle to the Circle members.

Question 5: "Do you think your group could improve its efficiency? If so, how?"

This question elicited some interesting differences. While many of the subjects in all patterns felt some improvement was possible, practically all of the subjects in the Circle felt improvement was possible. Circle members place great emphasis on organizing their groups, on working out a "system." Members of the other patterns, if they feel that any improvement at all is possible, emphasize a variety of possibilities for improvement -- elimination of slow people, more legible writing of messages, more practice, etc.

Table 10

Question #5: How Could the Group Improve?

	Circle	Chain	Y	Wheel
Little or No	1	8	10	9
Plan-Organize	17	5	0	3
Particular People	0	4	2	2
Method	0	2	2	1
Practice	2	2	2	2
Elimination	1	2	3	3
Writing	1	0	2	2
Miscellaneous	3	2	4	3

Question 6: "How many more problems do you think it would take before you would get 'fed up'?"

Subjects were asked to answer this question by placing a checkmark along a scale from 0 to 100 or more. No differences are apparent in the answers to this question.

Table 11

Question #6: How Many More Trials?

	Circle	Chain	Y	Wheel
Mean	40.6	31.9	37.7	37.5
Median	25.0	25.0	25.0	25.0

Question 7: "Rate your group on the scale below."

The scale referred to in this question was a straight line with "poor" at one end and "excellent" at the other. For purposes of analysis, the ratings were transposed into numbers, 0 for poor to 100 for excellent.

Table 12

Question #7: Rating of the Group

(Poor=0, Medium=25, Average=50, Better than Average=75, Excellent=100)

	Circle	Chain	Y	Wheel	P. Values
Mean	56.2	60.3	70.5	71.0	O-W $p < .05$
Median	50.0	62.5	75.0	75.0	
Number of "Excellents"	0	1	2	5	

It will be seen that the same progression of differences, found in most of our other measures, holds for this question, the progression from Circle through Chain through Y through Wheel. It is interesting, also, that once again the high-participation Circle group thinks less well of itself than the lower participation patterns.

Question 8: "How did you like your job in the group?"

Again, in this question, subjects were asked to indicate their feelings by placing a check on a rating scale marked "disliked it" at one end and "liked it" at the other. For purposes of analysis, the scale was translated into numerical scores from 0 at the dislike end to 100 at the like end. Each rating was estimated only to the closest decile. The results are given in Table 13.

Table 13

Question #8: Enjoyment of the Job

	Circle	Chain	Y	Wheel	P. Values
Mean	65.6	62.3	58.4	46.7	O-W $p<.02$
Median	75.0	62.5	50.0	45.0	
Range	0-100	0-100	0-100	0-100	

Again, we find the order Circle, Chain, Y, Wheel, but, in contrast to question 7 in which Circle people thought least of their own groups, Circle people, in question 8, enjoy their own jobs most of all.

Question 9a: "Who had the best job?" and 9b: "Who had the worst job?"

This question turned out to be an ambiguous one. Although a great majority of subjects equated "best" with "most responsible," a minority expressly equated "best" with "least responsible" or "easiest." If we had taken the answers actually marked, we should have had a measure of attitudes toward hard and easy jobs, rather than a measure of recognition of differences in responsibility.

Since our interest was in the latter phenomenon, we translated the data in this way: We equated high responsibility with "best," and low responsibility with "worst." Thus our data tell us which positions were recognized most often as most responsible positions, and which were seen as least responsible.

Table 14

Question # 9a, and 9b: Best and Worst Jobs

(Letters are for positions most often recognized; figures in parentheses are proportion of people in that pattern recognizing that position.)

#9a. Best Job*

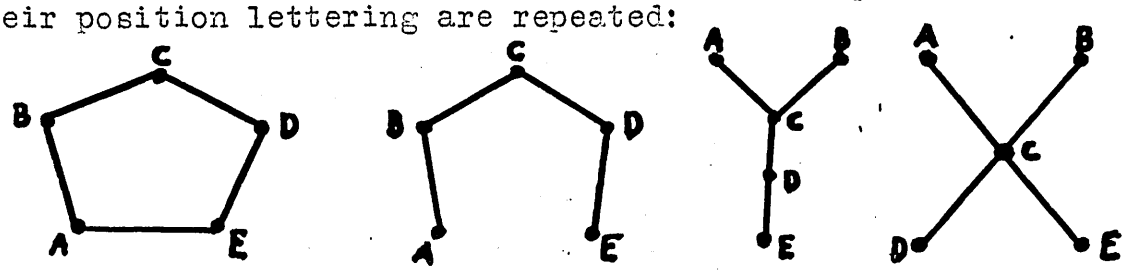
	Circle	Chain	Y	Wheel	P. Values
Mode	None(10/25)	C(14/25)	C(15/26)	C(21/25)	Ch-W $p < .05$

#9b. Worst Job*

	Circle	Chain	Y	Wheel
Mode	None(10/26)	A(12/34) E(14/34)	E(12/30) A(7/30) B(5/30)	E(5/25) B(3/25) D(3/25) A(2/25)

Again, we find the Circle, Chain, Y, Wheel progression, and again there are clear differences between most central and most peripheral positions. For example, in the Chain, C is the

*For the convenience of the reader the four patterns and their position lettering are repeated:



most central position and is seen by fourteen of twenty-five people as the most responsible position. A and E, the most peripheral positions, are named 12 and 14 times respectively out of 34, as least responsible positions.

Question 10a: "Check below the proportion of necessary messages you personally sent in the last five trials."

Question 10b: "Check below the proportion of necessary messages you personally received in the last five trials."

The data from these questions are presented in Table 15 below. The figures are percentages. Although the differences seem small, some are reliable enough to be significant.

Table 15

Question #10a and 10b: Necessary Messages in Last Five Trials

(Percentages)

#10a. Necessary Sent Messages

	Circle	Chain	Y	Wheel	P.	Values
Mean	81.8	86.7	86.0	99.1	O-W	$p < .01$
Median	82.5	90.0	100.0	100.0		

#10b. Necessary Received Messages

	Circle	Chain	Y	Wheel	P.	Values
Mean	80.5	77.9	78.4	94.5	O-W	$p < .05$
Median	90.0	87.5	97.5	100.0	Ch-W	$p < .10$

Our order of patterns is very slightly (and not significantly) changed this time. Nevertheless, the figures do corroborate our earlier findings of a generally confident (but unhappy?) Wheel group in contrast to a generally uncertain (but happy?) Circle group. It is interesting, too, that in all patterns subjects were more certain of the necessity of the messages they sent than of the necessity of those they received.

Question 11: "Do you think you solved the problem in the fewest messages possible?

In tabulating the data for this question, we counted the number of "no" answers.

Table 16

Question #11: Fewest Messages?

(Number of "No" answers)

Circle	Chain	Y	Wheel
23	11	7	6

The surprising thing about these results is the number of Chain people who felt they had solved the problem in the minimum messages when no Chain group had actually done so; and, in contrast, the number of Wheel people who felt they had not solved the problem in the minimum messages, when most of them had done so.

Note again the order Circle, Chain, Y, Wheel.

Question 12: "See if you can recall how you felt about the job as you went along. Draw the curve below."

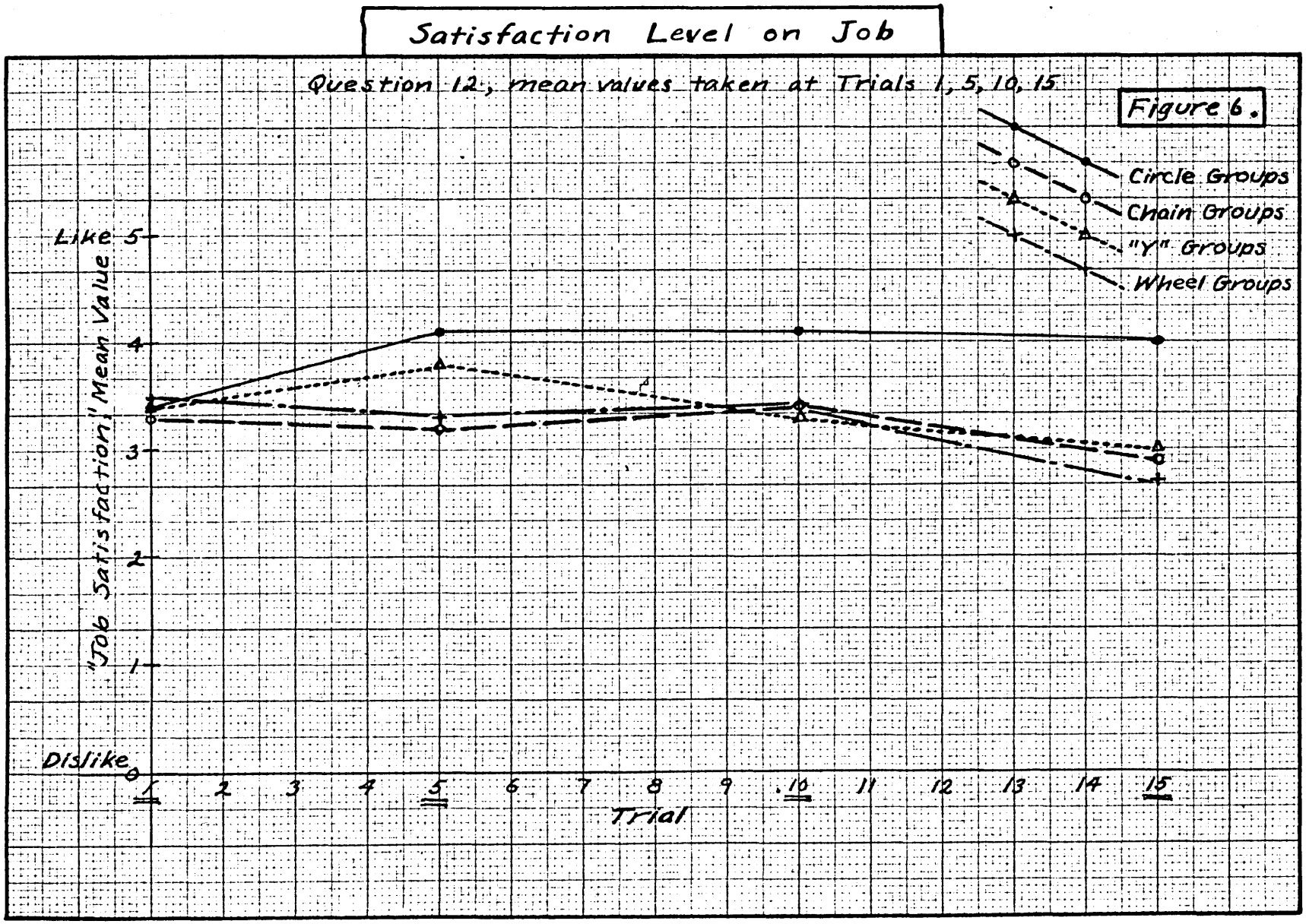
As in the first question, subjects were asked, in this one, to sketch a curve into a space provided for it. (See Appendix 2) We measured the height of these curves on a 6 point scale at trials 1, 5, 10, and 15. We averaged these heights for each group, and then plotted the average of the group averages for each pattern. The results are shown graphically in Figure 6, and tabularly in Table 17.

Table 17

Question #12: Progressive Feelings Curves

	Trial 1		Trial 5		Trial 10		Trial 15		P. Values
	M	Md	M	Md	M	Md	M	Md	
Circle	3.4	4	4.1	5	4.1	5	4.0	5	O-W $p < .20$
Chain	3.3	4	3.2	3	3.4	4	2.9	3.5	(15th trial)
Y	3.4	5	3.8	5	3.3	4	3.0	4	
Wheel	3.5	5	3.3	4.5	3.4	5	2.7	3	

Although the differences between groups are not statistically significant at any point, the trend of increasing satisfaction in the Circle and decreasing satisfaction in the Wheel seem to corroborate our findings in Question 8 (satisfaction with one's job). Except for a modest Y-Chain reversal, our order is, as usual, from Circle to Wheel.


Satisfaction Level on Job
Question 12, mean values taken at Trials 1, 5, 10, 15
Figure 6.
Circle Groups
Chain Groups
"Y" Groups
Wheel Groups
Like 5
4
3
2
1
Dislike 0
"Job Satisfaction" Mean Value
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Trial

Message Analysis Results for Total Patterns

Another source of information available to us, in addition to direct observations and questionnaires, was the messages themselves. These messages were collected at the end of each experimental run and coded for ready identification. The task of making sense out of several thousand little pieces of cardboard bearing such words and phrases as "Roger," "Red doesn't have △," "□ or +," was not an easy one. The cards were separated by trial, by group, and by pattern; the card's color served to identify the person who had sent it. Out of the analysis of all of these cards, there emerged a series of categories for classifying messages. Some of these categories probably overlap with others, and, hence, some messages were counted in more than one category.

These are the categories into which messages were placed:

a. Informational messages are messages bearing symbols (either one's own or someone else's) other than answer symbols.

b. The answer sent category covers this last group, really a special class of informational messages.

c. Organizational messages are those which seek to set some plan for behavior during future trials. Thus, for example, the message, "From now on send me all your information first," or, "Don't bother to send me anything but the answer, I'm dead end," are classified as organizational messages.

d. Methods messages are those involving future planning of methods of writing messages. Thus, "Send me all your symbols," "Send only the symbol you haven't got."

e. Fillers are corroborative messages. "O.K.," in reply to a request, "Will do," "Thank you," "I've done what you asked" are considered fillers.

f. Information requests are, as the name indicates, requests for information, but for symbol information only. "Send me your symbols," "What have you got," "What does blue have."

g. Orders are demands on others for immediate (this trial) action of any kind other than return of information. "Send Red these symbols," "Check your switches," "Write more clearly." Many of these border on information requests.

h. Out of field messages are those having nothing to do with the issue at hand. "Let's play tit-tat-toe," "Isn't it a pretty day," "What are you doing tonight" are examples.

i. Aggressive messages may be combined with orders, in which case they are coded in both categories. But if they are out of the field, they are coded only in the aggression category. Aggression is considered as a special case of out of field behavior. Examples are: "What the hell's the matter with White," "This group is no damn good," "Stick a pin in those guys, will you," "Blue is a dope."

j. Recognition of error messages are deduced rather than directly observed. That is, they are messages which, when seen in relation to preceding messages, indicate a discovery by the sender that an "answer" he has received is impossible. "It can't be because I don't have it."

k. The elimination category indicates the number of members in a group who used "the method of elimination," i.e., who sent the symbol they did not have, rather than the five symbols they did have. Elimination was a great timesaver but was not universally used. If it was clearly demonstrated that a given individual perceived and tried to use elimination, he was considered an elimination man. Complete elimination means that all members of a group used the elimination method; partial elimination means one to four members used that method; none means no members used it.

There is a considerable correlation among some of these categories. We have not sought to quantify the extent of the relationship between orders, fillers, and information requests, but it is clear that those groups, and even those individuals, high in one were usually high in the others.

A complete breakdown of these message data is presented in Table 18. In Table 18, p. values are shown for the larger differences between patterns. Many of the differences, it will be noted, could readily have occurred by chance, but some are quite significant.

Several things stand out from the analysis represented by Table 18. First, our now familiar progression, from Circle to Chain to Y to Wheel, continues into this area -- at least for those message categories which show up any significant differences between patterns.

More specifically, it can be seen that Circle members indulge in much more sending of informational messages than members of the other patterns. Circle members also send more answers to one another. But when it comes to message activity directed toward planning and organization, the Circle is the least active pattern.

The next area in which significant differences occur is in the recognition of error category. The Circle members recognize erroneous information from other Circle members more often than members of the other patterns. Of course, Circle members made more errors to begin with, hence had more opportunities to recognize them. Even so, proportionately, the Circle still recognizes more of its errors than the Chain does. (The Circle has a mean of 4.8 error messages for a mean of 16.6 errors; the Chain has a mean of 1 error message for a mean of 9.8 errors.)

There is yet another suggestive, though certainly not conclusive finding, that emerges from the message analysis. We were concerned, before beginning these experiments, lest

Table 18

Total Pattern

Message Analysis

Information Messages:

	Circle	Chain	Y	Wheel	P. Values
Mean	283.2	180.8	123.6	100.6	O-Ch $p < .01$
Median	273.0	177.0	132.0	100.0	Y-W $p < .20$
Range	242-354	111-272	79-156	80-137	

Answer Sent:

	Circle	Chain	Y	Wheel	P. Values
Mean	90.8	61.8	60.2	65.2	
Median	90.0	64.0	61.0	65.0	--------
Range	81-104	53-65	58-61	63-69	

Organization:

	Circle	Chain	Y	Wheel	P. Values
Total	15	42	42	45	O-Ch $p < .10$
Mean	3.0	8.4	8.4	9.0	O-W $p < .10$
Median	2.0	6.0	9.0	8.0	

Method:

	Circle	Chain	Y	Wheel	P. Values
Total	17	13	5	30	Y-W $p < .80$
Mean	3.4	2.6	1.0	6.0	
Median	1.0	0	1.0	1.0	

Fillers:

	Circle	Chain	Y	Wheel	P. Values
Total	33	32	27	47	O-W $p < .40$
Mean	6.6	6.4	5.4	10.8	
Median	5.0	5.0	7.0	8.0	

Table 18 (Cont.)

Information Requests:

	Circle	Chain	Y	Wheel	P. Values
Total	81	53	66	47	O-W $p<.40$
Mean	16.2	10.6	13.2	9.4	
Median	9.0	10.0	7.0	9.0	

Out of Field:

	Circle	Chain	Y	Wheel	P. Values
Total	7	9	11	4	
Mean	1.4	1.8	2.2	.8	--------
Median	1.0	1.0	1.0	0	

Aggression:

	Circle	Chain	Y	Wheel	P. Values
Total	12	5	3	10	
Mean	2.4	1.0	.6	2.0	--------
Median	0	0	0	0	

Orders:

	Circle	Chain	Y	Wheel	P. Values
Total	37	32	31	52	Y-W $p<.70$
Mean	7.4	6.4	6.2	10.4	
Median	4.0	4.0	5.0	5.0	

Recognition of Errors:

	Circle	Chain	Y	Wheel	P. Values
Total	24	5	2	5	O-W $p<.05$
Mean	4.8	1.0	.4	1.0	
Median	5.0	0	0	0	

Elimination

	Circle	Chain	Y	Wheel
Complete:	2	1	0	1
Partial:	0	4	3	3
None:	3	0	2	1

subjects find short cuts for solving the problem, thus making certain pattern comparisons difficult. Such short cuts were found very frequently in the form of what we have called "elimination."* Instead of taking time to write down their five symbols, many subjects, discovering that only six symbols existed in all, wrote just the missing symbol, thus saving considerable writing time. This method was used by at least one member in two of the Circle groups, in all the Chain groups, in three of the Y groups, and in four of the Wheel groups. In both the Circle cases, the method was used by all five members during final trials. In the Chain, though present in every group, elimination was used only once by all five members, twice by three members, and twice by just one member. In the Y, the method was adopted once by four members (the fifth man was not the center), and twice by two members. There was at least one case (in the Wheel) in which a member who suggested the use of elimination was ordered not to use it.

The questions raised here are two. Is the idea of elimination more likely to occur in some patterns than in others? It occurred in every Chain group, but in only two of the Circle groups. We suspect that the idea of elimination would occur

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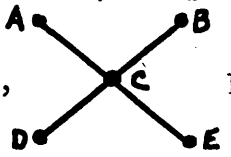
*This experimental finding has posed the question whether pattern as such affects the possibilities for insight in a problem solving group. Preliminary research using forms of detour problems indicate that patterns very probably have such an effect.

with equal frequency in all patterns, given an adequate sample. The second question is whether or not an innovation like elimination would be more readily accepted in some patterns than in others. All the Circle people accept elimination in both groups in which one member's insight makes it available. But though available in five groups, it is accepted universally by only one Chain group. Elimination is accepted by all members in only one of four Wheel groups, and in none of the three Y groups.

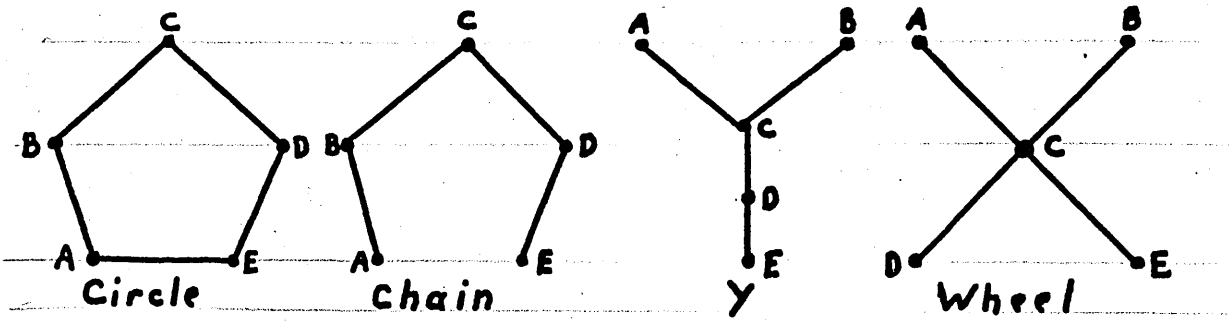
B. A Positional Analysis of the Data:

Until now, our concern has been with differences among communication patterns. We have compared the behavior of all subjects who worked in one pattern with the behavior of all subjects who worked in another.

There is, however, a second general way of approaching the data. Within patterns, there are different positions -- particular locations within a pattern that differ from other locations in centrality, in number of neighbors, in participation potential. In the Wheel, for example, 

position C differs radically from the other four positions. In the sections that follow, we present the data so that comparisons between positions within patterns can be made.

Here, again, are the four test patterns with positions labelled. These positional labels apply in all the tables that follow:



Observation of the patterns indicates that not every position within a pattern is necessarily different from every other one. Every position in the Circle is, in fact, like every other one. No one has more neighbors, is more central, or is closer to anyone than anyone else. In the Wheel, the four peripheral positions are alike, and so on. Despite our inability to differentiate these positions from one another, we have, for purposes of analysis, set up our data as if all positions in each pattern were actually different from one another. Thus, we offer in the tables that follow five different figures for the Circle. Each figure represents the five people, one in each group, who occupied that position. Actually, the five people in "position A" are a random group of five selected one from each Circle pattern. Any differences between Circle positions can, in a way, be considered as a measure of chance variability. If differences between Circle positions are as large as differences between "really" different positions (e.g., the center and ends of the Chain), we must be cautious about attributing any significance to the latter differences. Similarly, we should

expect, for significance, that the difference between the center and any peripheral position ("really" different positions) in the Wheel will be greater than the difference between any two not different peripheral positions in the same pattern.

Once again, we have subdivided our analysis into three sections: directly observed time, error, and message data; questionnaire results; and message analysis data.

1. Direct Observations

a. Time: Since the first man to get an answer is not necessarily the first to throw his switch, we cannot attach much significance to a count of the positions most frequently getting answers first. Nevertheless, the data for the last five trials are shown in Table 19.

Table 19

Position Getting Correct Answer First in Last 5 Trials

	A	B	C	D	E
Circle	8	5	1	5	4
Chain	1	3	14	3	2
Y	2	8	15	0	0
Wheel	7	1	10	3	4

b. Messages: In Table 20, is given the number of messages sent from each position during each of fifteen trials. The most central positions, it will be seen, indulge in the greatest message activity, the least central ones in the least activity. These data are plotted in Figure 7 .

Messages Sent by Position

(Data taken from message analysis)

Figure 7.

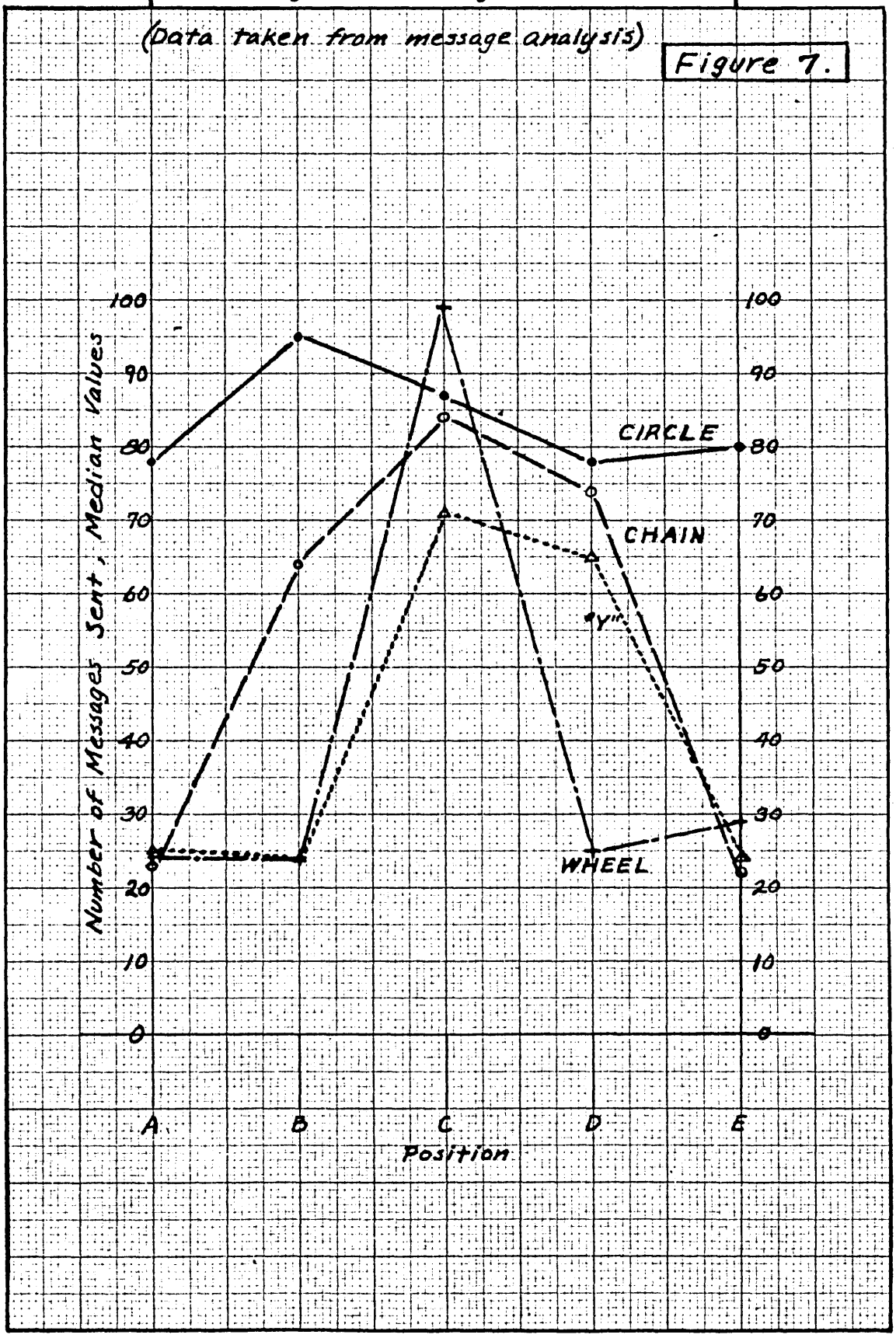


Table 20

Number of Messages Sent (by position)*

		A	B	C	D	E	P.	Values
Circle	M	78.4	90.0	83.6	86.2	81.0	A–B	p<.30
	Md	78.0	95.0	81.0	78.0	80.0		
	R	64–101	63–102	60–98	60–122	72–90		
Chain	M	24.8	70.8	82.4	71.8	27.6	C–E	p<.01
	Md	23.0	64.0	84.0	74.0	22.0		
	R	20–34	43–112	45–113	42–101	22–43		
Y	M	28.0	23.8	79.8	63.8	25.6	A–C	p<.01
	Md	25.0	24.0	71.0	65.0	24.0	D–E	p<.01
	R	20–44	21–28	65–104	43–78	21–37	D–C	p<.20
Wheel	M	29.4	26.2	102.8	26.6	30.2	C–E	p<.01
	Md	24.0	24.0	99.0	25.0	29.0		
	R	19–48	17–40	78–138	17–39	22–43		

c. Errors: The analysis of total errors made in each position showed nothing of significance. The data are shown in Table 21.

Table 21

Total Errors by Position

		A	B	C	D	E
Circle	M	2.4	2.6	3.2	3.4	5.4
	Md	1.0	2.0	3.0	4.0	3.0
Chain	M	2.6	2.4	2.0	1.2	1.4
	Md	1.0	2.0	1.0	1.0	1.0
Y	M	.8	.6	.4	.6	.4
	Md	1.0	0	0	0	0
Wheel	M	1.8	1.8	1.2	.8	3.2
	Md	1.0	2.0	0	1.0	1.0

*There is some inaccuracy in these figures because they were obtained from the message analysis rather than by direct count. Since for message analysis purposes a single message card may have been counted more than once, our totals are slightly larger than they would have been if taken from a direct count.

2. Questionnaire Results by Position

As in the analysis by total pattern, our questionnaire data are offered question by question in the following pages.

Question 1, Confidence Level and Question 2, Recognition of Organization show no significant differences among patterns.

Table 22

Question 1 - Confidence Level (final)

		A	B	C	D	E	P. Values
Circle	M	3.2	5.0	3.4	3.2	4.8	A-B $p<.10$
	Md	3.0	5.0	4.0	4.0	5.0	
Chain	M	5.0	4.0	4.6	4.6	4.7	
	Md	5.0	4.5	5.0	5.0	5.0	
Y	M	5.0	4.8	5.0	5.0	4.6	
	Md	5.0	5.0	5.0	5.0	5.0	
Wheel	M	5.0	5.0	5.0	4.6	4.4	
	Md	5.0	5.0	5.0	5.0	5.0	

Question 2 - Complete Recognition of Organization

	A	B	C	D	E	P. Values
Circle	0	0	1	0	0	
Chain	2	3	2	1	3	--------
Y	1	2	5	0	0	
Wheel	4	3	5	3	1	

Question 3, Recognition of a Leader: Our earlier analysis by total pattern showed clear cut recognition of the most central members of patterns as leaders. An analysis to determine whether or not particular positions tended to

recognize particular leaders offered nothing additional. The data showing which positions were recognized as leader are repeated for convenience.

Table 24

Question 3 - Recognition of a Leader (by Position) (Repeated)*

	A	B	C	D	E	Other	P. Values	
Circle	2	6	1	2	3	14	O-Ch	$p < .05$
Chain	0	4	12	2	0	8	O-Y	$p < .01$
Y	1	1	17	1	0	5	O-W	$p < .01$
Wheel	0	0	23	0	0	2	Ch-W	$p < .01$

Question 4, What Held the Group Back, and Question 5, How Could the Group Improve, showed no differences among positions.

Question 6, How Many More Trials: The findings here are suggestive but by no means conclusive. They are given in Table 25.

Table 25

Question 6 - How Many More Trials? (by Position)

		A	B	C	D	E	P. Values	
Circle	M	28.0	53.0	24.0	44.0	54.0	C-E	$p < .20$
	Md	25.0	50.0	25.0	25.0	50.0		
	R	15-50	5-100	10-50	20-100	0-100		
Chain	M	30.0	47.5	37.0	27.0	24.0	A-B	$p < .20$
	Md	20.0	40.0	25.0	25.0	22.0		
	R	0-100	10-100	25-60	10-50	0-50		
Y	M	33.4	38.0	33.4	48.0	36.0		
	Md	25.0	25.0	20.0	50.0	25.0	---------	
	R	5-100	20-100	10-100	10-100	15-100		
Wheel	M	8.8	52.4	48.0	35.0	40.0		
	Md	5.0	50.0	37.0	25.0	25.0	---------	
	R	0-25	0-100	15-100	0-100	0-100		

*Only in Y does any position recognize a leader different from others; position E in Y recognized A, B, C(twice) and D as leaders.

If there is any tendency, on the part of peripheral positions, toward unwillingness to go on working as long as central positions, the tendency is effectively obscured by the variability among equivalent positions.

Question 7, How Good Was Your Group: Once again the results are ambiguous. There are, however, considerably bigger differences between different than between not different positions. The most central Wheel position thinks least of the group. But the most central Y man thinks most of it. All of the differences could, quite probably, have occurred by chance, so that hypothesizing about these apparently paradoxical differences would not seem profitable.

Table 26

Question 7 - How Good Was Your Group? (by Position)

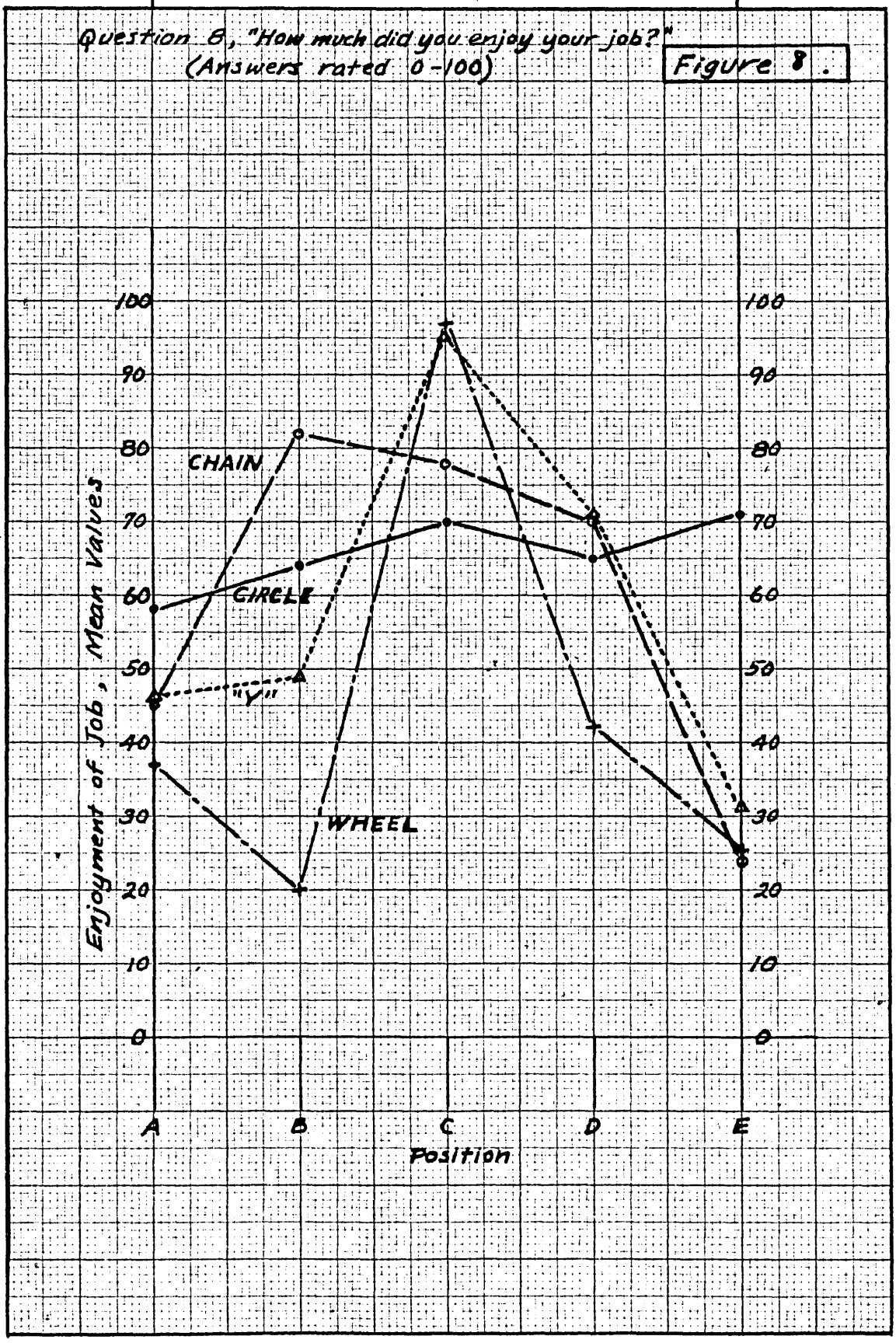
		A	B	C	D	E	P.Values
Circle	M	62.4	55.0	56.3	60.0	50.0	A-E $p<.20$
	Md	62.5	50.0	50.0	50.0	50.0	
	R	37.5-87.5	50-75	50-62.5	50-75	50-50	
Chain	M	65.0	50.0	65.0	57.4	50.0	
	Md	75.0	67.5	62.5	50.0	50.0	-------
	R	37.5-75	50-75	25-100	25-87.5	37.5-63	
Y	M	72.6	62.5	80.0	67.2	70.0	
	Md	75.0	62.5	87.5	75.0	75.0	-------
	R	62.5-75	50-75	50-100	50-87.5	50-87.5	
Wheel	M	70.0	75.0	62.4	77.4	70.0	D-C $p<.30$
	Md	75.0	75.0	50.0	75.0	75.0	
	R	25-100	50-100	50-87.5	50-100	25.100	

Question 8, How Did You Enjoy Your Job? (Figure 8): Here, positional differences become apparent. In addition to the fact

Enjoyment of Job, by Position

Question 6, "How much did you enjoy your job?"
(Answers rated 0-100)

Figure 8.



that the general level of satisfaction of the Circle pattern is higher than that of other patterns, we find that the most central positions, in other patterns, are more satisfied than any Circle position. Peripheral positions, on the other hand, are lower than any Circle position. We get here, too, a nice progression along an activity dimension. The greater the message activity (see data on messages by position), the greater the job satisfaction -- with one exception. Circle positions, where message activity is as high as anywhere else, do not show as high a level of satisfaction as the most central positions in other patterns. We do not, then, have a clean cut relationship between activity level and satisfaction, but rather a relationship between satisfaction and something else -- perhaps centrality.

Table 27

Question 8 - How Did You Enjoy Your Job? (by Position)

		A	B	C	D	E	P. Values	
Circle	M	58.0	64.0	70.0	65.0	71.0	A-E	$p<.70$
	Md	50.0	100.0	80.0	60.0	80.0		
	R	0-100	0-100	20-100	40-100	25-100		
Chain	M	45.0	82.5	78.0	70.0	24.0	C-E	$p<.02$
	Md	50.0	90.0	75.0	70.0	0	C-AE	$p<.01$
	R	25-55	50-100	50-100	40-100	0-70		
Y	M	46.0	49.0	95.0	71.0	31.0	C-A	$p<.02$
	Md	40.0	40.0	100.0	75.0	20.0	C-AB	$p<.01$
	R	0-100	25-100	75-100	30-100	0-75	D-E	$p<.10$
Wheel	M	37.5	20.0	97.0	25.0	42.5	C-E	$p<.02$
	Md	50.0	15.0	100.0	0	35.0	B-C	$p<.01$
	R	0-50	0-40	85-100	0-75	0-100	ABED-C	$p<.01$

Question 9a and 9b, Who Had the Best and Worst Jobs: It was indicated in the total pattern analysis earlier, that answers

to these questions showed recognition, by the subjects, of differences in "responsibility" among positions. As is indicated in Table 28, the central positions were most clearly recognized as most responsible, and recognition became more precise in the order Circle, Chain, Y, Wheel. The treatment of the data (reversal of certain best and worst judgments) described in the total pattern analysis is repeated in Table 28.

Table 28

(Figures represent number answering)

Question 9a - Best Job (with reversals)

	A	B	C	D	E	None	Other
Circle	2	3	0	1	1	10	8
Chain	0	2	14	0	0	1	9
Y	1	1	15	1	0	1	1
Wheel	0	0	21	0	0	0	4

Question 9b - Worst Job (with reversals)

	A	B	C	D	E	None	Other
Circle	0	3	0	1	2	10	10
Chain	12	0	0	1	14	1	6
Y	7	5	1	0	12	1	4
Wheel	2	3	0	3	5	1	11

Question 10a and 10b, Necessary Messages Sent and Received, and Question 11, Was the Problem Solved in the Fewest Messages, showed no positional differences.

Question 12, Progressive Level of Satisfaction: Using our means and medians at the 1st, 5th, 10th, and 15th trials, we again find a generally higher satisfaction level in the more central positions; a lower level in the more peripheral positions. Moreover, our progression shows increasing satisfaction for the central positions, decreasing satisfaction for the peripheral positions, and a more or less constant level for the Circle positions. It is interesting that the median of every position in the Circle reaches the highest satisfaction level by the 15th trial.

The data for this question are shown in Table 29. We have also plotted the data in Figure 9 after having combined equivalent (not different) positions. Equivalent positions were: all Circle positions, positions A and E, and positions D and B in the Chain; positions A and B in the Y; and positions A, B, D, and E in the Wheel. The data thus combined highlight the trend toward higher satisfaction with increasing centrality.

Table 29

Question 12 - Progressive Level of Satisfaction (by Position)

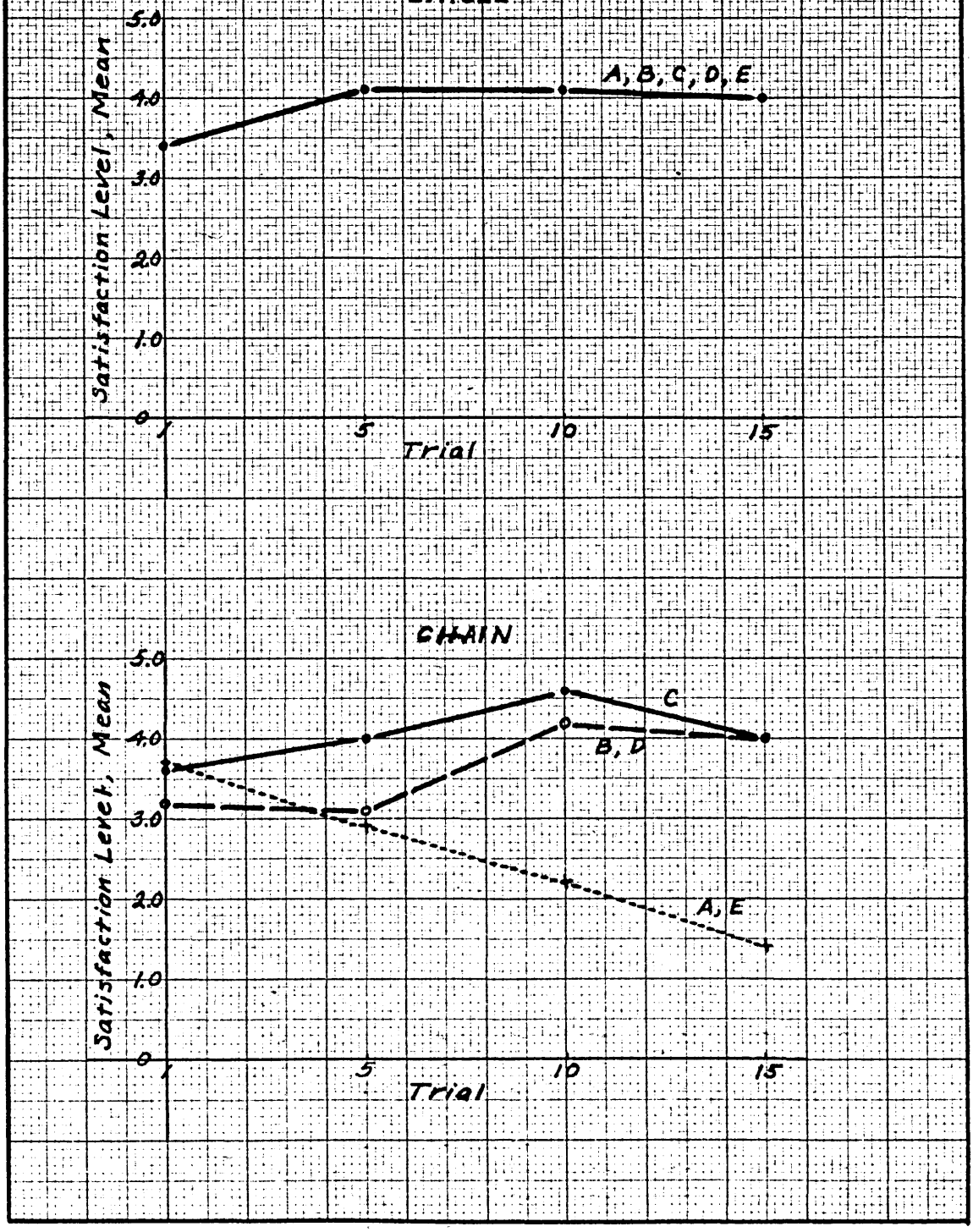
(These data are plotted in Figure 9)

Position	Trial	Circle		Chain		Y		Wheel		P. Values
		M	Md	M	Md	M	Md	M	Md	(15th Trial)
A	1	3.2	4.0	3.4	3.0	3.8	5.0	3.4	3.0	
	5	4.0	5.0	3.2	3.0	2.6	1.0	3.0	3.0	-------
	10	4.2	5.0	3.0	3.0	3.0	4.0	3.8	5.0	
	15	4.0	5.0	1.8	2.0	3.0	4.0	3.6	5.0	
B	1	3.2	3.0	4.3	3.5	5.0	5.0	4.8	5.0	
	5	4.0	5.0	4.3	4.5	3.7	4.5	3.0	4.0	-------
	10	4.4	5.0	4.6	5.0	2.7	2.7	2.6	2.0	
	15	4.0	5.0	3.8	5.0	2.2	1.0	2.5	3.0	

Job Satisfaction, by Position

Question 12, mean values taken at Trials 1, 5, 10, 15
(Data from "equivalent" positions combined)

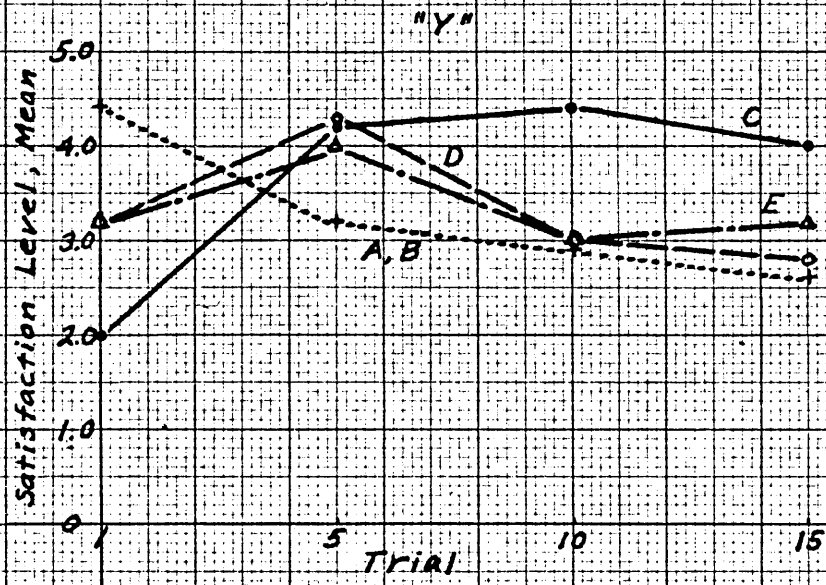
Figure 9a.



Job Satisfaction, by Position

Question 12, mean values taken at Trials 1, 5, 10, 15
(Data from "equivalent" positions combined)

Figure 9b.



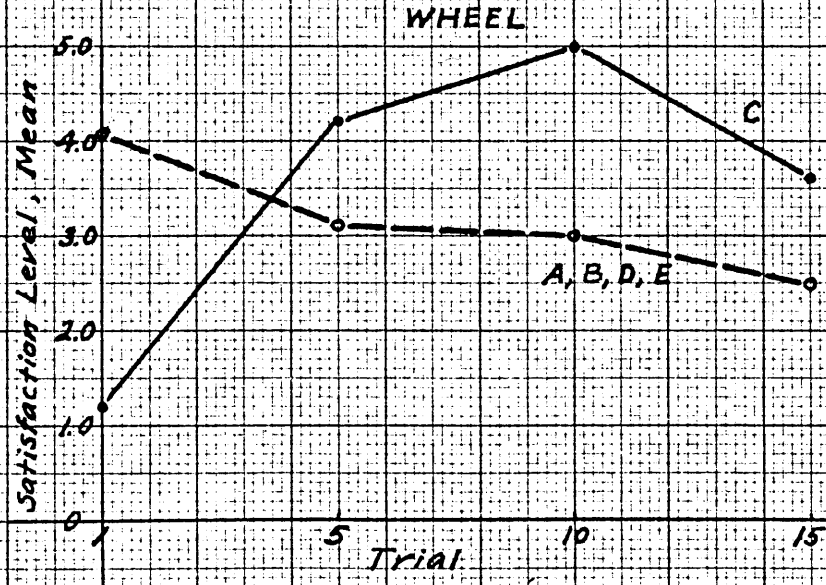


Table 29 (Cont.)

Position	Trial	Circle		Chain		Y		Wheel		P. Values (15th Trial)
		M	Md	M	Md	M	Md	M	Md	
C	1	3.0	5.0	3.2	3.0	2.0	2.0	1.2	1.0	
	5	3.8	5.0	4.0	4.0	4.2	5.0	4.2	5.0	Chain
	10	4.6	5.0	4.6	5.0	4.4	5.0	5.0	5.0	C-E $p < .05$
	15	4.0	5.0	4.0	4.0	4.0	5.0	3.6	5.0	
D	1	4.6	5.0	2.8	4.0	3.2	3.0	4.0	5.0	
	5	4.2	5.0	2.0	2.0	4.3	5.0	2.6	3.0	-------
	10	3.4	5.0	3.8	4.0	3.0	4.0	3.0	5.0	
	15	4.2	5.0	4.2	4.0	2.8	4.0	2.6	4.0	
E	1	3.1	3.0	4.0	5.0	3.2	5.0	4.2	5.0	
	5	4.7	5.0	2.7	3.0	4.0	5.0	3.7	4.5	-------
	10	4.0	5.0	1.4	0	3.0	4.0	2.5	2.5	
	15	3.8	5.0	1.0	0	3.2	3.0	1.3	2.0	

3. Message Analysis by Position

The same categories of messages are used in the sections that follow as were used in our total pattern analysis. This time, of course, the data are broken down by positions within patterns. All the data, for all categories of messages, are given in Table 30.

One of the things that immediately stands out from an examination of Table 30 is an apparent peculiarity in the informational message category. Although the most central man in the Chain sends more informational messages (52.2) than the other positions in that pattern, the same is not true of the most central men in the Y and the Wheel. In the Y, it is position D, the next-most central position, that sends most; while in the Wheel all positions are about equal. This peculiarity becomes quite understandable if we take into account (1) the kind of organization used in each pattern, and (2) the fact that the figures in Table 30 represent the

entire 15 trials, some of which occurred before the group got itself stably organized. In the Wheel, for example, the center man really needed to send no informational messages, only answers; but in the early trials, before his role was clarified, he apparently sent enough to bring his total up to the same level as the rest. In the Y, similarly, it is to be expected that position D, which must transmit to C its own and E's information, should send the most messages. And in the Chain, the slowest pattern to organize, it is not unlikely that the central man, C, should go on transmitting information from his left to his right and from his right to his left long enough to leave him with the highest total of informational messages in his pattern. This despite the fact that a "perfect" organization would require no informational messages from C in the Chain.

If we turn our attention to the answer messages, we find what we should expect to find, that the greatest number of answers comes from the most central members. There is, in fact, an almost one to one relationship between centrality and number of answers sent out.

Another, perhaps significant, point comes out of a consideration of organizational messages. This category is negatively correlated with positional centrality. The most peripheral men send the greatest numbers of organizational messages, the most central men least. The peripheral men are in positions, apparently, in which it is easy to perceive the limits of the pattern, "the dead ends," and in which also there is very little to do during the larger part of each trial.

Table 30

Analysis by Position

Message Analysis

1. Informational Messages Sent

		A	B	C	D	E	P. Values
Circle	M	50.0	60.0	52.6	62.8	57.8	A-D $p<.20$
	Md	45.0	62.0	52.0	59.0	65.0	
	R	39-71	47-73	43-65	52-84	40-72	
Chain	M	18.8	46.0	52.2	42.8	20.2	AE-C $p<.05$
	Md	19.0	30.0	51.0	47.0	20.0	AE-DB $p<.02$
	R	15-20	25-85	17-90	25-60	16-26	
Y	M	20.0	17.4	27.4	40.2	18.6	
	Md	17.0	17.0	22.0	45.0	18.0	------
	R	16-29	16-19	10-51	18-58	17-22	
Wheel	M	19.4	20.6	30.6	19.2	20.8	
	Md	18.0	17.0	28.0	18.0	20.0	------
	R	15-24	15-28	20-31	15-24	16-30	

2. Answers Sent

		A	B	C	D	E
Circle	M	22.2	21.0	20.0	11.6	16.0
	Md	22.0	24.0	20.0	9.0	16.0
	R	15-29	9-29	12-28	3-23	7-31
Chain	M	1.2	17.0	25.4	17.8	0
	Md	0	17.0	28.0	17.0	0
	R	0-4	16-19	14-30	16-22	0
Y	M	0	0	44.4	15.4	.4
	Md	0	0	44.0	15.0	0
	R	0	0	42-48	13-18	0-1
Wheel	M	.2	0	64.2	.4	.4
	Md	0	0	64.0	0	0
	R	0-1	0	61-69	0-2	0-2

3. Organizational Messages

		A	B	C	D	E	P. Values
Circle	M	.2	0	0	1.2	1.6	-----
	Md	0	0	0	1.0	1.0	
Chain	M	2.2	1.0	.2	1.2	3.8	C-AE $p<.01$
	Md	1.0	1.0	0	1.0	5.0	
Y	M	1.8	2.2	1.6	1.2	1.6	ABE-C $p<.40$
	Md	1.0	2.0	0	0	1.0	
Wheel	M	3.8	1.2	.8	2.0	1.2	
	Md	2.0	1.0	0	2.0	1.0	ABED-C $p<.20$

Table 30 (Cont.)

4. Method

		A	B	C	D	E
Circle	M	0	.6	.8	1.4	.6
	Md	0	0	0	0	0
Chain	M	.8	.2	0	.6	1.0
	Md	0	0	0	0	0
Y	M	0	.4	0	.4	.2
	Md	0	0	0	0	0
Wheel	M	2.4	.2	2.8	.2	.4
	Md	0	0	1.0	0	0

3. & 4. Method and Organization Combined

		A	B	C	D	E
Circle	M	.2	.6	.8	2.6	2.2
	Md	0	0	0	2.0	1.0
Chain	M	3.0	1.2	.2	1.8	4.8
	Md	1.0	1.0	0	1.0	5.0
Y	M	1.8	2.6	1.6	1.6	1.8
	Md	1.0	2.0	0	0	1.0
Wheel	M	4.4	1.4	3.6	2.2	1.6
	Md	2.0	1.0	1.0	2.0	2.0

5. Fillers

		A	B	C	D	E
Circle	M	1.0	1.4	2.0	1.4	.8
	Md	1.0	1.0	2.0	1.0	1.0
Chain	M	1.0	1.4	1.8	2.6	.6
	Md	0	1.0	0	3.0	0
Y	M	.8	1.2	1.0	1.8	.6
	Md	0	0	1.0	2.0	0
Wheel	M	1.0	1.8	2.4	.8	4.8
	Md	1.0	1.0	2.0	0	2.0

6. Out of Field-Totals

	A	B	C	D	E
Circle	2	4	0	1	0
Chain	1	3	0	4	1
Y	1	2	0	5	3
Wheel	1	0	2	0	1

Table 30 (Cont.)

7. Information Request

		A	B	C	D	E	P. Values
Circle	M	2.0	3.0	5.4	3.6	2.2	-----
	Md	1	2	2	2	2	
Chain	M	.4	1.8	3.4	3.2	1.8	AE-C $p<.30$
	Md	0	0	2	3	1	
Y	M	3.6	1.6	3.4	2.2	2.0	-----
	Md	1	2	3	2	2	
Wheel	M	.8	0	5.6	1.8	1.2	ABED-C $p<.02$
	Md	0	0	6	2	0	

8. Orders

		A	B	C	D	E
Circle	M	.8	.8	2.0	1.8	2.0
	Md	1.0	1.0	0	0	1.0
Chain	M	2.0	1.8	2.6	1.8	0
	Md	0	2.0	1.0	0	0
Y	M	1.4	.2	2.0	1.2	1.4
	Md	0	0	1.0	1.0	1.0
Wheel	M	1.2	2.2	5.4	1.0	.6
	Md	1.0	0	1.0	1.0	0

9. Recognition of Error

		A	B	C	D	E
Circle	M	1.8	1.6	.8	.6	0
	Md	2	1	1	1	0
Chain	M	0	.2	.2	.6	0
	Md	0	0	0	0	0
Y	M	.2	.2	0	0	0
	Md	0	0	0	0	0
Wheel	M	0	.2	0	.6	.2
	Md	0	0	0	0	0

10. Aggression-Totals

	A	B	C	D	E
Circle	0	4	0	8	0
Chain	0	3	0	2	0
Y	0	0	0	2	1
Wheel	2	0	3	3	2

11. Received Answer in Last 3 Trials-Totals

	A	B	C	D	E
Circle	13	16	17	15	18
Chain	15	11	4	13	15
Y	15	15	0	15	15
Wheel	15	15	0	15	15

Table 30 (Cont.)

12. Use of Elimination (no. using)

	A	B	C	D	E
Circle	2	2	2	2	2
Chain	1	2	2	3	5
Y	2	1	1	1	2
Wheel	3	2	2	2	3

13. Total Activity - Not Information or Answer (Totals)

	A	B	C	D	E
Circle	31	45	55	59	36
Chain	24	38	36	56	37
Y	40	31	40	41	33
Wheel	49	28	90	35	45

In contrast to organizational messages, orders and requests for information come from the most central positions, a finding which is in keeping with the idea that the most central man eventually learns that he is the key to the solution of the problem.

One other rather interesting point comes out of a count of the number of times each position received (from some other position) an answer in the last three trials (Table 30; 11). It will be seen that neither position C in the Y, nor position C in the Wheel received any answers in the last three trials. They were the positions that worked out the answers, and, hence, received none. Position C in the Chain, however, received answers four times in the last three trials. This, despite the fact that C was the most central Chain position and should have been, by the last few trials, performing the same function as C in the Y, and C in the Wheel. Apparently, the emergence of C as the leader in the Chain was not yet complete by the 13th trial.

None of the other categories in Table 30 show any clear cut positional differences.

Other Observations

In addition to the formal data presented in the preceding sections, there are available two other sources of material. Each group of subjects, immediately after the experiment was run, spent about a half hour talking with the experimenter. Some very distinct impressions emerged from these conversations. Our other source of material was a group of graduate students,

all familiar with the experimenter, who were induced to try a run on the Chain pattern. Their behavior differed in some respects from the behavior of the undergraduate subjects.

The predominant impression gained from the post-experimental discussions were two. First, there existed, we felt, a big difference in the post-experimental behavior of the Circle groups in contrast to the others. The Circle members came out fighting. They were active, aggressive, more interested in hashing things out with their fellows than talking to the experimenter. Their interest level was high, even after the 15th trial.

This kind of involvement characterized the leader position in other patterns, but seemed to be replaced by a resigned or sullen attitude on the part of peripheral members. These peripheral members displayed a certain amount of academic interest, but they had little to say about the progress of their own groups.

A second subjective observation, strengthened during the post-experimental talks with subjects, concerned the emergence of a leader. In both the Circle and Chain patterns, a struggle for leadership occurred more than once. In the Circle, the struggle never seemed to resolve, but seemed rather to be suppressed. That is, in the pressure of the situation, no time was available to fight it out. In the Chain, there were occasions in which the most central man tried to duck all responsibility by passing all information to one of his mates for a decision. Occasionally, he succeeded, but in at least one case, one could

perceive from the message analysis and from the subjects' reports the evolution of the realization by the most central man that like it or not he was the key.

The graduate student group, run on the Chain, manifested behavior that differed in degree, rather than kind, from the undergraduates. The peripheral A and E positions displayed their frustration overtly. They pulled down the barriers separating them. They snapped messages to other members so hard that the messages flew out onto the floor. They insisted on conversing aloud despite strict orders to the contrary, and they threw switches on and off at random. Although they had entered the situation more or less willingly, they complained afterwards of being tricked. All the while, however, the man in the most central position was quite interested, quite efficient, and quite at ease.

This difference between undergraduates and graduates seemed to us to be attributable to differences in the freedom subjects felt to express their aggression. The undergraduates, unfamiliar with the experimenter and with most of their fellow subjects, apparently weren't as free to get overtly aggressive as the equal-status graduate students.*

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*It is interesting that Smith and Bavelas, using the Circle and Chain patterns with a set of girls (all of whom knew one another well) are finding many more aggressive and out-of-field messages than we encountered. Incidentally, Smith and Bavelas' data, as yet unpublished, appear to corroborate ours in most respects.

VIII. Discussion

From our results, there begins to emerge a picture of differences in the behavior elicited by the various patterns and the various positions within patterns.

Patternwise, the picture is of differences of several sorts, but almost always in the order Circle, Chain, Y, Wheel. The greatest differences are between the Circle and the Wheel, while the Chain and Y fall between these two.

We may characterize, in a general way, the kinds of differences that occur between the Circle and the Wheel in this way. The Circle is active, leaderless, unorganized, erratic, and yet is fun for its members. The Wheel is less active, has a distinct leader, is well and stably organized, less erratic, and yet unsatisfying to most of its members. The Chain and Y fall between the extremes.

There are two questions which these differences bring to the fore. Did the hypotheses that we offered earlier predict the differences that have been found? And, second, are there any general characteristics of communication patterns that correlate with the observed behavioral differences?

A. Do the hypotheses match the observed behavior?

1. Our first hypothesis suggested that satisfaction with one's job, on an individual basis, should be related to "opportunities for participation." Such a relationship does,

in fact, seem to occur. From our table of participation opportunities (Table 2), it can be seen that position C, in the Wheel, should be the most "satisfied" position in any pattern. Reference to the results on question 8 (How did you enjoy your job?) bears out this prediction. Similarly, the four peripheral Wheel positions, which are lowest in participation opportunities, are also lowest in satisfaction. This relationship between participation opportunities and satisfaction is by no means perfect. We must, however, bear in mind that the hypothesis and the figures for "participation opportunities" were predicated on the assumption that patterns would be operated in the theoretically "best" manner — i.e. so as to yield minimum t. Only the Wheel actually did operate in this "best" way.

2. The second hypothesis, that patterns, in which maximum differences in participation opportunities occur, will be least satisfactory, does hold. Differences in participation opportunities line up the patterns in the order Wheel, Y, Chain, Circle; and question 8 (How did you like your job?) lines them up in the same order. Question 12 (How did you feel as you went along) also produces almost the same arrangement.

We also suggested, in our second hypothesis, that when participation opportunities were equally distributed among group members (as in the Circle), satisfaction would depend on the emergence of an organization. Clear organizations did not emerge in the Circle groups, yet satisfaction was high.

We suggest that an organization may have been perceived by the subjects that was not perceived by us, or alternatively, that the possibility of organization was perceived by the subjects. Our post-experimental talks with subjects seem to point to this latter alternative. The involvement of the subjects was high. Everyone had ideas. Though there was no actual organization, there were possibilities of organization. Questions 2 (Describe the organization of the group) and 5 (How could the group improve?) point to the perception of these possibilities by Circle members. Only one person, in answer to question 2, described the communication pattern. Their answers were "none" or "good" or "bad." In question 5, Circle members placed most emphasis on planning, leadership, and organization as sources of improvement, while only one person felt there was no possibility of improvement. The feeling seems to have been: "We aren't organized, but we can get organized. We can improve." While in the other patterns, members seemed to feel that they had done about as much as they could do.

3. Our third hypothesis, that centrality will determine leadership and organization, where personality is constant, seems unequivocally to have held. The greater a position's centrality, the clearer became the leadership role of the individual in that position. Where centrality differences between positions were slight, leadership by the most central individual is less clearcut, as, for example, in the Chain.

Leadership was measured by subjects' recognition of a leader (question 3), by observation of the directions of flow of different kinds of messages, and by determination of the sources of answer messages.

4. Our last hypothesis stated that the time taken to solve a problem would be limited at the lower end by pattern of communication. If pattern does set such a limitation on speed, the limitation is not in the direction we would have predicted. Our hypothesis, based on a theoretical t unit analysis, would lead one to expect greatest speed from the Circle pattern. Certainly our Circle pattern was not our fastest one.

There are three outstanding reasons for the failure of our t unit analysis to predict clock time. First, the t unit, itself, was too gross a measure. We defined t as the time required for the transmission of one message from its inception to its reception. In actuality, different kinds of messages required very different clock times for transmission. Subjects did, on certain occasions (by using two hands) send two messages simultaneously. They also laid out and wrote several messages before sending any. These kinds of variations, which are a function not so much of a subject's personality as of his number of neighbors, must be taken into account before theoretical t can be expected to correlate (to any extent) with clock time.

A second reason for the failure of t to relate to clock time is that our t unit analysis was based on the assumption that subjects would gravitate to the theoretically "best" operating organization. As we have seen, only the Wheel groups used the "best" method consistently.

Finally, it should be pointed out that differences in speed between patterns were subject to major fluctuations for reasons of differences in writing speed, dexterity in passing messages, and other extraneous factors.

B. What structural characteristics of communication patterns are related to the behavior of groups in the patterns?

Independent of the validity of our hypotheses, a more general problem may be considered. Are the behavioral differences among patterns and among positions related consistently to any structural characteristic of the communication patterns themselves? An examination of Table 2, which lists some outstanding structural characteristics of patterns, and a consideration of observed behavioral differences leads one immediately to the selection of "centrality" as a significant structural characteristic. Only centrality shows the same progression, Circle, Chain, Y, Wheel, as do most of the behavioral differences. On a positional basis, centrality also differentiates members of a pattern in the same order that their behavior does.

Because such a clear-cut relationship does occur between behavior and centrality, a more detailed consideration of the centrality concept is called for.

The central region of a structure is defined by Bavelas(1) as "the class of all cells with the smallest p to be found in the structure." The quantity, p, in turn, is defined as the largest distance between one cell and any other cell in the structure. The most central position in a pattern, then, is the position that is closest to all other positions. The most peripheral position is the one most distant from the most central position. Quantitatively, the centrality of position A in any pattern can be found by (1) summing the distances from each position to every other one; and (2) dividing this summation by the total distance of position A from every other position.

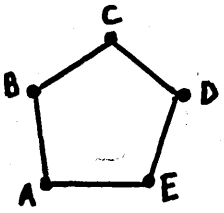
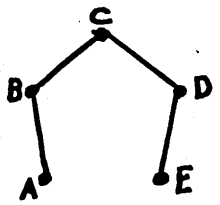
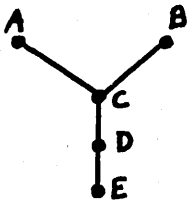
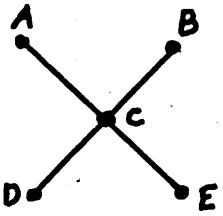
Centrality, it can be seen, is a function of the n of a pattern, as well as of the structure of a pattern. Thus, in a five-man Circle, the centrality of each man is 5.0. In a six-man Circle, the centrality of each man jumps to 6.0. The two most peripheral men in a five-man Chain each have a centrality of 4.0. But in a seven-man Chain, the two most peripheral men have centralities of 5.3

With these characteristics of centrality in mind, we may return to our data. In Table 31 are given the centralities of each position in each of our four test patterns. The sum

of centralities is also given. Both total centrality and distribution of centralities fall in the order Circle, Chain, Y, Wheel.

Table 31

Centralities

Pattern				
Position				
A	5.0	4.0	4.5	4.6
B	5.0	5.7	4.5	4.6
C	5.0	6.7	7.2	8.0
D	5.0	5.7	6.0	4.6
E	5.0	4.0	4.0	4.6
Total	25.0	26.1	26.2	26.4

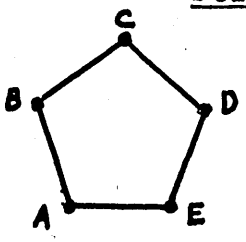
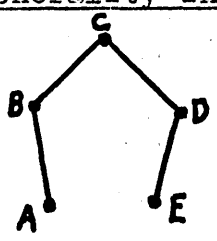
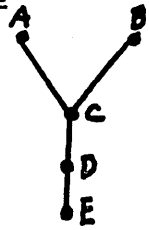
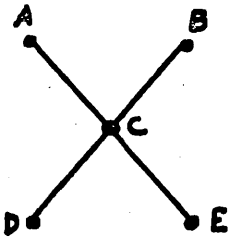
These centrality figures correlate with the behaviors we have observed. But it seems unreasonable to assume that the correlation would hold for larger n's. Certainly we would not expect more message activity or more satisfaction from peripheral positions in a Chain of a large n than from a five-man Chain. Yet the centralities of these peripheral positions increase with n.

To obviate this difficulty, a measure we may call "relative peripherality" may be extablished. The relative

peripherality of any position in a pattern is the difference between the centrality of that position and the centrality of the most central position in that pattern. Thus, for the peripheral men in a five-man Chain, the peripherality index is 2.7 (the difference between their centralities of 4.0 and the centrality of the most central position 6.7). For a Chain of seven persons, the peripherality index of the end men rises to 4.0. For a total pattern, the peripherality index may be measured by summating all the peripherality indices in the pattern.

Table 32

Peripherality Index

Pattern				
Position				
A	0	2.7	2.7	3.4
B	0	1.0	2.7	3.4
C	0	0	0	0
D	0	1.0	1.2	3.4
E	0	2.7	3.2	3.4
Total Peripherality Index	0	7.4	9.8	13.6

Observed differences in behavior correlate very nicely with these peripherality measures. The extent of this relationship is shown in Figures 10 to 15 . By total pattern, it can be seen that messages and satisfaction (measured by question 8) vary consistently with total peripherality index (Figures 10, 11). Except for the Wheel, errors also correlate with total peripherality index (Figure 12). Similarly, by position, messages and satisfaction vary with peripherality (Figures 13, 14). Our error measure, however, shows no clear relationship with peripherality of position (Figure 15); a finding which is diagnosed in detail later in this section. Recognition of a leader also seems to be a function of peripherality, but in a somewhat different way. A review of our leadership findings will show that leadership becomes more clear-cut as the differences in peripherality within a pattern become greater. Recognition of a leader seems to be determined by the extent of the difference in centrality between the most central and next most central man.

Before going further, it is of interest to consider where other patterns, of n 5, would fall on the relative centrality scale.

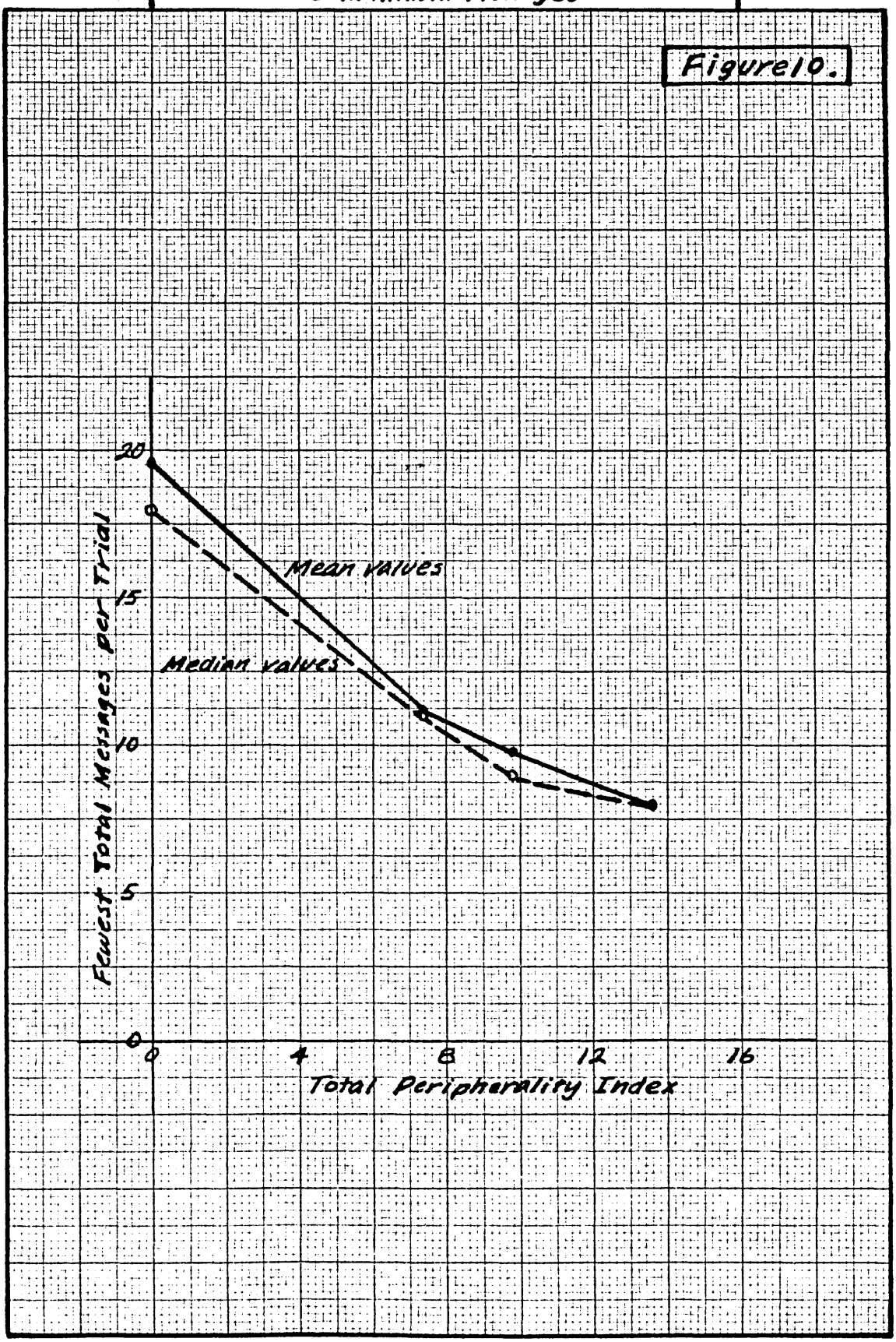
The total peripherality indices (sum of centrality differences) of our four patterns are:

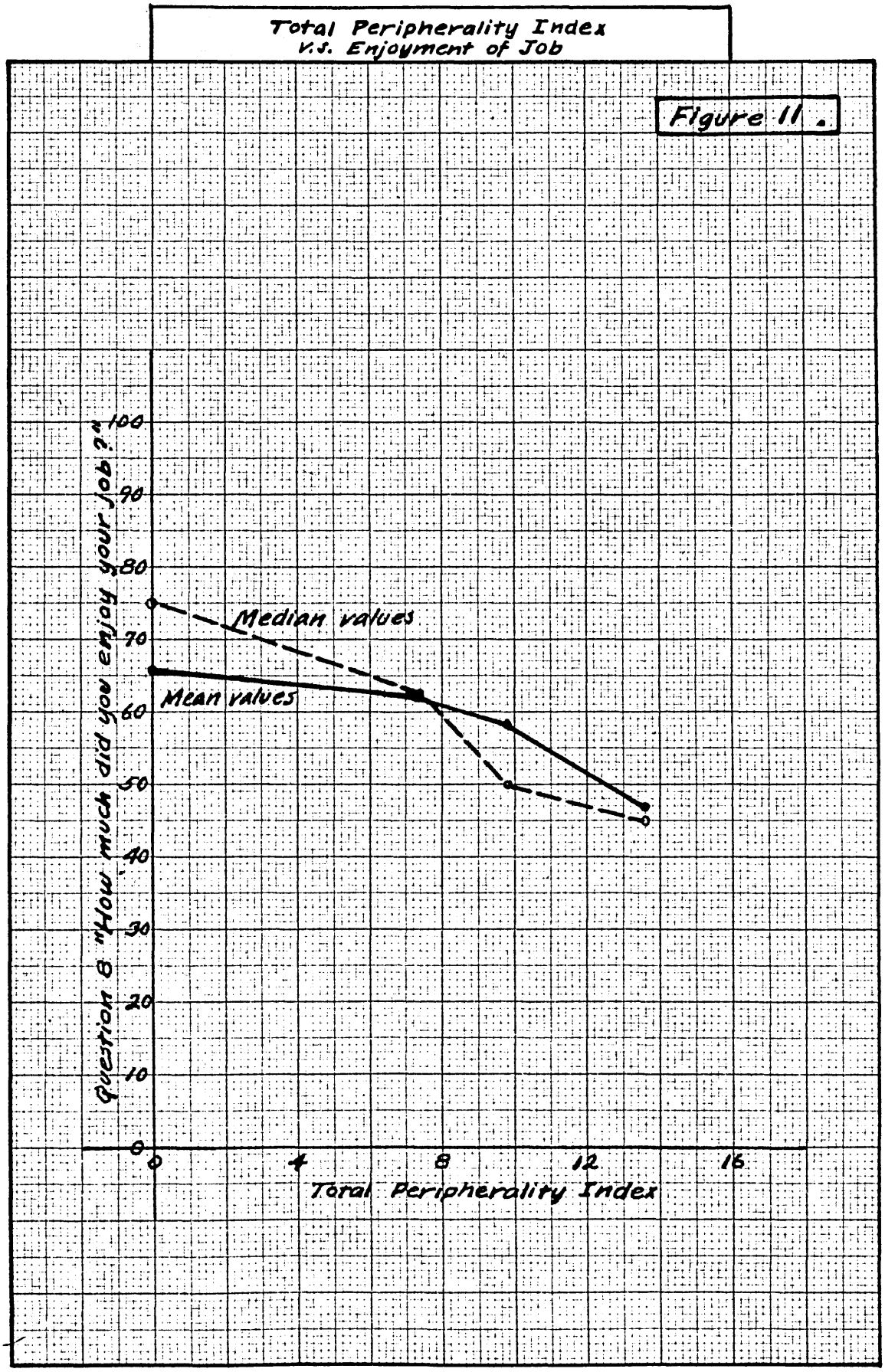
Circle	Chain	Y	Wheel
0	7.4	9.8	13.6

The pattern  has a total peripherality index of 7.0, which would lead to the expectation that total pattern

Total Peripherality Index
v.s. Minimum Messages

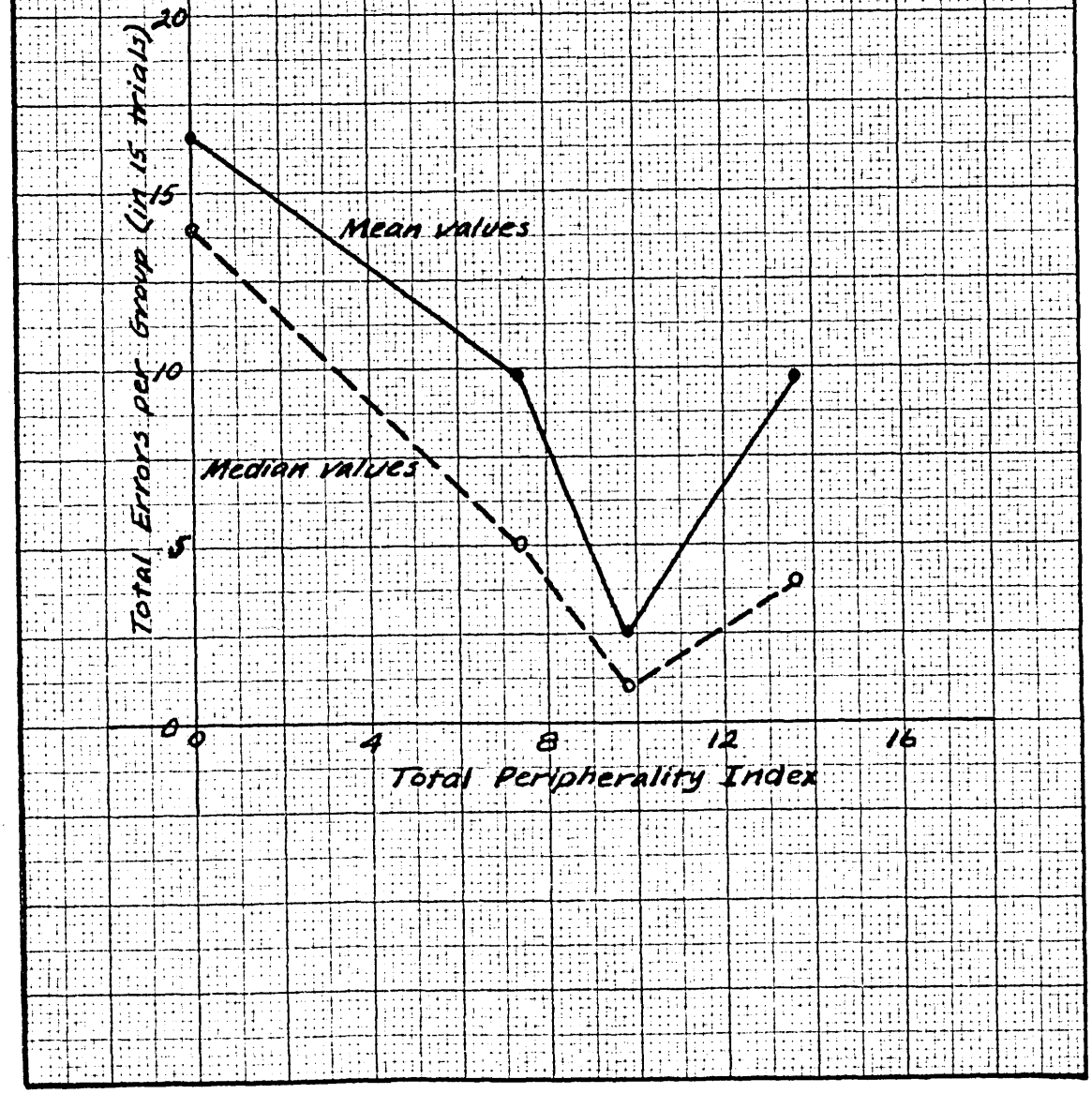
Figure 10.




Total Peripherality Index
v.s. Enjoyment of Job
Figure 11.
Question 8 "How much did you enjoy your job?"
100
90
80
70
60
50
40
30
20
10
0
Median values
Mean values
0
4
8
12
16
Total Peripherality Index

Total Peripherality Index
v.s. Errors

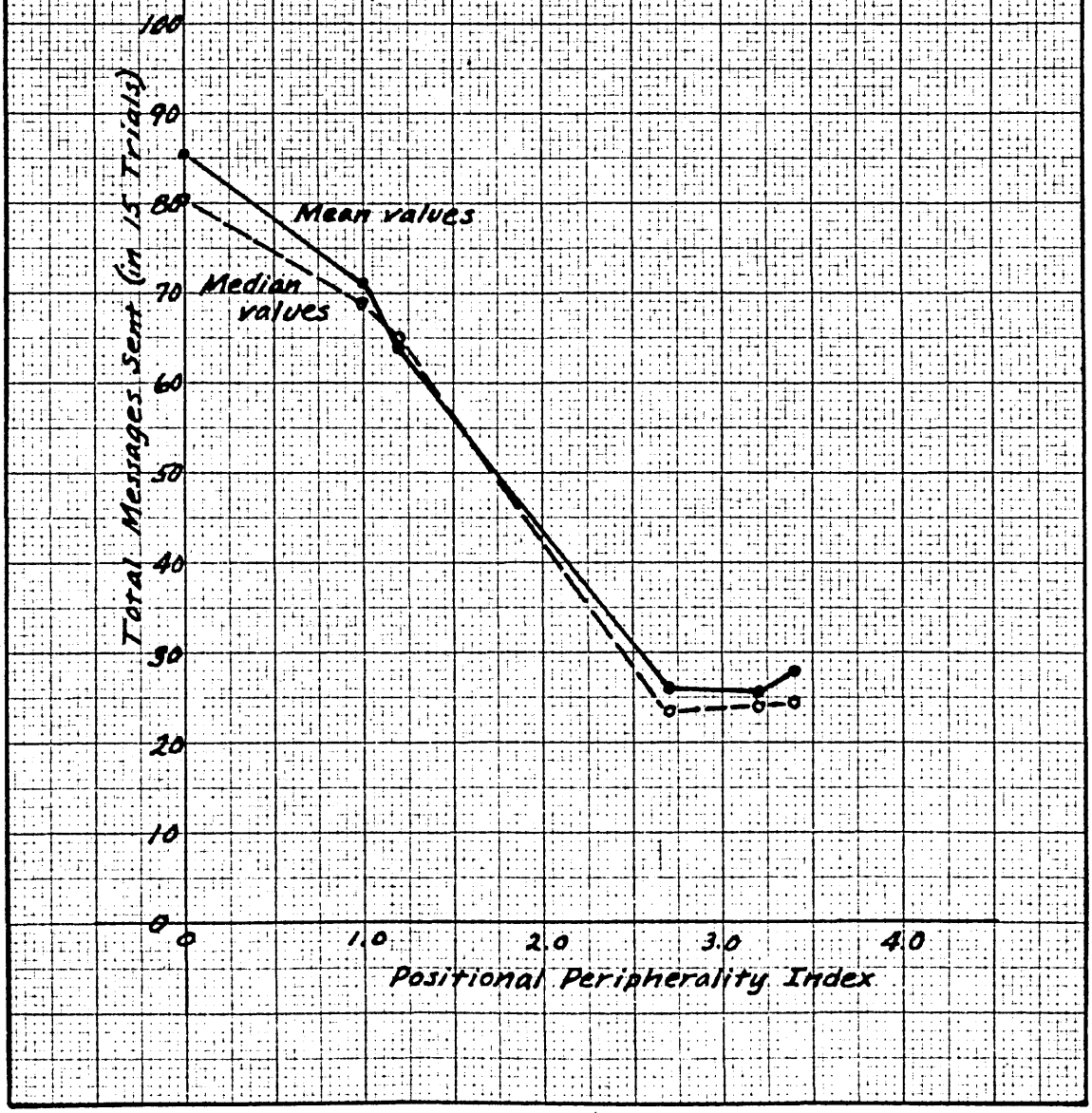
Figure 12.



Positional Peripherality Index
v.s. Messages Sent

Means and medians of the distributions at each centrality value of mean number of messages sent by each position with that centrality value.

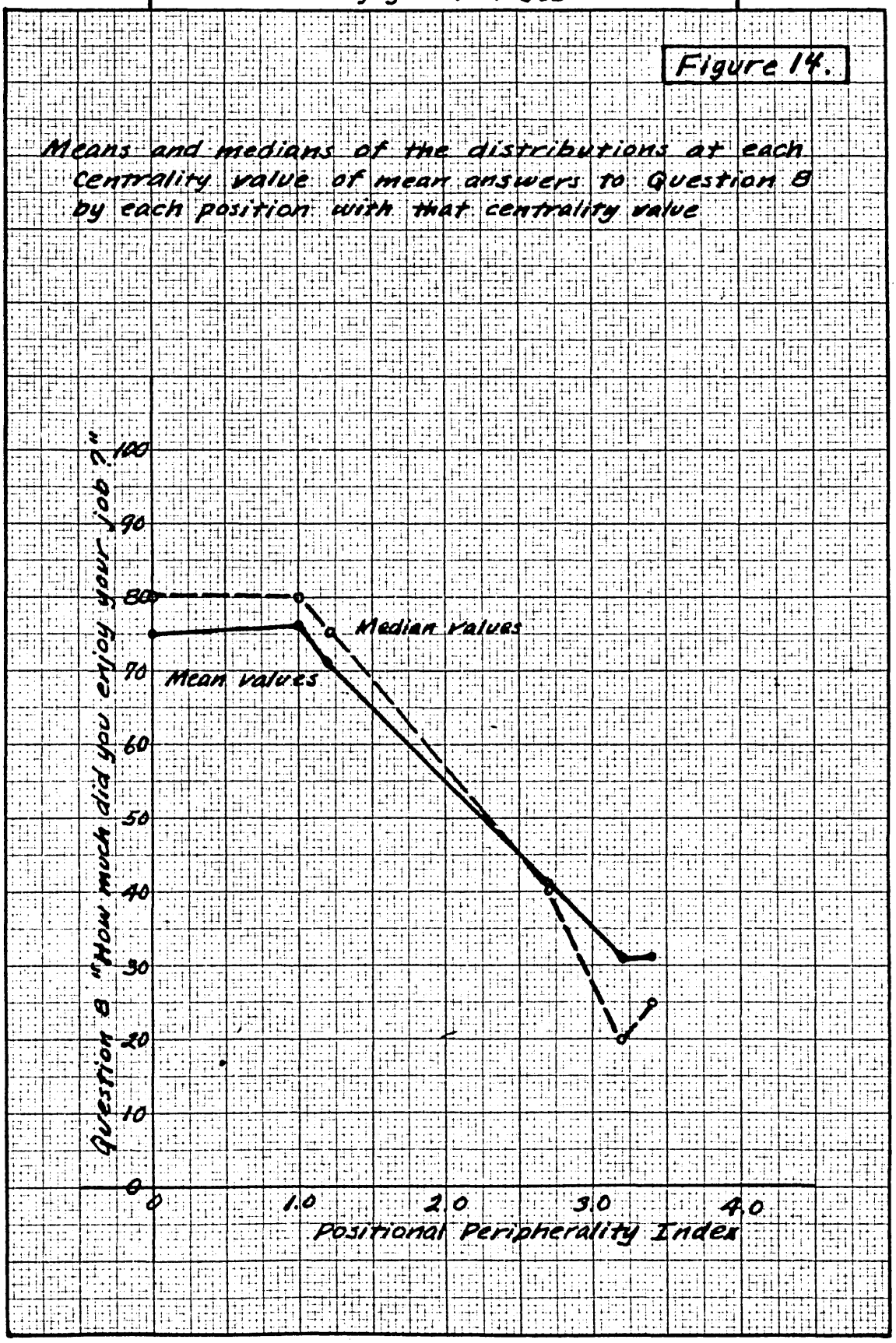
Figure 13.



Positional Peripherality Index
V.S. Enjoyment of Job

Figure 14.

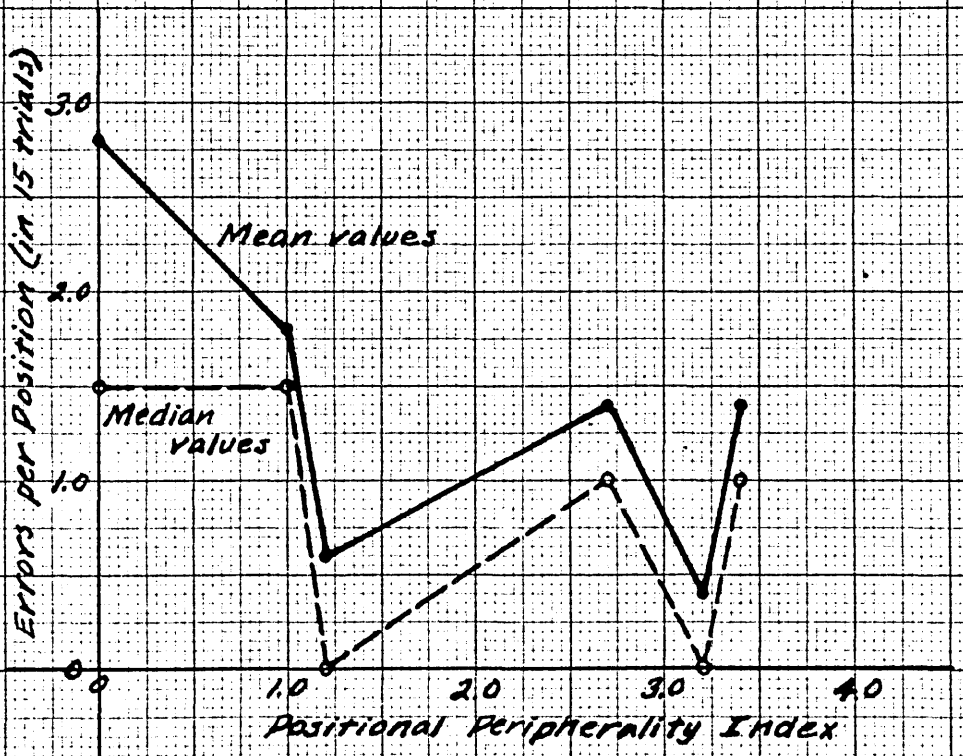
Means and medians of the distributions at each centrality value of mean answers to Question 8 by each position with that centrality value

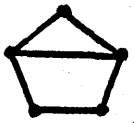
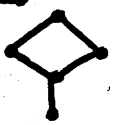
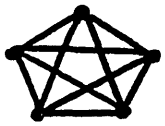


Positional Peripherality Index
V.S. Errors

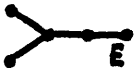
Figure 15.

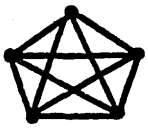
Means and medians of the distributions at each centrality value of mean errors made by each position with that centrality value



behavior would lie somewhere between Circle and Chain. The pattern  has a total peripherality index of 2.7, and the pattern  yields a figure of 6.4. Both of these should also lie between Circle and Chain.  , however, gives a total peripherality index of 11.4, placing it between Y and Wheel. And the maximum communication pattern  has a 0 value for total peripherality like the Circle.

By individual position, patterns other than ours give suggestive results.

Thus, the two peripheral men (A and B) in  have the same peripherality indices as a man E in the  .  is like the Circle when considered by individual position -- both yield peripherality indices of 0 for all positions. If centrality is the relevant pattern variable, we should expect, both individually and totally, the same kinds of behavior from  and  . We would hesitate, however, to place too much emphasis on the positional aspect of our peripherality-centrality analysis. We hesitate because positions of equal peripheralities, but in different patterns, show considerable variability in behavior, and because the relationship of individual peripherality indices to errors is not at all clear. In

terms of total pattern, however, we would predict similar behavior for Circle and  .

Given a relationship between total peripherality index and total pattern behavior, and a relationship between peripherality of position and positional behavior (except for errors), there arises the question of explaining these relationships. Stated a little differently, our question is: What is the mechanism by which the peripherality or centrality of a pattern or a position affects the behavior of persons occupying that pattern or position?

Our reconstruction of the experimental situation leads us to this analysis of the centrality-behavior relationship:

1. Let us assume standard subjects motivated to try to solve our experimental problem as quickly as possible. Let them be "intelligent" subjects who do not send the same information more than once to any neighbor. Let them also be subjects who, given several neighbors, will send, with equal probability, their first message to any one of those neighbors. Their next message will go to one of the remaining neighbors, and so on.

Given such standard subjects, the probability that certain positions will get an answer first is greater than the probability that certain other positions will get the answer first. In the Chain, position C is most likely to get the answer first; A and E least likely to get it. In

the Y and the Wheel, C also is most likely to get the first answer. But in the Circle, all positions have an equal opportunity, if we assume intelligent subjects, of getting the first answer.

To illustrate, consider the Chain pattern.  During time unit 1, A may send only to B. B may send either to C or to A. C may send either to B or to D. D may send either to C or to E. E may send only to D. No matter where B, C, and D send their messages, B and D will have, at the end of t_1, A's and E's information. During t_2, if B and/or D sent to C the first time, they will now send to A and E. If they sent to A and E the first time, they will send to C, and C will have the answer. Even if B and D do not send to C until t_3, C will either get the answer before or simultaneously with B and D. In no case, can any other position beat C to the answer. In the Wheel, C cannot even be tied in getting an answer. He will always get it first. On a probability basis alone, then, there are differences in the answer-getting potentials of different positions within and between patterns.

2. Our next concern is with subjects' perceptions of these answer-getting potentials. We suggest that these random differences in answer-getting potentials rapidly structure members' perceptions of their own roles in the group. These differences affect one's independence from, or dependence on, the other members of the group.

At this point, we may reconvert our subjects from intelligent automatons to more complex psychological entities. In the Wheel, for example, a peripheral subject perceives at first only that he gets the answer and information from C and can send only to C. C perceives that he gets information from everyone and must send the answer to everyone. The recognition of roles is easy. The peripheral men are dependent on C. C is autonomous and controls the organization.

In the Circle, a subject's perception must be very different. He gets information from both sides; sometimes he gets the answer, sometimes he sends it. He has two channels of communication. He is exclusively dependent on no one. His role is not clearly different from anyone else's.

In the Chain and the Y, it is neither so easy for all subjects to perceive their roles as in the Wheel, nor so difficult as in the Circle. Again, on a probability basis, C, in the Chain or Y, will not so rapidly emerge as the answer source as does C in the Wheel, but there will certainly be more rapid differentiation of roles than in the Circle.

3. Having closed the gap between structural pattern and subjects' perceptions of their roles in the group, the problem reduces to a purely psychological one. The question becomes: How do differences in independence of action bring about specific behavior differences of the sort we have observed? Granting that positional centrality limits independence

of action, how does this limitation bring about differences in messages, errors, leadership, and level of satisfaction?

Differences in satisfaction level are relatively easy to relate to independence. In our culture, in which needs for autonomy, recognition, and achievement are strong, it is quite reasonable that positions which limit independence of action (peripheral positions) should be unsatisfying.

A fairly direct relationship between centrality (and, hence, independence) and the speed with which a group gets organized is also perceptible. It has already been pointed out that C in the Wheel will always, on a probability basis, get the answer first. Unless subjects act "unintelligently," an organization, with C as the center, is forced on the Wheel groups by the structural pattern.

In the Circle, no such differences in role and, hence, in organization, are forced on the group. Any differences that emerge must result from differences between members rather than differences between positions. With our homogeneous subjects, such differences, and the organization consequent to such differences, were slow to emerge.

In the Chain and the Y, position does force differences in subjects' roles, but not so clearly as in the Wheel. It takes, we might guess, only a few trials for A and E, in the Chain, to perceive their dependence on their neighbors. But, for B and D, who may get the answer as quickly as C on some occasions, more trials must doubtless occur before the limitations of their positions are perceptible. A similar analysis is possible for the Y pattern.

Message activity can also be related to centrality by means of the independence-of-action concept. A peripheral person in any pattern can send messages to one other position only. Only one informational message is called for. Extra messages would be repetitious. Central positions, however, are free to send more than one non-repetitious informational message until an organization evolves. Once the most central man perceives that he is most central, he realizes that he need send no informational messages. But so long as the most central man does not perceive his own position, it is perfectly intelligent to send informational messages to whomever he feels may require some information.

In the Circle, where no position is central or peripheral, where every person may send to two others, and where no differentiation of roles rapidly occurs, informational (and other) message activity should be, and is, greatest throughout the fifteen trials.

At the other extreme, in the Wheel pattern, we should expect (and we find) a rapid drop in message activity during the first few trials. The peripheral positions apparently soon perceive that only one informational message is needed from them, and the central position soon perceives that only answer messages are needed from him.

It is somewhat more difficult to tie accuracy of performance to centrality differences and the limits they impose

on independence. It will be recalled that although total errors more or less lined up in the order Circle, Chain, Y, Wheel, the Wheel did not produce fewest errors. We also found that the proportion of total errors left uncorrected was less for the Circle than for the Chain and Y. The peculiarity of the Wheel we attributed to one group that had difficulty with the idea of elimination.

If the behavior of the Wheel pattern was truly fortuitous, then an explanation, in terms of centrality, is possible for both of these phenomena, i.e., total error differences and differences in self-correcting tendencies.

Differences in self-correcting tendencies (if they were real) might be very likely to depend on centrality differences. For if centrality determines one's independence of action, it seems very likely that positions most limited in independence should begin to perceive themselves as subordinates whose sole function is to send information and await an answer. That they should then uncritically accept whatever answer they receive is perfectly in keeping with their subordinate, relatively unresponsible positions. In contrast, positions (and patterns) in which independence is great, and in which more than one source of information is available, should be critical positions that check their answer before accepting them.

Whether or not this reasoning is adequate to explain differences in proportions of total errors corrected, we are

still left with the task of explaining differences in total errors. Total errors, it will be recalled, were correlated with total peripherality indices (the Circle produced most errors), but showed no clear relationship with the relative centrality of particular positions.

A consideration of our definition of error may shed some light on this apparent anomaly.

The "errors" that we recorded were signals from the subject that indicated a wrong answer. But these wrong answers derived from a variety of sources. First, subjects might wrongly interpret the correct information they received. They might also make errors in throwing switches; and they might also correctly interpret wrong information. In all three cases, "errors" were recorded.

We suggest that if this variety of phenomena are all recorded as errors, it is to be expected that we should find a total pattern relationship with centrality, but no positional relationship. Our reasoning can be illustrated by an example. Suppose that the central man in the Wheel wrongly interprets information sent to him, and, hence, throws an incorrect switch. This is a "real" error. He then funnels out the wrong answer to the other members. At least three of these intelligently conclude that the answer sent them is correct and, hence, throw the wrong switches. We then have three "false" errors consequent to our single "real" one.

So long as real errors are made by only one member, we should expect comparatively few total errors. But when several independent decisions are made (as in the Circle), we should expect more real errors, more multiplication of these (and more correction of them), and a larger total of errors.

This process should lead to differences between patterns that correlate with centrality, but not with positional differences. The process simply multiplies real errors more or less constantly for a whole pattern, but obscures positional differences because the "real" and the "false" errors are indistinguishable in our data. The result is, on the one hand, a highlighting of any real errors in a pattern by their transmission and multiplication, and, hence, big pattern differences in total errors; but, on the other hand, the result is an obscuring of positional differences because of our inability to distinguish the "real" from the "false."

We submit further that pattern differences in real errors, if such there be, may be attributable to "over-information"; too much information to too many members which, under pressure, leads to errors. Central positions, in other words, or positions which are no less central than others in the pattern, should be the ones to yield the greatest number of real errors, while peripheral positions, which require no such rapid collation of information, should be the false error sources. Such an hypothesis would be in keeping with our total pattern findings and might also clarify our positional findings.

Only an experiment designed to differentiate real from false errors can really answer the question.

It is in keeping with this centrality-independence analysis also that we should find the recognition of a single leader occurring most frequently in the Wheel and Y groups. It is also to be expected that we should find Circle members emphasizing need for organization and planning in question 5, and seldom giving a complete picture of their pattern in question 4. Perhaps, too, it is reasonable to expect that the whole group should be considered good (question 7) in the highly organized Wheel, (and not so good in the unorganized Circle) even though one's own job is considered poor.

In summary, then, it is our feeling that centrality determines behavior by limiting independence of action, thus producing differences in activity, accuracy, satisfaction, leadership recognition, and other behavioral characteristics.

IX. Conclusions

Within the limits set by our experimental conditions -- group size, type of problem, source of subjects -- these conclusions seem warranted:

1. The communication patterns within which groups work affect their performance. For our tasks, our subjects, and our group sizes the major behavioral differences attributable to communication patterns are differences in:

(a) accuracy,

(b) total activity,

(c) satisfaction of group members,

(d) emergence of a leader, and

(e) organization of the group.

There may also be differences among patterns in:

(a) speed of problem solving,

(b) self-correcting tendencies, and

(c) durability of the group as a group.

2. The positions which individuals occupy in a communication pattern affect their behavior. One's position in the group affects:

(a) the chances of becoming leader of the group,

(b) one's satisfaction with one's job and with the group,

(c) the quantity of one's activity, and

(d) the extent to which one contributes to the group's recognition of the structure of the pattern within which the group is working.

3. The characteristic of communication patterns that is most clearly correlated with behavioral differences is centrality. Total pattern differences in behavior are correlated with a measure we have labelled the "peripherality index." Positional differences in behavior are correlated with positional peripherality indices of the various positions within patterns.

4. It is tentatively suggested that centrality affects behavior via the limits that centrality imposes upon independent action. Independence of action, relative to other members of the group is, in turn, held to be the primary determinant of (1) the definition of who shall take the leadership role, (2) total activity, (3) satisfaction with one's lot, and other specific behaviors.

More precisely, it is felt that where centrality and hence independence is evenly distributed, there will be no leader, many errors, high activity, slow organization, and high satisfaction. Whatever frustration occurs will occur as a result of the inadequacy of the group, not the inadequacy of the environment.

Where one position is low in centrality, relative to other members of the group, that position will be a follower position, dependent on the leader, accepting his dictates, falling into a role that allows little opportunity for prestige, activity, or self-expression.

APPENDIX I

Instructions

We've asked for your help today in an experiment on the ability of groups to solve abstract problems. This question is a basic one in any research team or other groups organized for solving problems.

Now, before we get started, let me lay down one general rule. Once we get under way, please don't talk to any other member of the group. Any conversation can throw the results off considerably. That's the only general rule.

Before starting the final experiment, we want to familiarize you with the problem you'll be doing. So, we're going to have each of you do, alone at first, what you'll later be doing together.

Each of you will get five large cards, on each of which will be five symbols like these. There is one symbol and only one which appears on all five cards. Your job is to find out what the common symbol is. When you find it, raise your hand.

Questions?

OK. When I say go, turn over the cards, find the common symbol, and when you've got it, raise your hand.

****

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

You still can't talk to one another, but you can communicate by writing messages, on these little cards, and passing them to your neighbors through the appropriate holes in this apparatus. But again, as you see, you can't send

messages to everybody, only to those to whom you have open channels. Look in your booth now and see what channels are open. For every open channel to someone there is an open channel from him. That is, you can get messages from anyone you can send to.

You will find large cards with symbols posted on the wall and plenty of small cards for messages. At the "go" sign, turn over the first large card and then send any messages you want to the men to whom you have a channel. 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 the same message card along. You can copy any messages you get and pass the copy along, but you can't send on the same card you have received from someone else. And you can write any messages you want to. Each man's message cards are in his own color.

Your job is not done until everyone on your team has the ans wer. Then and only then is the puzzle solved. When you have the right answer you can pass it along. So when anyone thinks he has the right answer, he can push the proper switch in his booth and then can go on working. When I see all five lights on my panel, I'll know the job is done.

You can push only one button at a time, so if you change your mind about the answer, switch off the first guess and switch on the second.

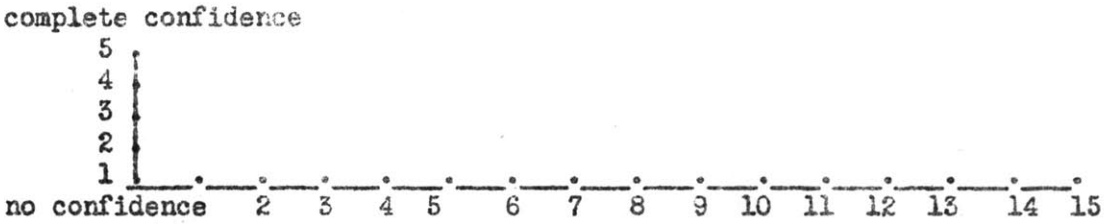
(Your team will be competing with other five-man teams to see how long it takes you to get the answer. The important thing is to get the answer in as short a time as possible. The shorter the time, the better your team's score.)

Start when I give the buzzer signal and stop when I give the buzzer signal. Ready?

After First Trial: (1) Put a rubber band around all the messages you have received. (2) Mark the top one TRIAL #1, and (3) drop them in the basket. (4) Turn all your switches back to the OFF position.

APPENDIX II

a. How confident are you (check on the line below) that your group got all the answers right?



. Describe briefly the organization of your group.

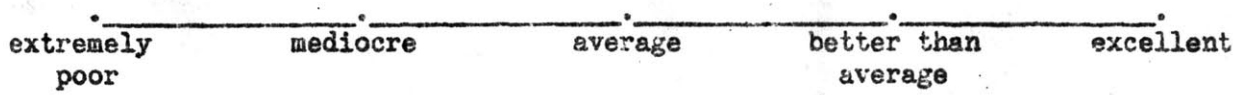
. Did your group have a leader? If so, who?

. Was there anything at any time that kept your group from performing at its best? If so, what?

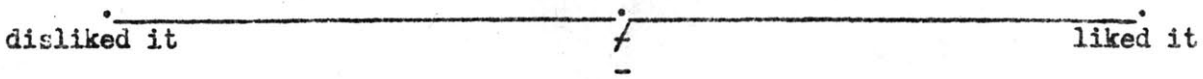
. Do you think your group could improve its efficiency? If so, how?

. How many more problems do you think it would take before you would get "fed up"?

. Rate your group on the scale below.



. How did you like your job in the group?



a. Who had the best job?

b. Who had the worst job?

10. a. Check below the proportion of necessary messages you personally sent on the last five trials.

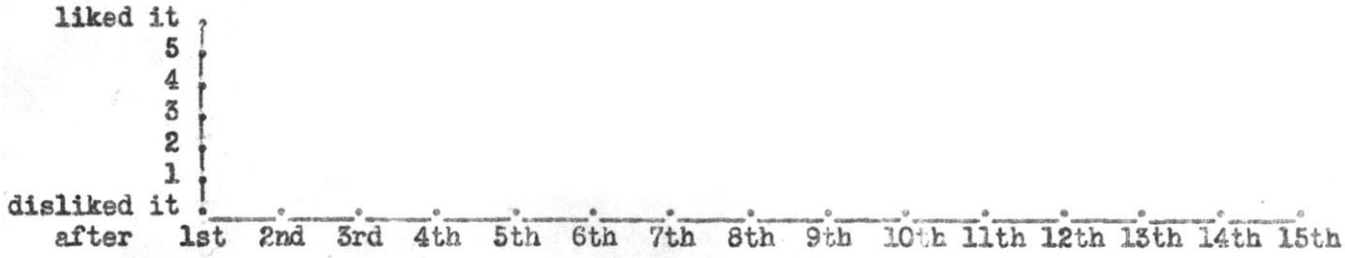
0 ——————————————————————— all necessary

b. Check below the proportion of necessary messages you personally received on the last five trials.

0 ——————————————————————— all necessary

11. Do you think you solved the problem in the fewest messages possible?

12. See if you can recall how you felt about your job as you went along. Draw the curve below.



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Supervisor, Wm. Filene's Sons, Boston, Summer, 1947

Consultant, Jordan Marsh Company, Boston

Publications:

1. "The Retention of Verbal and of Motor Skills," (with Harold Schlosberg), J. Exper. Psychol. Vol. 34, (5) October, 1944.

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