COMMUNICATION NETWORKS IN SMALL GROUPS

by

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THESIS

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ABSTRACT

In the present study, work is undertaken to find out how different communication networks affect the way in which a solution to a problem is derived by a small group, and also how these different communication patterns affect the behaviour of the members of the group. After some conclusions are drawn with regard to the small groups, certain generalizations are made, in order to see, how the results obtained from this study are applicable to large scale organizations. The use of this study, resides in that the results obtained can be used to improve the communications within organizations, so that their operations become more efficient.

ACKNOWLEDGEMENTS

I am especially indebted to Dr. Kenan Şahin, who as my thesis advisor, suggested the present topic to me, provided me with instructions and ideas to construct an apparatus and to run the experiments in a successful manner, motivated me in my research throughout my work, made very helpful comments on the study and revised my thesis so that it took its final shape.

I also express my thanks to Dr. Ahmet Koç for his motivation and his instructions.

I am also indebted to my brother Albert Sidi whose help in selecting members for my experimental groups has been invaluable and also to my wife Renee without whom I would not have been able to conduct my experiments.

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Viktor Sidi

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CHAPTER I

INTRODUCTION

THE IMPORTANCE OF CUMMUNICATION

In today's world most of the activities which go on are within the boundaries of an organizational set-up. We can find an organizational set-up in most of our society's institutions. The organization of activities is a necessary aspect of any institution no matter what its objectives are. The institution may be a non-profit enterprise as a school, a hospital or it may be profit seeking and be an industrial, financial, service or commercial company. Organization of activities is a necessity for survival and progress, for in our complex world a large number of activities are tied or related to one another and if the harmony of the system is sought, all the integral parts of the system should be organized in a way, so that everything works smoothly.

The harmony to be maintained in an organization, heavily depends on the ability of its members to communicate with one another, when such a need arises. For this reason, a large emphasis should be laid upon the communication in the organization. Communication is created by the fact of employing symbols systematically between individuals in order to exchange ideas. Basically, the individual is dependent on communication and his ability to receive it. By the same token, organizations rely upon efficient communication in order to be effective. Going a step further we may say, that political, economic and social communities rely upon communication. The fact that huge organizations depend on communication in order to run, makes communication one of the most vital parts of our organizational needs.

DEFINITION OF THE PROBLEM

In this work an attempt has been made to answer the following questions: How should communication be organized? In what way can messages be sent among individuals so that a group can solve a problem quickly, arrive at an answer, draw a conclusion and make a decision in the fastest and yet most accurate manner? Should we have centralized or decentralized communication patterns? What are the effect of different communication networks on the speed at which and the accuracy with which a problem can be solved? How does a communication pattern affect the psychology of individuals? What is the effect of the psychology of the individuals on the solution of a problem?

These questions make up the problem to be studied in this work.

REVIEW OF PREVIOUS RESEARCH

Original work was done, to answer the questions paused above by A. Bavelas. Later Harold J. Leavitt published the results of his experiments with Freshman students at M.I.T. After Leavitt, Harold Guetzkow and Herbert A. Simon together made experiments of their own. Recently some theoretical work has been undertaken by A. M. Cohen.

CHARACTERISTICS OF THE PRESENT WORK

All previous researchers in this topic of looking for the communication pattern which allows the quickest and most accurate solution of problems by small groups, have attempted to test different communication networks. The present work gives the results of tests carried in all of these communication networks together, and also it gives the results of experiments made with an entirely new network, namely the Δ network.

MOTIVATION FOR THE TOPIC

The impact that communication has on various aspects of our lives, the importance of communication within the organizational setting, the wide range of applicability of communication research, the work of previous researchers and the fact that no such work has been previously undertaken in Turkey has led me to choose this topic for study.

DESCRIPTION OF THE STUDY

In order to carry out the experiments, five-man groups were operated in different communication networks. The procedure of the experiments will be explained in more detail later on. The advantage of having to experiment with small groups is that they simulate in a good manner a large scale organization, and yet they avoid the difficulties encountered in analysing a complex organizational set-up. In this way attempts to generalize some conclusions may be made.

CONCLUSIONS DERIVED

The results of the present study tend to agree in general with the findings of previous studies. In their broadest form the conclusions are, that centralized communication networks tend to speed up the organizational evolution of a group; in centralized networks groups stabilize their organizational pattern faster than in decentralized communication networks. However, it is the decentralized communication networks which give the greatest satisfaction to the members of the groups operating with them. Fuller details of these findings will be given in subsequent chapters.

ORGANIZATION OF THE STUDY

From this point on the work is divided into three main parts. These parts are, first the theoretical aspects of the study which incorporate such concepts as flexibility, efficiency, centrality and symmetry; second, the description of the study, which includes the organization in different networks and the description of the experiments; and third, the analysis of the results and the conclusions derived.

CHAPTER II

THE THEORY

OVERVIEW

This chapter considers the theoretical aspects of communication within small groups. It starts out by giving an overview of the subject and then presents Bavelas' approach. Then while discussing operational characteristics it presents the concept of flexibility. Then the chapter continues by indicating what the minimum number of communications and the minimum time required for the solution of a problem by a group are. It goes on discussing what the effects of communication patterns on individuals are, and develops the hypothesis. Along the way it presents such measures as the sum of the neighbors, the sum of the distances, the centrality index and the peripherality index, which help determining the efficiency of a group. The ~~the~~ chapter discusses the organization of different patterns. More details on all of these considerations are given in the following pages.

THEORETICAL CONSIDERATIONS

Introduction: A certain minimum amount of communication is required by a group of individuals who have a common objective, and who need cooperative action in order to be able to reach a decision. By this we mean that if a group is to solve a problem and if the information necessary for the solution of the problem is distributed among the members of the group, these members have to communicate with one another in order to obtain an answer to the problem. But we should be careful about the fact that it is not compulsory that each individual in the group communicate will all the other members of the group. In some instances it may be sufficient that each individual in the group merely be in contact with the network of communication to which other members of the group are also related, i.e., that he communicates only with one other member of the group.

The members of the group may be connected to one another in very different patterns. Out of this very large number of different patterns only a few are useful for the purpose of achieving effective performance. The aim of the present experiment is to determine whether different patterns of communication among the group members affect the task performance, i.e., whether the communication pattern among individuals affect the speed and the accuracy needed to reach an answer to a problem, and if an effect is determined, what the best pattern of communication is, to facilitate the task of finding a solution to a group's problem.

The pattern of communication that evolves within a group, is determined by several factors. Some of these factors might be the cultural background of each individual, his social class, his abilities and intelligence. Other determinants of the evolution of the pattern of communication within the group may be the task to be performed, i.e., the problem to be solved and the environment in which the group operates. This is also true for groups whose communication patterns have been determined by outsiders. In this case, differences may occur as to the number of links used - a link being the channel of communication between two individuals - the amount and kind of information conveyed - which may be called "channel capacity" - and the symmetry of the pattern of communication. The symmetry concept will be explained later on in more detail.

The Bavelas Approach[1]

A. Bavelas was the pioneer, who thought of defining dimensions for group structures and set the pace for subsequent experiments carried out by other people. The purpose of the experiment being to analyse the structure of communications in groups, individuals and communication channels are the principal items that are involved. The group may then be thought of as cells connected to one another. Here the cells represent individuals and the connections represent communication channels. Once these analogies have been defined in this way, the work of Bavelas may be found to be applicable to the description of communication patterns within groups.

Several dimensions defined by Bavelas may be used to study the communicative behavior in groups. For instance, the way in which communication patterns vary may be described by the "sum of the neighbors" that each individual has, each neighbor being defined as the individual with whom a member may directly communicate.

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[1] A. Bavelas, "A Mathematical Model for Group Structure", Applied Anthropology, 1948, VII, pp. 16-30.

Differences within and between structures may also be accounted for by the concept of "centrality" as defined by Bavelas.

This concept may be best seen when we define the most central position, as the position closest to all other positions in a pattern of communication. The distance between positions is defined by the number of communication links which is used to get from one position to another by the shortest route.

Some measures have been introduced by Bavelas to quantity the above concept of centrality. The "Sum of the Neighbors" measure is the summation, for the whole structure, of the number of positions one link away from each position. The "sum of the distances" is similarly the summation for all positions, of the shortest distances, in links from every position to every other one.

What defines a pattern is the manner in which the cells are connected and not the way in which they are represented on paper. Two patterns are said to be the same if they can be bent into the same shape without breaking a link. If a link is broken in this process, then the two patterns are said to be different. The dimensions defined by Bavelas can not define uniquely a pattern of communication. For uniqueness, more advanced techniques of mathematics and complex topological concepts which do not enter the scope of this study are necessary.

Later on, a similar concept, that of symmetry developed by Guetzkow and Simon will be presented. Interpretation of the results of the experiments by both concepts leads to the same conclusions.

OPERATIONAL CHARACTERISTICS

PATTERN FLEXIBILITY[2]

The individuals do not need to use all the communication channels available to them in order to obtain a solution to the problem. The following example will serve to illustrate this in a better way: Suppose the pattern of communication of seven links as shown in Figure 1 is given. The individuals may organize themselves in the following manners to solve the problem:

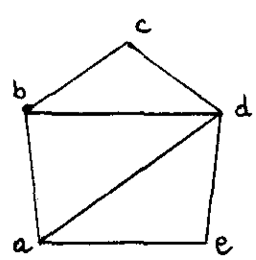

FIGURE 1.

- a and e send their information respectively to b and d
- b and d send their information together with what they receive to c
- c formulates the answer and sends it to b and d
- b and d send the answer respectively to a and e.

In this way three of the seven channels have been ommitted from the communication pattern and what we will call a chain network

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

has been established. This network may be represented as in Fig. 2.

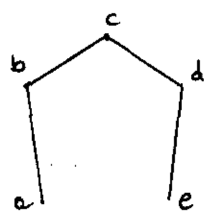

FIGURE 2.

This four link pattern may also be changed. If a, b, c, and e all send their information to d, and d arrives at an answer and then sends back the answer to a, b, c, and e, what we call a "wheel" pattern of communication will evolve. This pattern may be represented as in Fig. 3.

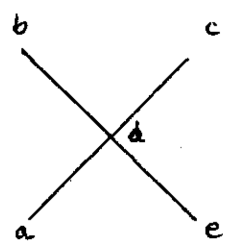

FIGURE 3.

This fact that, the communication pattern of the group may be changed as shown above so as to accomodate for a fast and accurate communication is termed the pattern flexibility.

<u>OPERATIONAL FLEXIBILITY</u>: Given a certain number of connections, and a fixed pattern of communication, this pattern may be used in several ways which we call operational flexibility. Going back to our chain network example, the decision can be made either by

a, or b, or c, or d, or e depending on who sends the information to whom and whether it is a, b,c, d or e who occupies the key position to formulate the answer. There the decision made is unique; however, patterns with two or three decision makers may also be used.

EFFICIENCY OF COMMUNICATION

The efficiency of communication may be defined as the combined speed and accuracy by which a solution to a problem is obtained. This speed depends on the pattern in which groups operate. This hypothesis is supported by the findings of the experiments. The following gives us a brief review of the theory behind this hypothesis.

The Minimum Number of Communications: For n individuals the minimum number of communication C is given by the following relationship:

$$C = 2\,(n - 1)^{*}$$

One communication here is considered to be one written message carrying information.

Therefore theoretically, with a certain number of individuals in a group as the only criterion, the pattern of communication is not important, since according to the above relationship,

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* Harold J. Leavitt, "Some Effects of Certain Communication Patterns on Group Performance", The Journal of Abnormal and Social Psychology, Vol. XLVI (1951), pp. 38-50.

the minimum number of communications C is dependant only on the number of individuals in the group n. Therefore, the minimum number of communications is the same for all patterns, provided that the number of individuals in the group remain constant.

The Minimum Time Required for the Solution: The assumption to be made here is that each individual in the group has the same ability; that is, the members in the group can think, work, write at the same speed and with the same accuracy. Given this assumption, the minimum time required by a pattern of communication to reach a solution to a problem can be computed. The time required for a message to be issued by an individual and be received by another will be defined as a "time unit". Two cases should be considered separately.

1. The number n of individuals in the group is odd. If we suppose that each member in the group can communicate with another member of the group "x + 1"** is the minimum number of time units required for a group with n members (n = 2a + 1) where a is a positive integer and where x is defined as follows:

$$2^x \quad n \quad 2^{x+1} \qquad \text{or} \qquad x \quad \log_2 n \quad x + 1$$

i.e. $x = \text{integer}\log_2 n$.

Therefore for a 5 man group the minimum time units required can be computed as follows:

** Harold J. Leavitt, "Some Effects of Certain Communication Patterns on Group Performance," The Journal of Abnormal and Social Psychology, Vol XLVI (1951), pp. 38-50.

$2^2 \quad 5 \quad 2^{2+1} \qquad 2^2 \quad 5 \quad 2^3$

$x + 1 = 3$ <u>Ans. = 3</u>

Therefore no 5 man pattern can be done in less than three time units, although they may take more than that.

2. The number of individuals in the group is even: If we suppose unrestricted linkage <u>"x"</u> is the minimum number of time units required for a group with n members with n = 2a where a is a positive integer and where x is defined as follows:

$$2^x = n \qquad \text{or } x = \log_2 n$$

Therefore for a 4 man group the minimum time units required can be computed as follows:

$2^2 = 4 \qquad x = 2$ <u>Ans. = 2</u>

Therefore no 4 man pattern can be completed in less than 2 time units although they may take more than that.

<u>EFFECTS OF PATTERNS ON INDIVIDUALS</u>

Performance may vary among groups because:

a. Certain differences exist among people.

b. The patterns produce certain forces that should be considered.

The problem is therefore one of analysing the forces acting on the individuals in the network at any position and finding out how they affect the individual behavior. If predictions can be made in this respect, then improvements can be made in organization

The central position is very important in this connection. Centrality is important because it shows how a position is strategically located with respect to others. This accounts for differences in the behavior of the individuals.

The available information is believed to be the most important determinant of the behavior of individuals. This is because it determines one's role in the group. The individual who has access to vital information and who has the ability to collect and process it is seen in another way by the group than a person who merely waits for the answer to come. Centrality which is a measure of the distance between members and therefore of the availability of information, is consequently very important in predicting how the individuals will behave while communicating with each other. Here the distance between members of the group is defined as the number of communication channels that are needed to be crossed for one individual to get a message through to another member of the group. The differences in centrality among different patterns which lead to differences in the parts played by the members operating in each of these different patterns of communication account for the differences in the responsability, independence or monotony of each individuals task's. These in turn should effect the behavior, i.e., the speed, the agressiveness, the accuracy and the flexibility of an individual.

DEVELOPMENT OF THE HYPOTHESES

The use of a five-man group can be said to simulate to a good extent a large-scale organization. This five man group has the characteristics of communication of the larger organization, but it also avoids some complexities associated with them.

The problem can be analysed from two points of view:

1. The effects of restricting communication among members or the organizational set-up of the group.
2. The effects of restricting communication among members or the operational task of the group.

The problem is therefore two-fold. To put it in Herbert A. Simon's and Harold Guetzkow's words the problem has a "procedural" or organizational aspect and a "substantive" or operational aspect. We may now state the Simon-Guetzkow hypothesis: "Imposition of certain restrictions or the communication channels available to a group effects the efficiency of the group's performance, not directly by linking the potential efficiency of task performance with optional organization in the given set, but indirectly by handicapping their ability to organize themselves for efficient task performance."[3]

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[3] Harold Guetzkow and Herbert A. Simon, "The Impact of Certain Communication Nets Upon Organization and Performance In Task-Oriented Groups", Management Science, Vol 1, Nos. 3 and 4, April-July, 1955.

Let us now turn to the hypothesis of Simon, Smithburg and Thompson. Their argument is that there is a two-fold communication in decision making organization:

"Communications must flow to the decision center to provide the basis for decision, and the decision must be communicated from the decision center in order to influence other members of the organizations whose cooperation must be secured in order to carry out the decision."[4]

In our experiment which followed the lines of the experiments carried out by Leavitt and afterwards by Simon and Guetzkow, with a group of five members, given five out of six symbols each, and with a problem requiring to find what the symbol common to all is, there is also a two-fold communication flow.

1. The flow of information: The only thing a member knows at the start of each trial is his own missing symbol. He need not know all the other missing symbols to formulate an answer. In order to get to a solution each individual has to know his answer only and then write it down. The exchange of information of this kind, i.e., the exchange of information pertitinent as to what some of the missing symbols are, is the preliminary step towards making a decision.

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

2. Flow of decision

The answer that is found by a member or some members of the group should be communicated to members who cannot or have not arrived at an answer. The decision is thus known by all the participants.

In any case a division of labor is required in the group in order to reach an answer. Here a dichotomous situation evolves since:

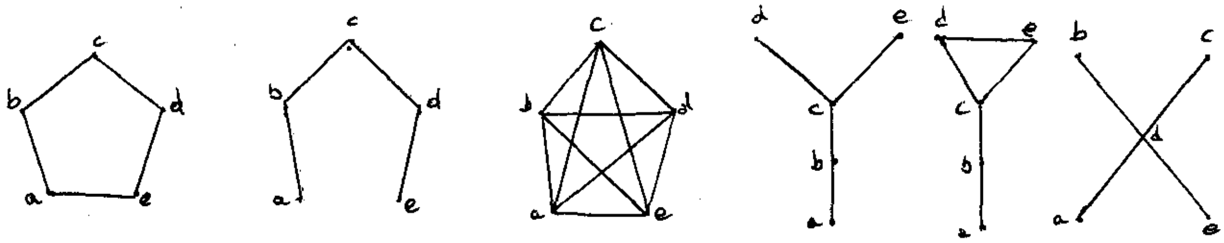
a. Either everyone may exchange information with everyone or a single participant collects all the information about the missing symbol.

b. Either everyone may form the solution of his own, or get specialized so that a single participent arrives at an answer. This leads to the fact that:

c. Either there is no circulation of answers or the answer is handed out by a single person.

The aim of the experiment is to find out which organizational arrangement and which communication restrictions are best, and how communication restrictions effect the organizational arrangement required to carry out the operating task.

In my experiment I used six different patterns of communication. These are as shown on the following page.



Circle   Chain   All-channel   Y   Δ   Wheel

Of these communication nets, the circle and the wheel patterns are the extreme cases.

In the circle net, if two neighbors send their information to respective other neighbors and if in turn, these members relay their information together with the information they received to the fifth member of the group, this last person may sort out the information, make a decision and send back the solution he found to the other members of the group, through the same channels used to reach him. Simon and Guetzkow call this pattern a "three level hierarchy".

In the wheel net, the persons who are, so to speak, on the periphery of the network may send their information to the individual who occupies the central position. This last member may process the information, make a decision and send back to the members on the periphery the answer he has come up with. Simon and Guetzkow call this pattern a "two level hierarchy".

These communication networks may be shown to be equally efficient, i.e., although the circle pattern requires more time to reach an answer because of the time delays involved in the relaying of information, both the circle and the wheel group require a minimum of eight messages to develop a solution.

As to the other networks, namely, those of the chain, Y and Δ patterns, although they require different times to reach a solution the minimum number of messages required is again eight.

The all channel group may evolve a communication pattern similar to any of those discussed before or others.

At this point a remark is worthwhile to be made. The channel usage analysis is misleading in that it supposes that the two level hierarchy is twice as efficient as the three-level hierarchy. The reason is that this analysis compares efficiency by the number of necessary relays. As the number of relays of the wheel group is half of that in the circle group, the assumption that the wheel group is twice as efficient as the circle group may appear to be correct. But we should not forget that relaying information is not the only task in the problem. There is the question of receiving, organizing and processing information which also requires some time. Therefore, the basis for comparison of the efficiency should be the cumulative time needed to perform all these tasks and in the proper sequence. To make a proper comparison of these efficiencies we must have a look at the "methods time measurement analysis" of the task made by Hellfach.[5]

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5 Harold Guetzkow and Herbert A. Simon, op. cit., p. 264.

The Methods-Time measurement is a motion time study. It is used extensively in industries. This analysis consists in identifying the basic motions needed to accomplish the operational task and assign these tasks some standard times. Hellfach analyzed each member in each position in the five man group. The group was arranged first as a three level hierarchy, that is in a circle pattern and then as a two-level hierarchy, that is , in a wheel pattern. Hellfach then made a composite analysis of the two patterns after having made allowances for the idle time associated with the kind of sequence followed by each arrangement. For instance it is assumed that a relayer is not able to issue information until he has received some. On the basis of this analysis he estimates the operating times as being .437 minutes or 26.22 seconds for the three level hierarchy and as .445 minutes or 26.70 seconds for the two-level hierarchy. This is, of course, not significant as far as the difference in operational motion time is concerned. As a matter of fact although it may appear to be strange, the three level hierarchy comes out to be slightly more efficient in this respect, since it is quicker in making an answer.

We may, therefore, conclude that, the restrictions imposed on the communication network has an effect on the performance of the problem. But this influence is not direct; it is only through the organizational arrangement that the restrictions can effect the task performance.

The restrictions do so by altering the ability of the members to organize themselves. As soon as the group discovers the optimum organizational set-up within the limits set by the restrictions in the network, the minimum time spent to solve the problem by the circle group, which is one of the extremes, should be approximately the same as that required by the wheel group which constitutes the other extreme case. If we generalize, we may say, that in any communication pattern, Circle, Chain, Y, Δ or Wheel, the minimum operational time required should be approximately equal in each group, once the groups have organized themselves in an optimum way, i.e., in a way that ensures the fastest and most reliable answers. A further generalization will lead to the conclusion, that there should be no difference in the minimum time requirements for the performance of the task with optimal organization, between the networks with restricted communication-such as the circle, chain, Δ , Y or wheel networks - and the network with unrestricted communication, i.e., the all-channel pattern, since the all-channel network, while organizing itself, will eventually evolve into one of the restricted patterns and will in the end become stablized with an optimal organizational set-up, for fast and accurate communication.

EFFECTS OF CENTRALITY

Before going into the details of the subject, it would be better to redefine some of the measures that were mentioned until now. If we name each member of a five-man group as A, B, C, D and E the following relationships exist:

Sum of the neighbors = Sum of the number of neighbors one link away from each member.

Example: In the wheel group (Fig. 4) the sum of the neighbors is computed as follows:

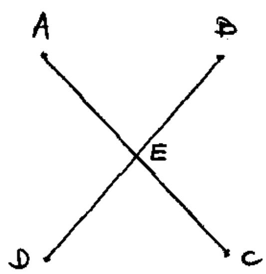

FIGURE 4.

A - E	1
B - E	1
C - E	1
D - E	1
E - A	1
E - B	1
E - C	1
E - D	1
Sum =	8

Sum of the distances = Sum of the minimum number of links from all members to all the other members.

Example: For the wheel group (Fig. 4) the sum of the distances is computed as follows:

	Minimum number of links
A - B	2
A - C	2
A - D	2
A - E	1
B - A	2

		Minimum number of links
B - C		2
B - D		2
B - E		1
C - A		2
C - B		2
C - D		2
C - E		1
D - A		2
D - B		2
D - C		2
D - E		1
E - A		1
E - B		1
E - C		1
E - D		1
Sum	=	32

$$\text{Centrality index} = \frac{\text{Sum of the distances}}{\text{Minimum number of links from one member to all other}}$$

Example: The centrality index of an individual on the periphery of a wheel group (Fig. 4) is computed as follows:

From the previous example:

Sum of the distances = 32

The minimum number of links from A to all other members is computed as follows:

A - B		2
A - C		2
A - D		2
A - E		1
Sum	=	7

The centrality index is: $\frac{32}{7} = 4.6$

In the same way we can calculate the minimum number of links for B, C and D and then calculate their centrality indices which turn out to be the same since they occupy positions similar to that occupied by A.

In a similar way the minimum number of links from E to all other members may be computed as follows:

E - A		1
E - B		1
E - C		1
E - D		1
Sum	=	4

The centrality index of E is: $\frac{32}{4} = 8.0$

This indicates that the position of E is more central than those of A, B, C and D.

Peripherality index = Centrality index of the most central member, i.e., the one with the highest centrality index
-- Centrality index of the particular member.

Example: The peripherality indices of members A, B, C, D and E in the wheel group (Fig. 4) may be computed as follows:

For A = 8.0 - 4.6 = 3.4
For B = 8.0 - 4.6 = 3.4
For C = 8.0 - 4.6 = 3.4
For D = 8.0 - 4.6 = 3.4
For E = 8.0 - 8.0 = 0.0

This indicates that in the wheel group E is the least peripheral (or the most central) of all members of the group while A, B, C and D are equally peripheral (or equally central) with respect to one another.

All distances are measured in number of links - a link being a channel of communication between two members. Therefore, the distance from A to E in the wheel group is 1, that from A to B is 2, etc...

Bavelas defined the central position or region of a network as:

"The class of all cells with the smallest p to be found in the structure"[6]

where p is defined as the longest distance between one position and any other position in the network.

The centrality is to be thought of as a function of both the type of the network and the number of the members in the group. For instance the centrality of each member in a six-man wheel group would be different from those found in the five-man wheel group since the number of individuals in a group would affect in different proportions the sum of the distances and the minimum number of links from one particular member to all the others.

The following table shows the centralities of different networks.

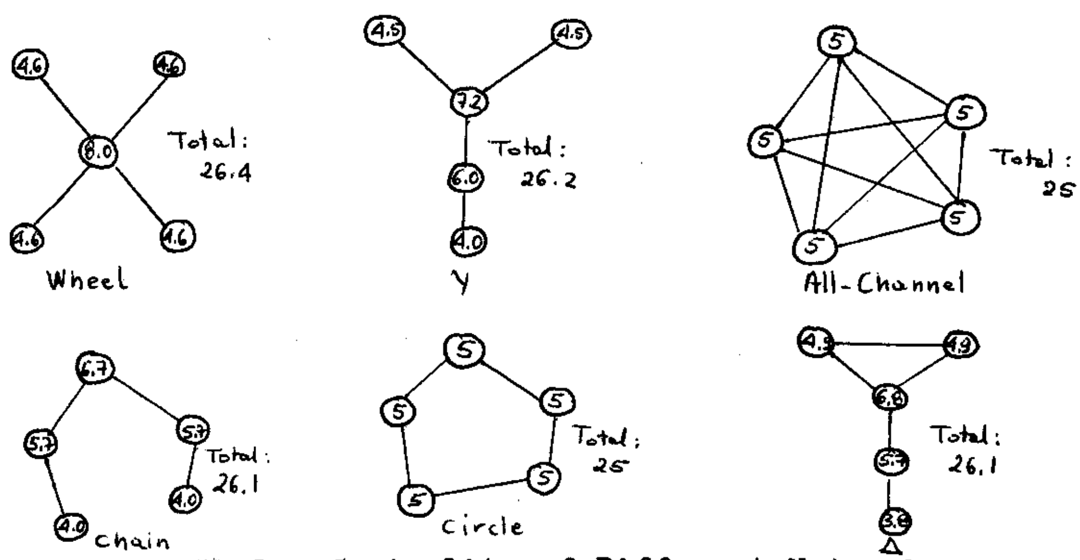

TABLE 1: Centrality of Different Networks

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[6] A. Bavelas, "A Mathematical Model for Group Structure", Applied Anthropology, 1948, VII, pp. 16-30.

The following figures show the peripherality indices of different networks.

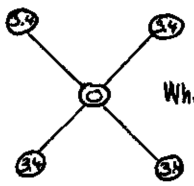

Fig. a

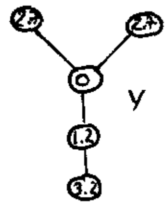

Fig. b

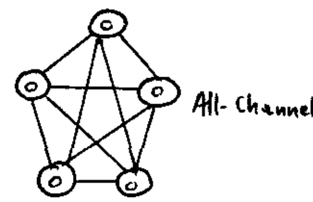

Fig. c

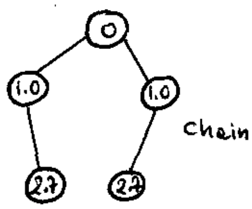

Fig. d

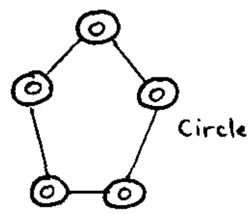

Fig. e

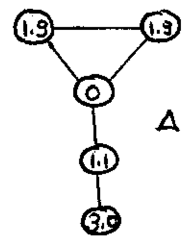

Fig. f

TABLE 2: Peripherality of Different Networks

Here it would also be worthwhile remembering that the minimum number of time units required to reach an answer to a problem in a five-man group was theoretically given for every pattern by the formula:

$$t = \text{integer } \log_2 n$$

where n is the number of individuals in the group, and that therefore, t was equal for any communication network to:

$$t = \text{integer } \log_2 5$$

$$t = 3 \text{ time units}$$

Here a time unit was defined as the time required for a communication to be issued and received. A communication here means a written message carrying some information.

It should also be remembered that the minimum number of messages needed by a group in order to reach an answer to a problem in any communication network was given by the formula

$$C = 2(n - 1)$$

where C is the number of communications and n is the number of individuals in the group.

The minimum number of communications for a five-man group is therefore:

$$C = 2\ (5 - 1) \qquad C = 8 \text{ communications}$$

The following table may then be constructed.

Network	No of Links	Sum of Neighbors	Sum of distances	Most Central Position	Min. time units	Min. no messages
Wheel	4	8	32	8.0	3	8
Y	4	8	36	7.2	3	8
All-channel	10	20	20	5.0	3	8
Chain	4	8	40	6.7	3	8
Circle	5	10	30	5.0	3	8
Δ	5	10	34	6.8	3	8

TABLE 3: Summary of Theoretical Aspects of Networks.

THE ORGANIZATION OF DIFFERENT PATTERNS

In this analysis let us first consider the all-channel group and make it the basis for comparison of all the other groups restricted according to different patterns of communication.

THE ALL-CHANNEL PATTERN

a. Number of open channels: The number of open one-way channels in this pattern is maximum, that is, 20. The members have, therefore, every channel open to them for communication. They have to develop a organizational arrangement by cancelling certain channels which are of no use. To select those which are useful from among those available is quite a difficult task, and each group has to do this for its own.

b. Number of symmetric positions: The number of symetric positions, that is positions which have no advantage over one another as far as the task is concerned, is 5 in the all-channel pattern. This makes the problem more difficult to solve.

c. Minimum number of relays necessary: The minimum number of relays necessary in the all-channel group is 0. Each member may communicate with the other, and no relays are necessary. This may seem to be an advantage at first, but when the disadvantages are taken into account it seems to be not of much value.

THE CIRCLE PATTERN

a. The number of open channels: The number of open channels is restricted very much when compared with the all-channel pattern. There are only 10 one-way channels available, amounting to a 50% reduction.

b. Number of symmetric positions: The number of symmetric positions is still the same, that is, 5. Therefore, there is not a relative advantage among the positions of the members of the group, as far as the making of the decision is concerned.

c. Minimum number of relay necessary: With the circle pattern the necessity of having at least two relays arises. That is, a three-level hierarchy evolves. This means that at first no single person of the group is within direct reach of the four other missing symbols. His two neighbors have to transmit him their information along with that information that they received which amounts to having two relays.

When we look at the circle pattern in this way we see that it needs to evolve an assymmetrical pattern which will permit the processing of information, and also it needs to establish relays. Although to a very small extent, some channel elimination is necessary.

THE CHAIN PATTERN

a. Number of open channels: In this pattern there is a 60% reduction in open channels. The number of open one-way communication channels is 8.

b. The number of symmetric positions: The number os symmetric positions can be seen in the following pattern 2-2-1. This means that two members of the group have similar positions, still two others have two other similar positions one has a still different position. But we can see no considerably advantageous position, as far as the solution of the problem is concerned. The positions are equipotential two by two.

c. Minimum number of relays necessary: This pattern requires a three-level hierarchy too. That is, it needs at least two relays to carry out the task. Again the two neighbors of a member have to transmit him their information together with what they receive, since no member has immediate access to the other four missing symbols.

Therefore, we may say that the chain net has a small advantage over the circle pattern in that it needs no elimination of channels, a task which already was minimal with the circle pattern. Although the chain arrangement is more assymmetrical then the circle set-up, there is still a need for evolving more assymmetry. As to the number of relays it is the same in both networks.

THE Δ PATTERN

a. Number of open channels: The number of open channels is reduced by 40 per cent, that is, there are 10 one-way communication channels. Therefore, there is a lot of organizational work to do with respect to the unncessary channels that have to be eliminated.

b. Number of symmetric positions: Only two positions are symmetrical here. The other three each have particular characteristics. There is the organizational problem of who is going to formulate the answer. So this is a complication.

c. Minimum number of relays required: If one of the extremities formulates an answer at least two relays are necessary. But if one of the intermediate positions makes the decision only one relay is sufficient. Therefore, the minimum number of relays required is one.

In short we may not say that the Δ pattern is more advantageous or disadvantageous than the chain pattern.

THE Y PATTERN

a. Number of open channels: Here again there is a 60% reduction in the number of channels, this number being 8. So there are no unncessary channels and no need to go through an elimination process. This is an advantage over the Δ pattern.

b. Number of symmetric positions: Here only two positions are symmetrical. The other three are different. The organizational problem of who is to formulate an answer is important. If one of the symmetrical positions or the other extremity is to form an answer this is very disadvantageous position since it requires two relays. So one of the intermediate positions should become the decision maker.

c. Minimum number of relays required: A minimum number of one relay is necessary. This happens when the decision maker occupies one of the intermediate positions.

In short the Y pattern is better than the Δ pattern in that it reduces the number of open channels and also it reduces the organizational set-up task.

THE WHEEL PATTERN

a. Number of open channels: Here the open channels are 8 in number. This means that there are no unncessary channels. The reduction is again 60%.

b. Number of symmetric position: The number of symmetric positions is 4. So one of the positions has a relative advantage over the others with respect to the decision making process in this arrangement. This is a superiority over the Y pattern.

c. Minimum number of necessary relays: The four people on the periphery of the network do not have the power of forming a solution unless they have information relayed by the person occupying the central position. Therefore, such a decision making process would not be advantageous. But if the person occupying the central position makes the decisions no relays are necessary since this person has direct access to the other four individuals in the periphery of the group. He may receive the information directly, form an answer and send back the solution directly to the other four individuals. This avoids the problem of relaying information and also the organizational problem as to which of the four persons on the periphery will make the decision. This makes the wheel pattern better than the Y pattern.

In this way, by reducing the number of open channels to a minimum, by having a good assymmetric position, and by needing no relays it reduces the organizational problem still further while keeping the operational task unchanged.

CONCLUSION

The circle group is the one which has the most difficulties. First of all this group has to select the member who is to make the final decision, then it has to establish at least two relays and also to eliminate some channels of communication which are unncessary. This last task is minimal.

The chain group is more advantageous than the circle group in that it does not need to eliminate unncessary channels. Otherwise the chain group still has to develop a decision center and also to establish at least two relays.

The Δ group has to establish one less relay than the chain. But it has to eliminate some channels of communication in order to achieve an efficient organizational arrangement. This arrangement needs also the selection of a decision center.

The all-channel patter holds an intermediate position as far as difficulty is concerned. It requires both the elimination of certain communication channels and the establishment of a decision center. The advantage of this group is that it needs no relays.

The Y - group is next to the Δ group in that it has the same organizational responsibility of establishing one relay and selecting a decision-maker, but it does have to eliminate channels.

The wheel group should have the least difficulty, because it has no channel to eliminate and no relays to establish. Since it has one assymmetric position, highly advantageous as far as the decision making is concerned it has pratically no organizational work to do.

From the above discussion we may see that the restrictions imposed on the network may either complicate the situation imposed by the unrestricted network that the all-cahnnel pattern is, as the circle and chain group do, or facilitate the process as the wheel and Y group do. This, of course, depends on the kind of the restriction.

At this point it may be appropriate to recall the Simon - Guetzkow hypothesis that indicate that these restrictions alter the organizational task rather than the operational task. With these considerations in mind we may now turn tothe experimental results.

CHAPTER III

THE EXPERIMENTS AND THE FINDINGS

OVERVIEW

This chapter starts by describing the experiment, the task, and the apparatus used. It continues by analyzing the results: it studies the groups as to their speed, their accuracy, their volume of communication and their stability. It tries to understand what the behavioral effects of the networks are, and tries to relate those psychological findings with the other elements. Along the way it analyses whether any difference between networks is statistically significant.

THE EXPERIMENT

The purpose of this experiment is to discover if any, the relationship between the behavior of the group and the pattern of communication in which it operates. The psychological effect on the group members of the various communication patterns, and the organizational and behavioral effect of this psychology were also to be investigated.

The experiment was done with groups of a constant size (5 members), employing two-way written communication and the task was the collection of information among members.

DESCRIPTION OF THE TASK

To each member of the group each labeled by a color, a card with five symbols out of a possible six was given. Each member's card was different from the others in that the missing symbol, that is, the sixth one, was different in each case.

In this way, in any set of five cards there was only one symbol in common. The discovering of the common symbol among the members was the purpose of the problem. To this end, the members in the group communicated with each other by means of written messages through the communication channels that were open to them. When a member of the group found out what the solution was he was allowed to communicate it to the others through the allowable channels. A message was considered to be each written information going from one member to another.

The trial was ended, whenever all five members of the group informed that they had discovered what the common symbol among them was. Then another trial was begun. In the new trial another set of cards, with another symbol common to all members was distributed. The groups were given 10 consecutive trials. The symbols used and the composition of the cards is given in Table 4.*

Six symbols used: O △ ◊ ▭ + *

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* The symbols are the same as those used by Bavelas.

Trial No.	Symbol missing from Black	Red	Brown	Green	Blue	Common Symbol
1	△	◊	*	o	□	+
2**	◊	o	□	△	+	*
3	+	*	□	△	◊	o
4	□	◊	△	*	+	o
5	o	*	+	△	□	◊
6	△	o	□	*	◊	+
7	□	+	o	◊	△	*
8	◊	*	□	+	o	△
9	*	◊	□	△	o	+
10	+	o	□	*	◊	△
11	o	+	△	◊	*	□
12	*	o	□	△	+	◊

TABLE 4: Symbols Used During the Experiments

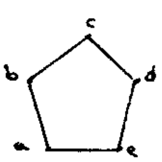
** The first two trials are given as warm ups.

THE APPARATUS

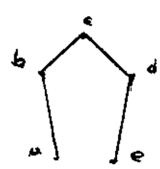
The members were all seated around a table. Each member was separated from the other by a vertical partition. The partitions had slots which permitted them to communicate with the other members of the group. Colored arrows showed the way messages had to be sent in order to reach the appropriate individual. Each member was given a pen writing in ink colored after each member's color label. The booths were also painted according to each member's color label. The members were provided with precoded message cards to carry information and also with blank cards which they used when trying to organize themselves. The cards carrying the symbols were given in the form of pads. Each card was numbered according to the trial number. When the trial was ended all a member had to do to begin the next trial was to turn over the page of the pad. Each member indicated that he had come up with the answer by raising his hand. When all five members had raised their hands the trial was ended and the next trial was started. Before the experiment started a series of instructions were read to the members and they were told that they were competing with other groups that tried to solve the same problems. Before the experiments began two preliminary trials were done in order to acquaint the members with their tasks. Between two trials 2 minute long intertrial periods were allowed to let the group organize themselves by communicating with the blank cards.

PATTERNS OF COMMUNICATION

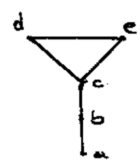
The following 5-man patterns were selected:



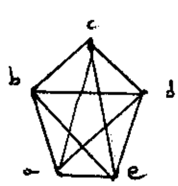
Circle



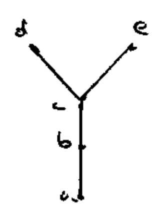
Chain



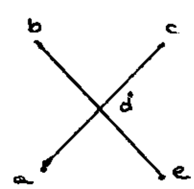
Δ



All-Channel



Y



Wheel

PROCEDURE IN SELECTING GROUP MEMBERS

In this study the experimental groups were all formed by students. In order to satisfy the requirements of the study, eighteen five-man groups operating three by three in each network were formed. The individuals constituting the groups were selected by a lottery system out of 42 available candidates.

SHORTCOMINGS OF THE STUDY

The main short coming of this study is the way in which members of the groups have been selected. Actually for the 18 five-man groups formed 90 people should have been used. However, as it was almost impossible to collect so many people, I had to make do with the 42 students that I could find. In view of this shortcoming I tried to overcome any bias by applying a lottery system to the individuals and in this way randomized to a great extent the participation in the group.

The second shortcoming is, that I had to make do with ten trials per experiment because beyond that number participants lost their patience and the continuation of the trials became irrelevant.

Another shortcoming was the use of only three experimental groups per network. The reason for this was that it became prohibitive to experiment with more than 18 groups in view of the huge number of participants needed, of the costs to be incurred and of the time required.

Despite these shortcomings, I tried to have the study as complete as possible, and it is my personal opinion that the results would have not been much different had these shortcomings not occured.

ANALYSIS OF THE RESULTS

The time taken by a certain group to reach an answer is the major determinant of this experiment. An answer was accepted when all the members of the group had found it. When we compare the average times for each network the following is seen:

1. The Circle Groups

The circle groups are the slowest of all. From graph II it seems that up until the fifth trial they do not seem to agree upon organizational patterns so as to reduce the time required to get to an answer. After the fifth trial they seem to improve constantly but they do not reach a stable time floor before the experiment is over.

2. The Chain Group

The chain network allows the groupsoperating in this structure to work quicker than the circle group and to improve its organization each time a bit more. According to the graph it seems that the groups seem to reach a quasi-constant time pattern towards the middle of the experiment but then continue to be more rapid as the trials go on. However, it does not reach a constant time level before the experiment ends although the ultimate clock-time for the last experiment is shorter than that of the circle network. (Graph III and Graph I).

3. The Δ Groups

The Δ Groups are quicker than the circle and chain groups. (Graph I) In addition to that they appear to be more steady in the evolving of their structural organization. Their rate of improvement appears to be smoother. However, they,like the circle and chain groups do not attain a constant time level at the end of the trials, but their final clock-time is very much the same as that of the chain groups.

4. The All-Channel Groups

The All-Channel network occupies an intermediate position on Graph I. Although the beginning and ending clock-times of both the Δ and All-Channel groups are very close to each other, the major difference appears to be the curvature of their curves. The slope in the Δ network appears to be steeper than that in the All-Channel network. This would mean that the All-Channel network tends to be steadier than the Δ network, and will eventually evolve a more stable time floor quicklier than the Δ network.

5. The Y Groups

The Y Groups appear to get organized very fast. From the fourth trial on they show that they already have developped an efficient organizational pattern since their clock-time is more or less stable. (Graph VI) On the whole their clock-time seems to be shorter than all the other groups except for the wheel group. (Graph I)

6. The Wheel Groups

The Wheel network allows the groups to be the fastest of all. They are quick in organizing themselves and get to an answer very fast. (Graph I)

The results that were discussed above confirm in a way our assumptions: that the group would more easily develop an efficient organizational pattern if the organizational task is little complicated and will have difficulties in developing an efficient organizational arrangement if the organizational task is hard to cope with.

Our empirical findings suggest too that this is true since the circle, chain, Δ , all-channel, Y and wheel groups organize more and more efficiently as one follows this sequence of networks. Therefore our experiments are an empirical evidence supporting our arguments.

	Wheel	Y	All-Channel	Chain	Circle	Δ
First Group	57.2*	63.9	94.7	130.8	173.0	102.9
Second Group	58.6	77.4	101.2	136.6	160.8	114.9
Third Group	56.6	55.4	88.2	128.2	171.6	133.1
Mean	57.5	65.6	94.7	131.9	168.5	117.0

* Figures are in seconds

TABLE 5: MEANS OF THE GROUPS

	Wheel	Y	All-Channel	Chain	Circle	Δ
First Group	34.0*	38.3	62.0	69.0	116.0	60.7
Second Group	33.0	45.0	61.0	86.7	105.0	67.7
Third Group	31.0	32.7	56.0	65.7	125.7	74.0
Mean	32.7	38.7	59.7	73.8	115.6	67.5

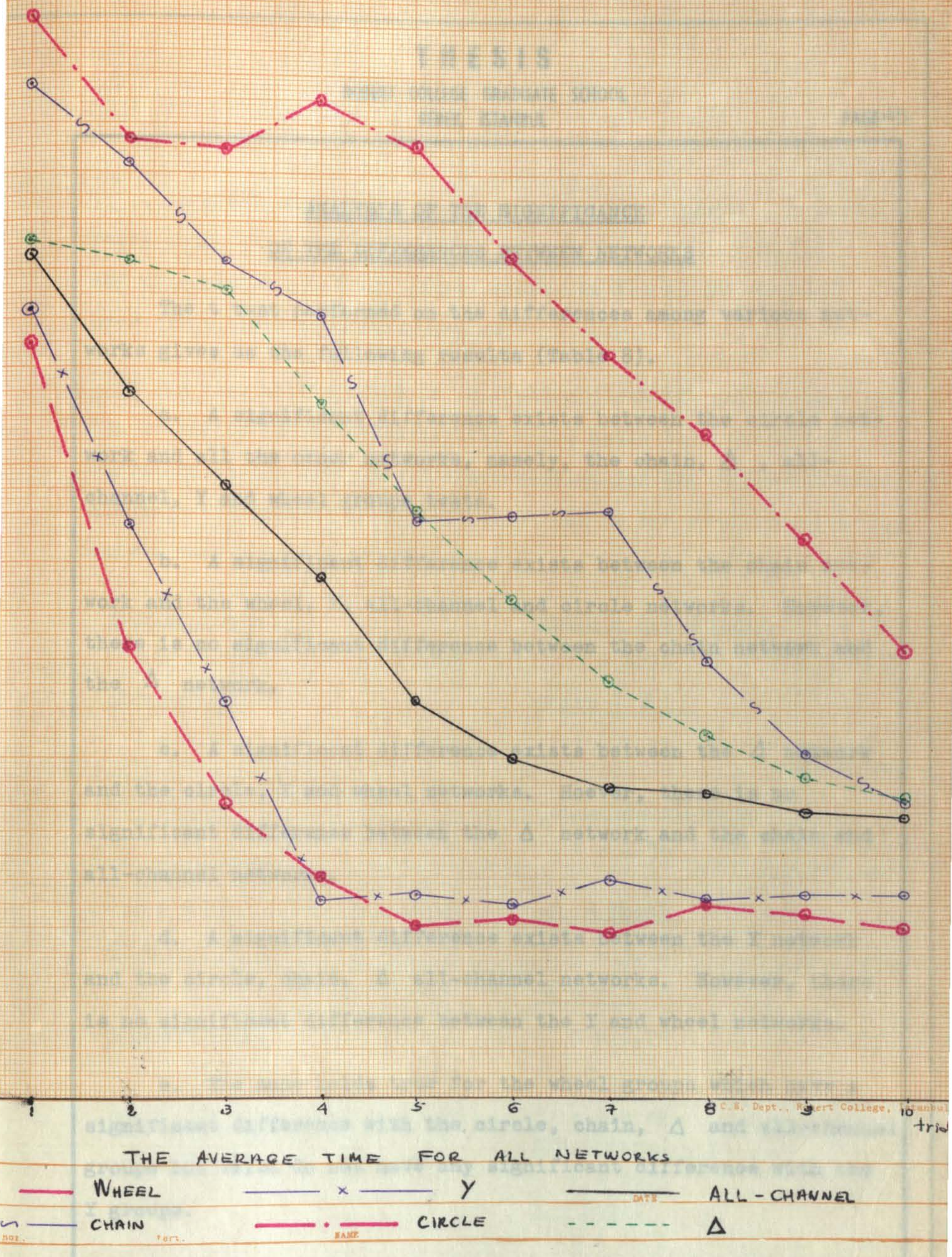
* Figures are in seconds

TABLE 6: MEANS OF THE THREE FASTEST TRIALS

	Wheel	Y	All-Channel	Chain	Circle	Δ
First Group	572*	639	947	1308	1730	1029
Second Group	586	774	1012	1368	1608	1149
Third Group	566	554	882	1282	1716	1331
Mean	574.7	655.7	947.0	1319.3	1684.7	1169.7

* Figures are in seconds

TABLE 7: TOTAL TIMES IN EXPERIMENTS


1
2
3
4
5
6
7
8
9
10
trial
THE AVERAGE TIME FOR ALL NETWORKS
WHEEL
Y
ALL - CHANNEL
CHAIN
CIRCLE
Δ

GRAPH I

ANALYSIS OF THE SIGNIFICANCE OF THE DIFFERENCES BETWEEN NETWORKS

The t test performed on the differences among various networks gives us the following results (Table 8).

a. A significant difference exists between the circle network and all the other networks, namely, the chain, Δ , all-channel, Y and wheel groups tests.

b. A significant difference exists between the chain network and the wheel, Y, all-channel and circle networks. However, there is no significant difference between the chain network and the Δ network.

c. A significant difference exists between the Δ network and the circle, Y and wheel networks. Hoever, there is no significant difference between the Δ network and the chain and all-channel networks.

d. A significant difference exists between the Y network and the circle, chain, Δ all-channel networks. However, there is no significant difference between the Y and wheel networks.

e. The same holds true for the wheel groups which have a significant difference with the circle, chain, Δ and all-channel groups but which do not have any significant difference with the Y groups.

In conclusion we may say that there is a significant difference among all the groups except between the Δ and chain, and all-channel and Y and wheel groups, as far as the average over their total time is concerned.

In view of the previous conclusion about the performance and the stability of the networks this shows again that the wheel structure is the best net of communication for the criterion used although a Y pattern of communication can do the same job with only a very slight lower performance.

ø = 18

Circle - Wheel	t = 16.45	p .0005
Circle - Y	t = 7.95	p .0005
Circle - All-Channel	t = 7.91	p .0005
Circle - Chain	t = 4.56	p .0005
Circle - Δ	t = 3.11	p .002
Chain - Wheel	t = 16.21	p .0005
Chain - Y	t = 15.19	p .0005
Chain - All-Channel	t = 4.76	p .0005
Chain - Δ	t = 1.01	p .15 Significant
Δ - All-Channel	t = 1.35	p .10 significant
Δ - Wheel	t = 3.92	p .0005
Δ - Y	t = 2.74	p .007
All-Channel - Wheel	t = 5.68	p .0005
All-Channel - Y	t = 2.29	p .017
Y - Wheel	t = 0.73	p .22 sig.

TABLE 8: TEST OF SIGNIFICANCE OF THE DIFFERENCE BETWEEN GROUPS

ANALYSIS OF THE SIGNIFICANCE OF THE DIFFERENCE AMONG THE NETWORKS FOR THE THREE FASTEST TRIALS

The result of the t test performed to find out any significant difference among groups is as follows (Table 9).

a. There is a significant difference among the circle networks and the other networks, namely, the chain, Δ , all-channel, Y and wheel networks.

b. The difference between the chain networks and the circle Y and wheel networks is significant. However no significant difference exists among the chain groups and the Δ and all-channel groups.

c. The difference between the Δ group and the circle, Y and Wheel group is significant, but the difference between Δ and the All-Channel and chain networks is not significant.

d. The difference between the All-Channel network and the circle, Y and wheel groups is significant, but there is no significant difference between the All-Channel network and the and chain networks.

e. A significant difference exists between the Y groups and all the other networks except for the wheel network.

f. A significant difference exists between the wheel networks and all the other networks except for the Y network.

Circle - Wheel		Chain - Δ	
t = 6.49	p .0025	t = 0.40	p .30
Circle - Y		Δ - Wheel	
t = 5.22	p .0036	t = 4.45	p .005
Circle - All-Channel		Δ - Y	
t = 4.23	p .0045	t = 2.61	p .034
Circle - Δ		Δ - All	
t = 3.21	p .017	t = 0.87	p .23
Circle - Chain		All - Wheel	
t = 2.24	p .038	t = 6.18	p .001
Chain - Wheel		All - Y	
t = 2.96	p .022	t = 2.48	p .037
Chain - Y		Y - Wheel	
t = 2.24	p .038	t = 0.78	p .25 significant
Chain - All			
t = 0.99	p .19		

TABLE 9: TEST OF SIGNIFICANCE FOR THE 3 FASTEST TRIALS

NUMBER OF MESSAGES

The total number of messages sent by the three groups in each network is as follows:

Wheel	278	Chain	609
Y	363	Circle	841
All-Channel	927	Δ	534

Classifying those according to percentages over the total number of averages exchanged in all groups.

1.	All-Channel	26.0%	4.	Δ	15.1%
2.	Circle	23.7%	5.	Y	10.1%
3.	Chain	17.3%	6.	Wheel	7.8%

The results seem to imply that as the number of symmetric positions increase in a network, the level of activity of the group increases too.

ERROR COUNT

An error is defined as a wrong answer to the problem.

	Wheel	Y	All-Channel	Chain	Circle	Δ
1st group	1	0	3	1	4	2
2nd group	0	2	2	2	0	1
3rd group	0	1	3	1	3	0
	1	3	8	4	7	3

TABLE 10: NUMBER OF ERRORS IN GROUPS

The classification of the groups in terms of errors in descending order is:

1. All-Channel
2. Circle
3. Chain
4. Δ and Y
6. Wheel

It seems that as more restrictions are put on the network the number of errors is reduced.

STUDY OF CENTRALITY

When we compare the figures of centrality with our data, we see that a certain relationship exists. However, this relationship may change with the size of the group. One cannot jump to the conclusion that more activity occurs in groups of larger sizes.

The peripherality measure that was previously defined, is introduced to avoid such difficulties. This is because a relative measure is obtained when the centrality index of a certain member is subtracted from that of the member occupying the most central position. The summation of all indices of peripherality in a network gives the total peripherality of the network, which is a somewhat more indicative measure than the measure of centrality.

When we compare our data with the theoretical peripherality indices we see that a positive correlation exists. We may, therefore, infer that there is a relationship between the peripherality and the behavior, i.e., the speed and accuracy at which the group operates. Until now we said that the structure of the network had certain effects on the organizational as well as on the problem solution aspects of the problem. Both of these are clearly a function of the behavior of the group. To the extent that the behavior of the group is related to the peripherality indices we can arrive at certain deductions to illustrate this, let us assume a perfect situation. By the term perfect, the group is understood to work at maximum speed and also the members are understood to be perfectly rational, that is, that no information is carried twice between two same individuals. Also, it is assumed that the probability that a member sends a message to anyone of his neighbors is the same. Under such circumstances, certain individuals in a group and in a certain network would be likely to arrive at an answer sooner than the others. This would be due to their more advantageous position that they occupy in the network. The question of who occupies the most favorable position is answered by the highest centrality index or better by the peripherality index which gives the relative advantage that each member has over the other. Clearly, the positions having a peripherality index equal to zero would be in a more favorable position to get to an answer first. To make this more explicit, let us carry the problem to its extreme and take a wheel group. Here only the person occupying the central position can formulate the ansser first, since he will get all the information needed to get a solution. Therefore, in any given structure, whether it has been considered here or not, by studying the peripherality indices one can estimate who in the end will be able to find answer to problems first and therefore staff those positions with people with adequate qualifications for the job, i.e., more intelligent, more capable, more dynamic, faster and more accurate.

THE STABILITY

H. Guetzkow and H. A. Simon give the definition of stability as: "The extent to which a given pattern persists over a sequence of trials". By this definition, they mean that a certain group after building up an organizational set-up may use some of the available channels and not use others. As time goes on and the group discovers more efficient ways to communicate and thus come to an answer, they may drop some of their channels of communication and use new ones as the need arises. The extent to which a certain communication pattern existed is termed stability. Certain criteria must be set to be able to determine which group is stable and which one is not. Guetzkow and Simon suggest the following rating:

1. A segment is stable if only one or two of the channels are used once, twice or three times during the segment.

2. A segment is semi-stable when three to one-half of the total channels are once, twice or three times used during the segment.

A segment is defined here as the number of trials analysed at once for stability.

The messages I analyzed were examined as to their contents, i.e., as to whether they were information carrying or answer carrying messages. The segments were identified so to be 1 - 4, 5 - 7, 8 - 10 giving more allowance to the first trials since it was a period which may be considered as warm up.

Table 11 shows the findings:

WHEEL NETWORK

	First Group		Second Group		Third Group	
	Inf.	Ans	Inf	Ans	Inf	Ans
1 - 4	SS	S	S	S	SS	SS
5 - 7	s	s	s	s	s	s
8 - 10	S	S	S	S	S	S

Y - NETWORK

	First Group		Second Group		Third Group	
	Inf	Ans	Inf	Ans	Inf	Ans
1 - 4	SS	SS	US	S	US	US
5 - 7	SS	S	S	S	SS	S
8,- 10	S	S	S	S	SS	S

ALL-CHANNEL NETWORK

	First Group		Second Group		Third Group	
	Inf	Ans	Inf	Ans	Inf	Ans
1 - 4	US	US	US	US	US	US
5 - 7	US	SS	US	SS	US	US
8 - 10	SS	S	US	SS	S	SS

CHAIN NETWORK

	First Group		Second Group		Third Group	
	Inf	Ans	Inf	Ans	Inf	Ans
1 - 4	US	SS	US	SS	US	US
5 - 7	SS	S	SS	SS	S	SS
8 - 10	S	S	S	S	S	S

CIRCLE NETWORK

	First Group		Second Group		Third Group	
	Inf	Ans	Inf	Ans	Inf	Ans
1 - 4	US	US	SS	US	US	SS
5 - 7	US	SS	SS	S	US	SS
8 - 10	S	S	S	S	SS	SS

Δ NETWORK

	First Group		Second Group		Third Group	
	Inf	Ans	Inf	Ans	Inf	Ans
1 - 4	US	SS	US	US	US	US
5 - 7	SS	S	SS	SS	SS	SS
8 - 10	S	S	S	S	SS	S

In this table:

S = stable

SS = semi-stable

US = unstable

TABLE 11: STABILITY OF GROUPS

The per-cent stability of the networks, i.e., percentage of groups which are stable, semi-stable and unstable to the total number of groups in the network is as follows:

THE WHEEL NETWORK

	Information	Answer	Total
Stable	77.78	88.89	83.33
Semi-stable	22.22	11.11	16.67
Unstable	0	0	0

THE Y - NETWORK

	Information	Answer	Total
Stable	33.34	77.78	55.55
Semi-stable	44.44	11.11	27.78
Unstable	22.22	11.11	16.67

THE ALL-CHANNEL NETWORK

	Information	Answer	Total
Stable	11.11	11.12	11.12
Semi-stable	11.11	44.44	27.77
Unstable	77.78	44.44	61.11

THE CHAIN NETWORK

	Information	Answer	Total
Stable	44.45	44.45	44.45
Semi-stable	22.22	44.44	33.33
Unstable	33.33	11.11	22.22

THE CIRCLE NETWORK

	Information	Answer	Total
Stable	33.34	44.45	33.00
Semi-stable	22.22	33.33	27.77
Unstable	44.44	22.22	33.33

THE Δ NETWORK

	Information	Answer	Total
Stable	22.23	44.45	33.33
Semi-stable	44.44	33.33	38.39
Unstable	33.33	22.22	27.78

TABLE 12: PER-CENT STABILITY OF NETWORKS

By looking at the totals we may classify networks according to their stability, semi-stability and instability.

Classification of Networks according to their stability

1. The Wheel Network 83.33%
2. The Y Network 55.55%
3. The Chain Network 44.45%
4. The Circle Network 39.00%
5. The Δ Network 33.33%
6. The All-Channel Network 11.12%

Classification of networks according to their semi-stability

1.	The Δ Network	33.33%
2.	The Chain Network	33.33%
3.	The Y Network	27.77%
4.	The All-Channel Network	27.77%
5.	The Circle Network	27.77%
6.	The Wheel Network	16.67%

Classification of networks according to their unstability

1.	The All-Channel Network	61.11%
2.	The Circle Network	33.33%
3.	The Δ Network	27.77%
4.	The Chain Network	22.22%
5.	The Y Network	16.67%
6.	The Wheel Network	0

The examination of the stability of groups sheds even more light on our theory. When we look at our stability tables, we see that the wheel networks are the most stable of all, as far as their organizational set up is concerned. Following the wheel groups are the Y, Chain, Circle, Δ and All-Channel groups which are less and less stable, in that order.

The instability table shows, that the order is the same except for the circle and Δ groups, which have changed places, when we list them in increasing order of instability. The switch of places between the Δ and the circle groups is that part of their percentages is taken up by their semi-stable positions.

This result makes a testimony for the hypothesis that groups become more stable when certain restrictions are put as far as their communication channels are concerned. This puts the wheel network into an organizational advantage.

THE PSYCHOLOGICAL EFFECTS OF THE NETWORKS

As we remember, we had divided the task of solving the problem into two: the organizational task and the solving task. During the organizational inter-trial periods members of the group do get aware of their answer formulating capacity. Certain individuals become aware of the fact that, perhaps, they can not arrive at an answer at all while others recognize that they only can form an answer. This might most probably happen in the wheel group. However, in the all-channel or circle groups people might become aware that all positions are equipotential. These facts are also clearly shown by the peripherality and centrality indices

The factor of having answer formulating power should in some way affect psychologically the members of the group. In their essence the discussions of peripherality and symmetry boil down to the same conclusion. In fact they are the same. The effect of the psychological state in which members fall due to their position potential, on the organizational task cannot be overemphasized.

For one thing the extent to which the psychology of the group effects the speed of the process, the number of messages communicated is uncertain and cannot be reckoned. However, it should be recognized that the centrality, peripherality and symmetry affect behavior by reducing or increasing independence as the case may be.

In order to find out the effect of each network on the psychology of the individuals in the group, the following questions were paused to each participant at the end of the experiment:

1. How do you rate your satisfaction in the group during the experiment?

   Good   Fair   Bad

2. Did your group have a leader?

   Yes   No

3. Do you think a change in the organization of the group is necessary to improve the efficiency?

   Yes   No

The answers to the first question were found to be as in Table 13.

	Good	Fair	Bad
Wheel	8%	38%	54%
Y	9%	63%	28%
All-Channel	61%	22%	17%
Δ	11%	57%	32%
Chain	47%	38%	15%
Circle	63%	26%	11%

TABLE 13: Satisfaction rating in networks

The answers to the second question were distributed as in Table 14.

	Yes	No
Wheel	100%	-
Y	98%	2%
All-Channel	62%	38%
Δ	91%	9%
Chain	65%	35%
Circle	59%	41%

TABLE 14: Awareness of leadership rating

The answers to the third question were distributed as in Table 15.

	Yes	No
Wheel	3%	97%
Y	3%	97%
All-Channel	12%	88%
Δ	6%	94%
Chain	17%	83%
Circle	23%	77%

TABLE 15: Need for change in the networks

= If we classify the networks in terms of satisfaction in descending order:

1. The Circle Network
2. The All-Channel Network
3. The Chain Network
4. The Δ Network
5. The Y Network
6. The Wheel Network

If we classify the networks in terms of dissatisfaction in descending order.

1. The Wheel Network
2. The Δ Network
3. The Y Network
4. The All-Channel Network
5. The Chain Network
6. The Circle Network

The results of this classification are compatible. The members of a network who show most satisfaction are the least dissatisfied with their task and vice-versa. There is only a change in the places of the Y network and the Δ network. This is clearly due to the distribution of "fair" answers in the two networks.

The classification of leaders in terms of awareness of leadership in order of increasing awareness is as follows:

1. The Circle Network
2. The all-Channel Network
3. The Chain Network
4. The Δ Network
5. The Y Network
6. The Wheel Network

The groups most liable to change can be classified as follows:

1. The Circle Network
2. The Chain Network
3. The All-Channel Network
4. The Δ Network
5. The Wheel and Y Networks

Combining these results in Table 16.

Order	Satisfaction	Awareness of Leadership	Need for Changes
1	Circle	Circle	Circle
2	All-Channel	All-Channel	Chain
3	Chain	Chain	All-Channel
4	Δ	Δ	Δ
5	Y	Y	Y
6	Wheel	Wheel	Wheel

TABLE 16: Combined table of satisfaction, awareness of leadership and need for change

This table may be read as, e.g., the circle groups which offer the greatest amount of satisfaction have their members the least aware of the presence of a leader and are the groups which are the most liable to change. A close inspection of this table shows us that a close correlation exists between the satisfaction of the group members, their awareness of a leader and that the possibility of a change in organization is related to those factors. We may say that, the level of satisfaction of an individual in the group is inversely proportional to his awareness of the presence of a leader. This suggests to us that the more symmetrical positions in the network and the less the restrictions imposed by the network the more the satisfaction of the participating persons, and the more the satisfaction of these persons, the more they are able to realize the changes necessary to improve the efficiency of the group. But this leads us to another situation, because as the members will suggest other patterns of communications in order to increase the efficiency of the group, the network will tend to become more and more restricted, with less and less symmetrical positions which will lead to the awareness of a leader in the group and which will create dissatisfaction. Therefore, even if we have a highly decentralized pattern at the beginning offering to the members of the group a great deal of satisfaction, this network will slowly drift towards a more centralized pattern for the sake of efficiency.

COMPARISON OF RESULTS WITH PREVIOUS WORKS

Leavitt had used 15 trials per experiment and Guetzkow and Simon had used 20. However, due to the prohibitive amount of time, money and people required for experiments of such a large scale, I had to make do with 10 trials per experiment .

All the studies done up to now had involved only male students. In the present study both men and women students were used in the experimental groups in a mixed pattern.

The comparison of the mean times for the three fastest trials in the circle and wheel networks which are the only common networks used by Leavitt, Guetzkow and Simon and I, can be shown in the following comperative Table 17.

	Leavitt	Guetzkow and Simon	Present Study
Wheel	31.8 sec	27.6 sec	32.7 sec
Circle	49.8 sec	43.8 sec	115.6 sec

TABLE 17: Comparison of Previous and present results.

The difference may be accounted for by the small number of trials per experiment that were done during the study. It is to be expected that the mean of the three fastest trials until the 10th trial will be higher than those until the 15th or 20th trials. This is especially true for the circle network which is the slowest to stabilize. This also accounts for the greater difference among the circle networks than the wheel networks.

As to the concluding results, the results of the present study are compatible with the findings of Guetzkow and Simon. Their study concludes that it is the organizational task which is important rather than the operational task, and their findings say that, freedom of communication in a network, is more restricting from the organizational point of view, than restricted communication patterns. The present study confirms this conclusion,

CHAPTER IV

CONCLUSION

In the analysis of different groups in different networks the initial hypothesis was that the time required by a group to organize itself was different than the time required to arrive at an answer. In fact it was said, that there should not be any significant difference in the time required by different groups, in different networks, once they were efficiently organized. This hypothesis seems to be confirmed by the empirical results obtained. Therefore, the crucial matter becomes not how fast the group arrives at an answer, but how fast it can organize itself into an efficient pattern of communication. The speed of organization can be increased by eliminating unnecessary channels, by organizing relay, and by putting persons into non-symmetric positions, i.e., with a high centrality or low peripherality index so that they can play the part of a key-man.

On the other hand, from the answers of the participants to a questionnaire, it was found that certain characteristic psychological factors, such as enjoyment of the task, awareness of leadership, which are related to satisfaction, were present during the experiments. But I do not feel that one can jump to a conclusion of assessing a one to one relationship between the psychology of the individual and the organization and performance of the groups. By this I mean that the measure of symmetry or centrality does not establish a bridge between satisfaction and performance, i.e., we cannot say that the limits put on the independence of action, via centrality which affects the psychological behavior of the group, have a large impact, if at all, on the performance of the group.

However, we may say that, if symmetrical positions are evenly distributed, this will prevent the emergence of a leader for a time, will reduce the speed of organization and will increase satisfaction. However, with symmetrical positions evenly distributed, the group will be more aware of the opportunities to reorganize the pattern into a more efficient one.

As a result we may conclude, that we cannot say that one network is more advantageous than another, as far as the performance after the most efficient organization has been established is concerned. However, if organizational speed is of interest, a wheel or Y or Δ network may be the best solution. On the other hand, if individual satisfaction is at stake, a more equalitarian, more participative network such as the all-channel, the chain or the circle networks may be selected. The aim of each arrangement being different, it is up to the management to select a communication network that best fits its own policies and the environmental conditions in which the institution is located. The problem then boils down to one in which efficiency of communication or rather efficiency of organizing communication, as far as speed and accuracy are concerned, is to be weighed carefully against satisfaction of the individuals belonging to the institution.

However it should be kept in mind that, all the results derived here are the communications which are carried out exclusively in the written medium. All generalization made here hold only for written communication. However, one might say that since the initial assumption was that each individual participating in the experiment was equally capable and intelligent, these individuals would be also equally capable if they were doing oral communication. Therefore, under this assumption the generalization may be made.

SUGGESTIONS FOR FURTHER RESEARCH

In order to broaden the present studies, it would be interesting to do some research with groups of larger size, namely, groups with six, seven, eight or more members. The results of these studies can then be compared with the findings of experiments using five-man groups.

In this way one might see the extent to which the generalization made from the results of five-man group experiments are valid.

Another kind of research would be to study two or more groups, operating with similar or different communication networks and connected among them by one or more channels. The groups may also be varied in size. Such arrangements may be asserted to simulate the communication within and between departments in an organization. For instance, a wheel network with another network at its hub and networks of varying size and nature on the periphery may be thought to simulate a centralized organization managed by a committee. By motivating research in this direction, it is my belief, that great improvements may be brought to communications in organizations.

The experiments that were performed do not take into account the prejudices that may exist. If one wishes to measure the effect of prejudices, he may perform experiments with a slightly different apparatus, namely, with an apparatus having transparent partitions. Or better, control groups where individuals do not know each other, and experimental groups whose people see each other through transparent partitions may be experimented with and the existing differences in results, if any, can be tested as to their significance.

In this work satisfaction was measured as enjoyment of the task the members of a group carried out. However, the acceptability of the decision was not tested. Anyway, the final answer to the problem did not lend itself to such an investigation because the answers did not really matter to the participents. However, if anybody wishes to measure the acceptance of the final answer by the members of the group, he might introduce some kind of rewarding system in the experiment. The reactions of the individuals to that kind of a test may be measured by making them answer a questionaire similar to the one used here to measure satisfaction of performing the task.

APPENDIX A

RESULTS OF THE EXPERIMENTS

Trial No.	MEMBERS I	II	III	IV	V	End	Time Elapsed
1	148*	139	136	141	145	148	12
2	87	90	83	94	97	97	14
3	66	63	52	55	59	66E**	14
4.	34	37	30	43	41	43	13
5	28	36	26	33	30	36	10
6	45	34	29	41	38	45	16
7	35	33	24	27	30	35	11
8	35	32	25	28	30	35	10
9	35	33	24	28	31	35	11
10	32	28	20	25	30	32	12

* All figures are in seconds ** E means error

TABLE 18a: THE WHEEL NETWORK First Group

Trial No.	MEMBERS I	II	III	IV	V	End	Time Elapsed
1.	172	165	160	169	163	172	12
2	80	93	77	84	89	93	16
3	57	60	47	50	54	60	13
4	45	38	35	48	42	48	13
5	38	34	25	27	31	38	13
6	28	31	21	24	34	34	13
7	25	22	19	28	30	30	11
8	38	34	31	36	41	41	10
9	30	28	25	32	35	35	10
10	33	27	22	30	35	35	13

TABLE 18b: THE WHEEL NETWORK Second Group

Trial No.	MEMBERS I	II	III	IV	V	End	Time Elapsed
1	140	145	134	137	142	145	11
2	85	80	72	77	89	89	17
3	50	53	44	48	56	56	12
4	40	46	34	38	43	46	12
5	30	24	21	33	28	33	12
6	30	25	22	27	32	32	10
7	30	33	26	35	38	38	12
8	43	41	35	38	45	45	10
9	40	34	30	37	43	43	13
10	34	31	28	37	39	39	11

TABLE 18c: THE WHEEL NETWORK Third Group

Trial No.	Total Time	Time Elapsed
1	155	12
2	93	16
3	61	13
4	46	13
5	36	12
6	37	13
7	34	11
8	40	10
9	38	11
10	35	12

TABLE 18d: THE WHEEL NETWORK Averages

Trial No.	MEMBERS I	II	III	IV	V	End	Time Elapsed
1	155	147	152	157	161	161	14
2	110	101	92	90	95	110	20
3	70	65	60	71	57	71	14
4	29	20	25	32	29	32	12
5	40	34	29	38	42	42	13
6	40	36	30	39	41	41	11
7	39	34	28	37	42	42	14
8	45	42	33	38	44	45	12
9	45	42	35	39	45	45	10
10	48	43	38	47	50	50	12

TABLE 19a: THE Y NETWORK First Group

Trial No.	MEMBERS I	II	III	IV	V	End	Time Elapsed
1	169	166	159	162	155	169	14
2	144	138	134	142	146	146E*	12
3	112	108	100	111	104	112	12
4	53	48	43	55	52	55	12
5	50	47	40	43	48	50	10
6	46	44	33	37	40	46	13
7	60	57	46	50	53	60E	14
8	43	37	33	41	44	44	11
9	45	40	35	43	47	47	12
10	45	41	32	37	41	45	13

TABLE 19b: THE Y NETWORK Second Group

Trial No.	MEMBERS I	II	III M	IV	V	End	Time Elapsed
1	141	144	147	150	155	155	14
2	89	85	93	96	99	99	14
3	64	61	58	64	53	64	11
4	36	30	27	33	36	36	9
5	31	28	24	30	33	33	9
6	30	22	27	30	32	32	10
7	34	31	23	27	34	34E	11
8	34	30	22	26	34	34	12
9	32	27	22	33	30	33	11
10	31	28	24	31	34	34	10

* E means error

TABLE 19c: THE Y NETWORK Third Group

Trial No.	Total Time	Time Elapsed
1	162	14
2	118	15
3	82	12
4	41	11
5	42	11
6	40	11
7	45	13
8	41	12
9	42	11
10	42	12

TABLE 19d: THE Y NETWORK Average

Trial No.	MEMBERS I	II	III	IV	V	End	Time Elapsed
1	160	171	167	176	164	176	16
2	125	132	128	135	140	140E	15
3	108	115	124	111	120	124	16
4	99	107	101	96	92	107	17
5	78	75	73	70	81	81	11
6	60	65	62	68	57	68E	11
7	59	64	62	62	55	64	9
8	65	59	61	55	57	65E	8
9	61	61	57	54	50	61	11
10	61	52	55	58	50	61	11

TABLE 20a: THE ALL-CHANNEL NETWORK First Group

Trial No.	MEMBERS I	II	III	IV	V	End	Time Elapsed
1	168	182	172	178	163	182	19
2	148	143	140	153	148	153	13
3	131	131	122	126	136	136	14
4	101	96	100	109	105	109E	13
5	95	90	94	86	82	95	13
6	70	82	79	74	76	82	12
7	62	70	67	72	70	72E	10
8	53	57	60	63	66	66	13
9	50	56	60	60	54	60	10
10	46	55	57	51	53	57	11

TABLE 20b: THE ALL-CHANNEL NETWORK Second Group

Trial No.	MEMBERS I	II	III	IV	V	End	Time Elapsed
1	144	162	150	140	155	162	22
2	142	140	130	127	136	142	15
3	113	116	105	119	112	119E	14
4	91	100	96	105	93	105	14
5	59	64	69	67	54	69	15
6	57	60	60	48	53	60E	12
7	42	47	57	54	51	57	15
8	55	57	50	40	46	57E	17
9	55	55	39	44	49	55	16
10	48	53	56	43	40	56	16

TABLE 20c: THE ALL-CHANNEL NETWORK Third Group

Trial No.	Total Time	Time Elapsed
1	173	19
2	145	15
3	126	15
4	107	15
5	82	13
6	70	12
7	64	11
8	63	13
9	59	12
10	58	13

TABLE 20d: THE ALL-CHANNEL NETWORK Average

Trial No.	MEMBERS I	II	III	IV	V	End	Time Elapsed
1	185	179	190	195	199	199	20
2	188	183	178	174	170	188	18
3	170	164	157	173	178	178	21
4	194	186	180	175	183	194	19
5	112	106	96	101	106	112E	16
6	98	93	88	80	84	98	18
7	132	129	124	118	128	132	14
8	77	72	67	78	81	81	14
9	63	59	54	63	67	67	13
10	57	54	51	57	59	59	8

TABLE 21a: THE CHAIN NETWORK First Group

Trial No.	MEMBERS I	II	III	IV	V	End	Time Elapsed
1	211	207	202	193	199	211	18
2	173	168	161	172	177	177	16
3	165	160	155	149	160	165	16
4	151	145	134	140	144	151E	17
5	108	113	117	121	125	125E	17
6	145	135	139	144	150	150	15
7	129	124	116	120	124	129	13
8	109	105	98	109	113	113	15
9	74	70	66	74	80	80	14
10	67	63	55	59	64	67	12

TABLE 21b: THE CHAIN NETWORK Second Group

Trial No.	I	II	III (MEMBERS)	IV	V	End	Time Elapsed
1	215	210	203	196	207	215	19
2	210	200	189	195	206	210	21
3	165	157	161	167	172	172	15
4	156	150	140	144	149	156	16
5	120	114	106	110	114	120E	14
6	104	99	94	105	111	111	17
7	96	92	87	96	101	101	14
8	73	68	64	73	76	76	12
9	63	59	53	56	60	63	10
10	58	53	44	48	54	58	14

TABLE 21c: THE CHAIN NETWORK Third Group

Trial No.	Total Time	Time Elapsed
1	208	19
2	192	18
3	172	17
4	161	17
5	119	16
6	120	17
7	121	14
8	90	14
9	71	12
10	61	11

TABLE 21d: THE CHAIN NETWORK Averages

Trial No.	MEMBERS I	II	III	IV	V	End	Time Elapsed
1	199	208	210	205	193	210	17
2	194	196	193	182	189	196E	14
3	208	219	224	220	215	224E	16
4	213	208	203	196	209	213E	17
5	201	205	202	197	191	205	14
6	168	175	181	177	172	181E	13
7	144	138	150	153	149	153	15
8	123	134	138	135	129	138	15
9	99	112	117	111	106	117	18
10	77	87	93	88	83	93	16

TABLE 22a: THE CIRCLE NETWORK First Group

Trial No.	MEMBERS I	II	III	IV	V	End	Time Elapsed
1	220	225	219	208	214	225	17
2	192	203	193	188	182	203	21
3	186	180	169	175	180	186	17
4	160	169	174	170	165	174	14
5	187	191	186	182	175	191	16
6	166	161	156	150	160	166	16
7	133	145	148	144	139	148	15
8	129	124	112	118	123	129	17
9	100	96	90	101	104	104	14
10	79	72	66	79	82	82	16

TABLE 22b: THE CIRCLE NETWORK Second Group

Trial No.	MEMBERS I	II	III	IV	V	End	Time Elapsed
1	230	224	212	220	225	230E	18
2	177	183	188	182	171	188	17
3	162	156	166	175	168	175E	19
4	216	222	226	220	211	226	15
5	189	186	181	192	197	197	16
6	169	172	168	163	157	172E	15
7	158	153	141	148m	154	158	17
8	127	132	137	143	137	143	16
9	110	116	122	125	121	125	15
10	87	97	102	97	93	102	15

TABLE 22c: THE CIRCLE NETWORK Third Group

Trial No.	Total Time	Time Elapsed
1	222	17
2	197	17
3	195	17
4	205	15
5	196	15
6	173	15
7	153	16
8	137	16
9	115	16
10	92	16

TABLE 22d: THE CIRCLE NETWORK Averages

Trial No.	MEMBERS I	II	III	IV	V	End	Time Elapsed
1	165	154	150	153	165	165	15
2	154	157	138	149	144	154	16
3	148	144	140	128	133	148	20
4	119	115	111	127	121	127	16
5	91	85	93	96	103	103E	18
6	87	82	74	78	83	87E	13
7	61	56	45	49	54	61	16
8	60	56	52	59	63	63	11
9	55	47	51	56	62	62	15
10	59	55	50	57	53	59	9

TABLE 23a: THE Δ NETWORK First Group

Trial No.	I	II	III	IV	V	End	Time Elapsed
	MEMBERS						
1	162	158	166	176	171	176	18
2	181	175	169	160	164	181	21
3	172	167	154	159	164	172	18
4	130	121	125	133	128	133	12
5	108	105	94	99	103	108	14
6	92	88	85	89	81	92E	11
7	84	78	71	62	67	84	22
8	68	58	65	73	69	73	15
9	64	59	55	68	63	68	13
10	59	55	51	58	62	62	11

TABLE 23b: THE Δ NETWORK Second Group

Trial No.	MEMBERS I	II	III	IV	V	End	Time Elapsed
1	175	171	179	183	186	186	15
2	178	173	167	180	176	180	13
3	174	165	169	175	179	179	14
4	168	164	154	161	165	168	14
5	151	145	142	148	153	153	11
v 6	127	123	120	126	131	131	11
7	112	107	100	104	109	112	12
8	87	82	78	88	85	89	10
9	68	64	57	66	61	68	11
10	63	58	53	62	66	66	13

TABLE 23c: THE Δ NETWORK Third Group

Trial No.	Total Time	Time Elapsed
1	176	16
2	172	17
3	166	17
4	143	14
5	121	14
6	103	12
7	86	17
8	75	12
9	66	13
10	62	13

TABLE 23d: THE Δ NETWORK Averages

THE WHEEL NETWORK

First Group	Second Group	Third Group
32	30	32
35	34	33
35	35	38

THE Y NETWORK

First Group	Second Group	Third Group
32	44	32
41	45	33
42	46	33

THE ALL-CHANNEL NETWORK

First Group	Second Group	Third Group
61	57	55
61	60	56
64	66	57

THE CHAIN NETWORK

First Group	Second Group	Third Group
59	67	58
67	80	63
81	113	76

THE CIRCLE NETWORK

First Group	Second Group	Third Group
93	82	102
117	104	125
138	129	143

THE Δ NETWORK

First Group	Second Group	Third Group
59	62	66
61	68	68
62	73	88

TABLE 24: Study of the Three fastest trials

THE WHEEL NETWORK

$\mu = 12.3$

THE Y NETWORK

$\mu = 12.2$

THE ALL-CHANNEL NETWORK

$\mu = 13.8$

THE CHAIN NETWORK

$\mu = 15.5$

THE CIRCLE NETWORK

$\mu = 16.0$

THE Δ NETWORK

$= 14.5$

TABLE 25: Elapsed time to formulate an answer from the first candidate to the last

APPENDIX B

CALCULATION OF THE STANDARD DEVIATION OF NETWORKS

CALCULATION OF THE STANDARD DEVIATION

THE WHEEL NETWORK

$\bar{X}$	$\bar{X}^2$
57.2	3271.84
58.6	3433.96
56.6	3203.56
172.4	9909.36

$$\sigma_{\bar{x}} = \sqrt{\frac{9909.36 - \frac{(172.4)^2}{3}}{2}}$$

$$\sigma_{\bar{x}} = 1.02$$

$$\sigma = \sqrt{N} \times \sigma_{\bar{x}} = \sqrt{10} \times 1.02 = 3.22$$

THE Y NETWORK

$\bar{X}$	$\bar{X}^2$
63.9	4083.21
77.4	5990.76
55.4	3069.16
196.7	13143.13

$$\sigma_{\bar{x}} = \sqrt{\frac{13143.13 - \frac{(196.7)^2}{3}}{2}}$$

$$\sigma_{\bar{x}} = 11.08$$

$$\sigma = \sqrt{N} \times \sigma_{\bar{x}} = \sqrt{10} \times 11.08 = 35.01$$

THE ALL-CHANNEL NETWORK

$\bar{X}$	$\bar{X}^2$
94.7	8968.09
101.2	10241.44
88.2	7779.24
284.1	26988.77

$$\sigma_{\bar{x}} = \sqrt{\frac{26988.77 - \frac{(284.1)^2}{3}}{2}}$$

$$\sigma_{\bar{x}} = 6.50$$

$$\sigma = \sqrt{N} \times \sigma_{\bar{x}} = \sqrt{10} \times 6.50 = 20.54$$

THE CHAIN NETWORK

$\bar{X}$	$\bar{X}^2$
130.8	17108.64
136.8	18714.24
128.2	16435.24
395.8	52258.12

$$\sigma_{\bar{x}} = \sqrt{\frac{52258.12 - \frac{(395.8)^2}{3}}{2}}$$

$$\sigma_{\bar{x}} = 4.41$$

$$\sigma = \sqrt{N} \times \sigma_{\bar{x}} = \sqrt{10} \times 4.41 = 13.94$$

THE CIRCLE NETWORK

$\bar{X}$	$\bar{X}^2$
173.0	29929.00
160.8	25856.64
171.6	29446.56
505.4	85232.20

$$\sigma_{\bar{x}} = \sqrt{\frac{85232.20 - \frac{(505.4)^2}{3}}{2}}$$

$$\sigma_{\bar{x}} = 6.67$$

$$\sigma = \sqrt{N} \times \sigma_{\bar{x}} = \sqrt{10} \times 6.67 = 21.08$$

THE Δ NETWORK

$\bar{X}$	$\bar{X}^2$
102.9	10588.41
114.9	13202.01
133.1	17715.61
350.9	41506.03

$$\sigma_{\bar{x}} = \sqrt{\frac{41506.03 - \frac{(350.9)^2}{3}}{2}}$$

$$\sigma_{\bar{x}} = 15.2$$

$$\sigma = \sqrt{N} \times \sigma_{\bar{x}} = \sqrt{10} \times 15.2 = 48.03$$

CALCULATION OF THE STANDARD DEVIATIONS ACCORDING TO TOTAL TIMES

WHEEL

X	X^2
572	327184
586	343396
566	320356
1724	990,936

$$S = \sqrt{\frac{990.936 - \frac{(1724)^2}{3}}{2}}$$

S = 10.2

Y

X	X^2
639	408321
774	599076
554	306916
1967	1,314,313

$$S = \sqrt{\frac{1,314,313 - \frac{(1967)^2}{3}}{2}}$$

S = 110.8

All-Channel

X	X^2
947	896809
1012	1024144
882	777924
2841	2,698,877

$$S = \sqrt{\frac{2,698,877 - \frac{(2841)^2}{3}}{2}}$$

S = 65.0

CHAIN

X	X^2
1308	1,710,864
1368	1,871,424
1282	1,643,524
3958	5,225,812

$$S = \sqrt{\frac{5,225,812 - \frac{(3958)^2}{3}}{2}}$$

S = 44.1

CIRCLE

X	X^2
1730	2,992,900
1608	2,585,664
1716	2,944,656
5054	8,523,220

$$S = \sqrt{\frac{8,523,220 - \frac{(5054)^2}{3}}{2}}$$

$S = 66.7$

A

X	X^2
1029	1,058,841
1149	1,320,201
1331	1,771,561
3509	4,150,603

$$S = \sqrt{\frac{4,150,603 - \frac{(3509)^2}{3}}{2}}$$

$S = 152.0$

STANDARD DEVIATION OF THE THREE FASTEST TRIALS

THE WHEEL NETWORK

$\bar{X}$	$\bar{X}^2$
34.0	1156.00
33.0	1089.00
31.0	961.00
98.0	3206.00

$$\sigma_{\bar{x}} = \sqrt{\frac{3206.00 - \frac{(98.0)^2}{3}}{2}}$$

$\sigma_{\bar{x}} = 1.63$

$$\sigma = \sigma_{\bar{x}} \sqrt{N} = 1.63 \times \sqrt{3} = 2.82$$

THE Y NETWORK

$\bar{X}$	$\bar{X}^2$
38.3	1466.89
45.0	2025.00
32.7	1069.29
116.0	4561.18

$$\sigma_{\bar{x}} = \sqrt{\frac{4561.18 - \frac{(116.0)^2}{3}}{2}}$$

$$\sigma_{\bar{x}} = 6.15$$

$$\sigma = \sigma_{\bar{x}} \sqrt{N} = 6.15 \times \sqrt{3} = 10.65$$

THE CHAIN NETWORK

$\bar{X}$	$\bar{X}^2$
69.0	4761.00
86.7	7516.89
65.7	4316.49
221.4	16594.38

$$\sigma_{\bar{x}} = \sqrt{\frac{16594.38 - \frac{(221.4)^2}{3}}{2}}$$

$$\sigma_{\bar{x}} = 11.29$$

$$\sigma = \sigma_{\bar{x}} \sqrt{N} = 11.29 \times \sqrt{3} = 19.55$$

THE CIRCLE NETWORK

$\bar{X}$	$\bar{X}^2$
116.0	13456.00
105.0	11025.00
125.7	15800.49
346.7	40281.49

$$\sigma_{\bar{x}} = \sqrt{\frac{40281.49 - \frac{(346.7)^2}{3}}{2}}$$

$$\sigma_{\bar{x}} = 10.35$$

$$\sigma = \sigma_{y} \sqrt{N} = 10.35 \times \sqrt{3} = 17.93$$

THE Δ NETWORK

$\bar{X}$	$\bar{X}^2$
60.7	3684.49
67.7	4583.29
74.0	5476.00
202.4	13743.78

$$\sigma_{\bar{x}} = \sqrt{\frac{13743.78 - \frac{(202.4)^2}{3}}{2}}$$

$$\sigma_{\bar{x}} = 6.65$$

$$\sigma = \sigma_{\bar{x}} \sqrt{N} = 6.65 \times \sqrt{3} = 11.52$$

THE ALL-CHANNEL NETWORK

$\bar{X}$	$\bar{X}^2$
62.0	3844.00
61.0	3721.00
56.0	3136.00
179.0	10701.00

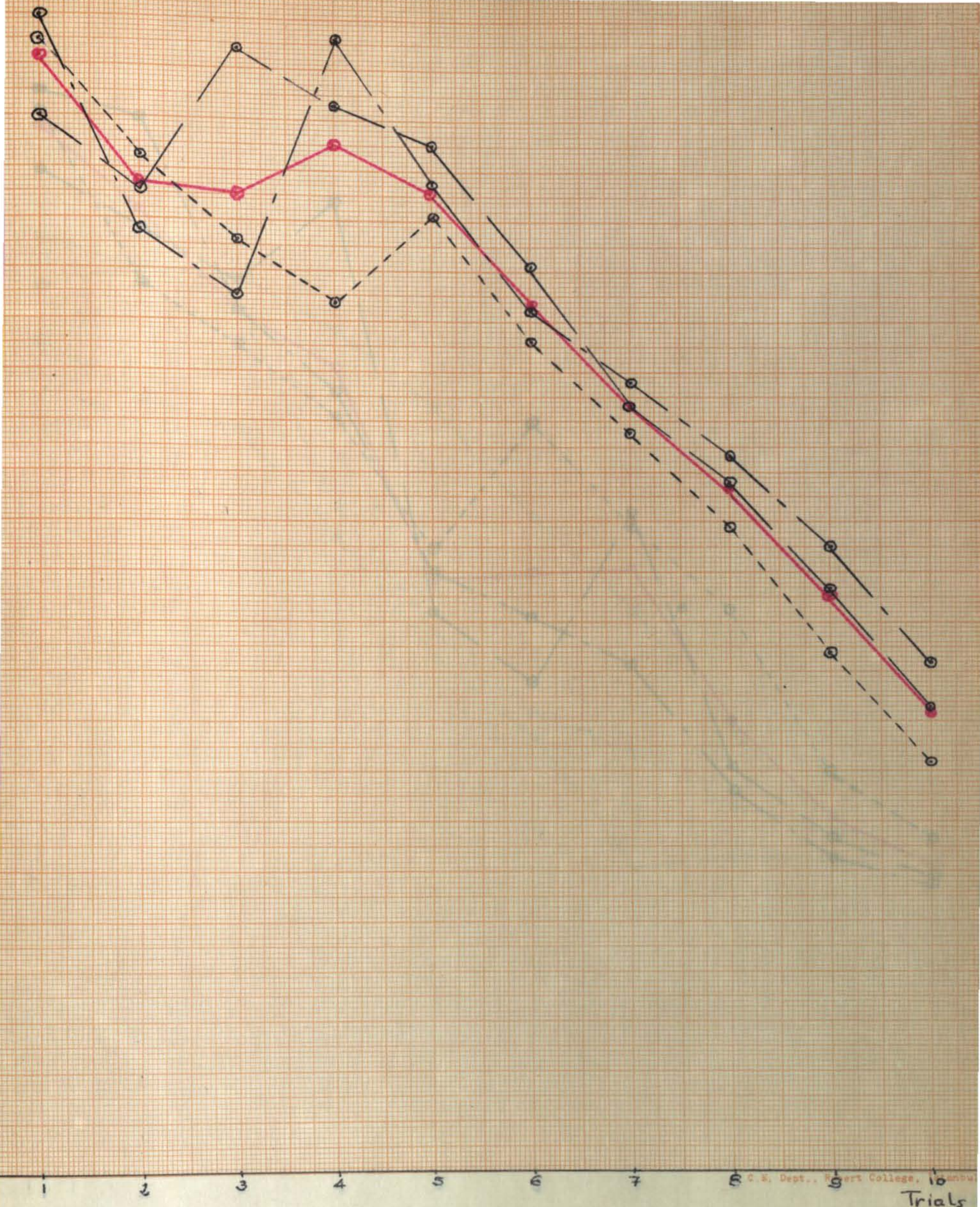
$$\sigma_{\bar{x}} = \sqrt{\frac{10701.00 - \frac{(179.0)^2}{3}}{2}}$$

$$\sigma_{\bar{x}} = 3.21$$

$$\sigma = \sigma_{\bar{x}} \sqrt{N} = \sqrt{3} \times 3.21 = 5.56$$

APPENDIX C

GRAPHS



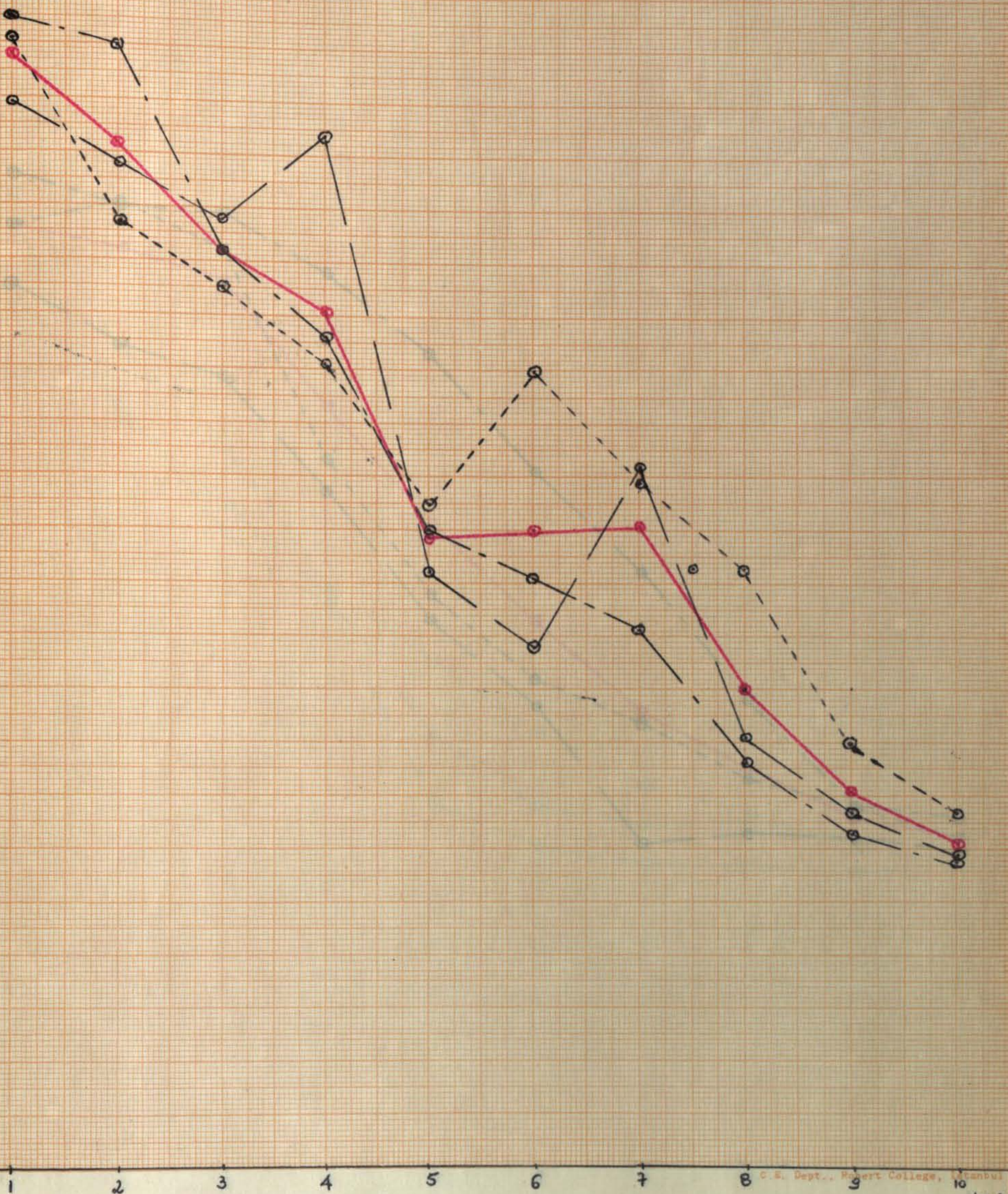
AVERAGE TIME PER TRIAL IN THE CIRCLE NETWORKS

GRAPH II

DATE

HOR. 2 cm = 1 trial VERT. 1cm = 10 sec NAME

——— Average for the network

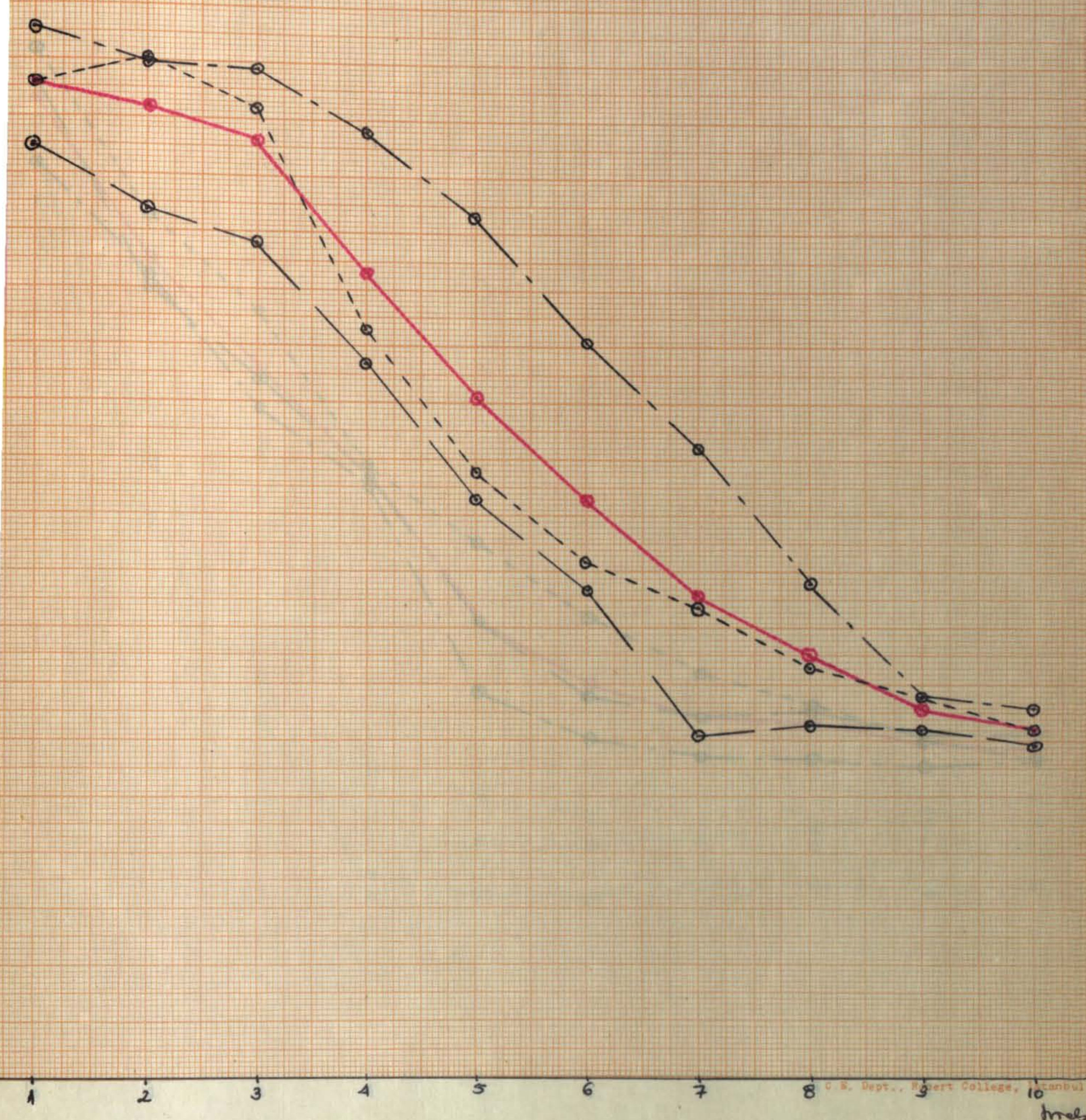


AVERAGE TIME PER TRIAL IN THE CHAIN NETWORK

GRAPH III

DATE

HOR. 2cm = 1 trial VERT. 1cm = 10sec NAME —— AVERAGE FOR THE NETWORK

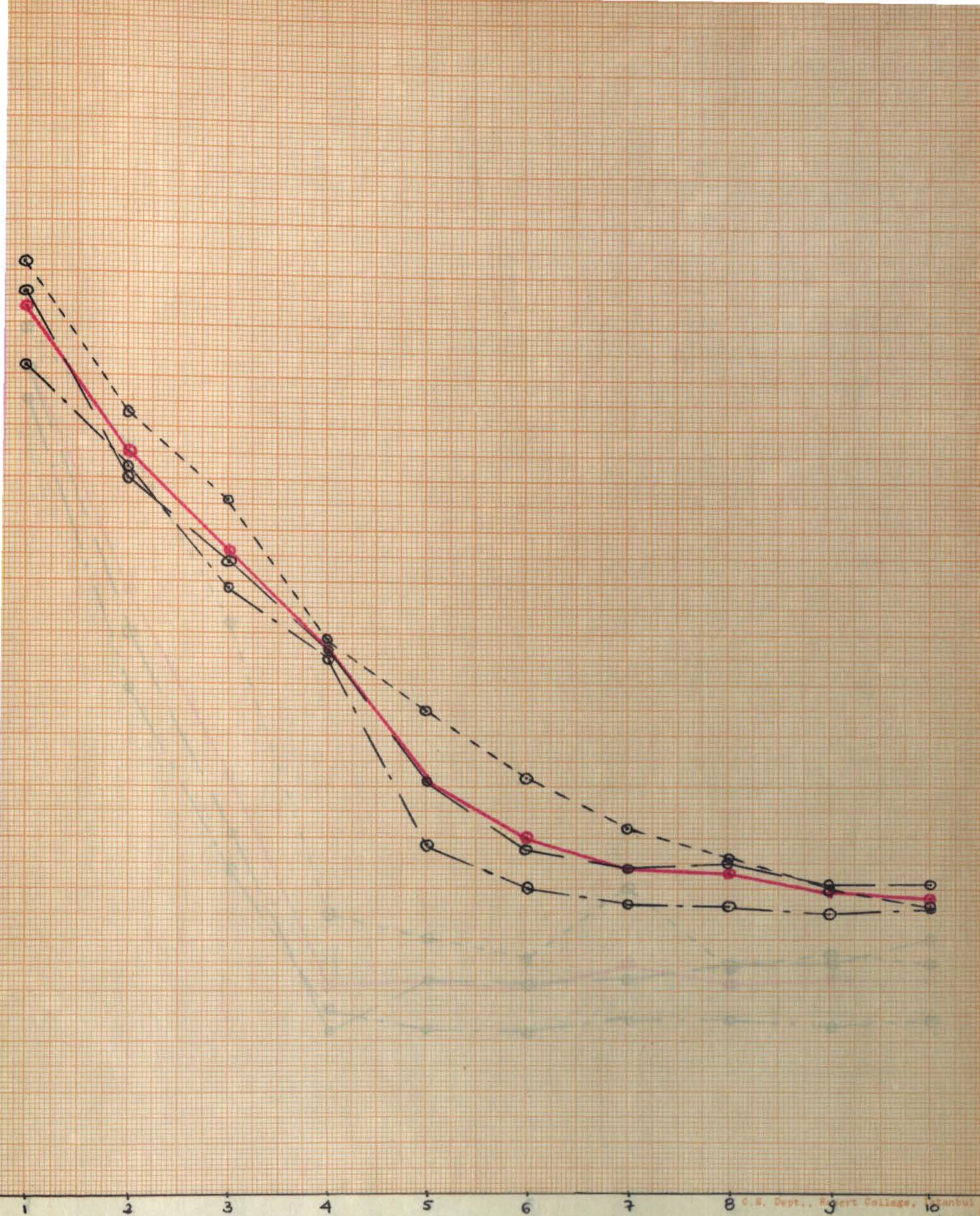


AVERAGE TIME PER TRIAL IN THE Δ NETWORK

GRAPH IV

hor. 2cm = 1 trial vert. 1cm = 10 sec

——— AVERAGE FOR THE NETWORK

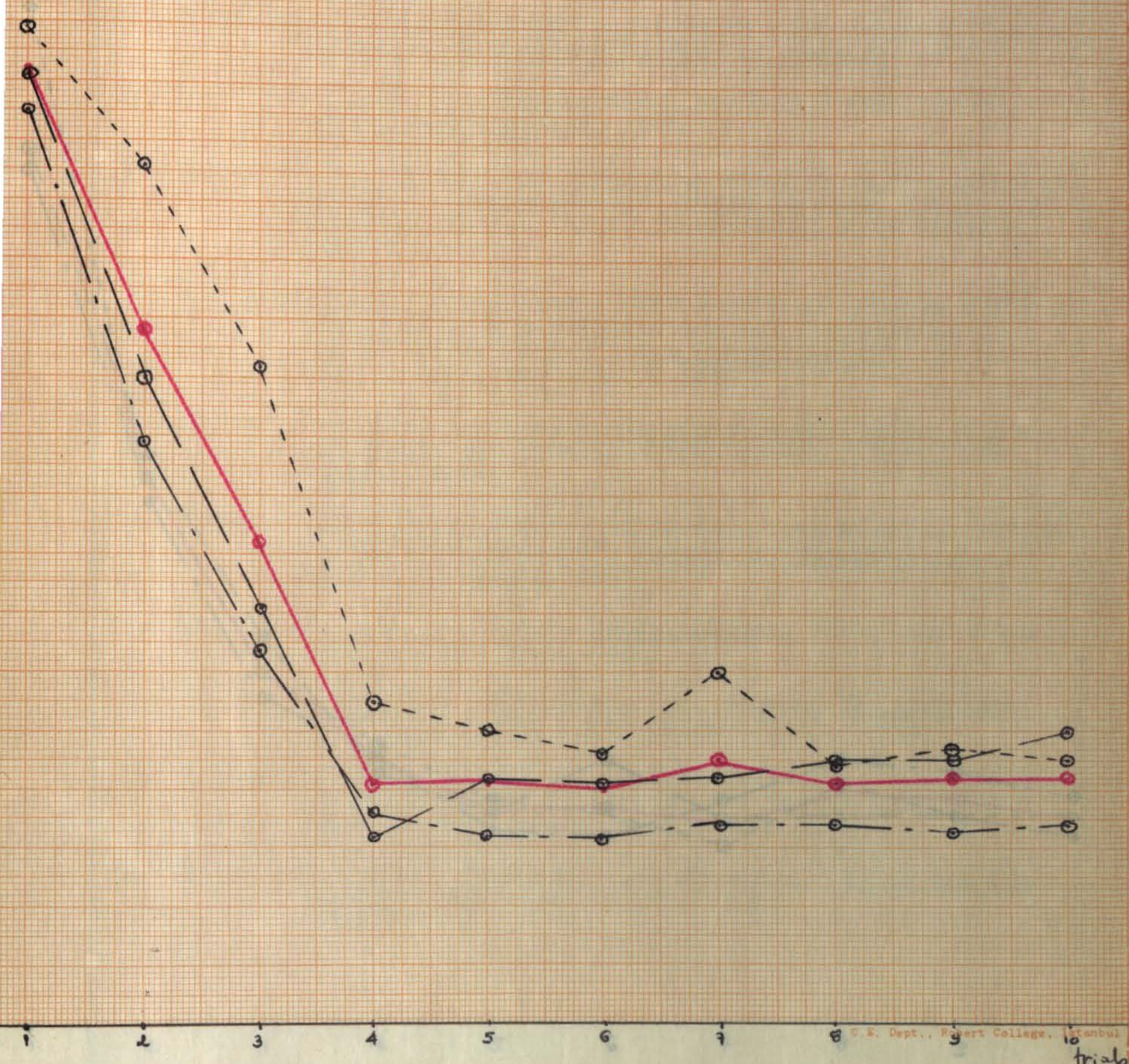


AVERAGE TIME PER TRIAL IN THE ALL-CHANNEL NETWORK

GRAPH V

DATE

Hor. 2cm = 1 trial Vert. 1cm = 10 sec NAME ——— AVERAGE FOR THE NETWORKS

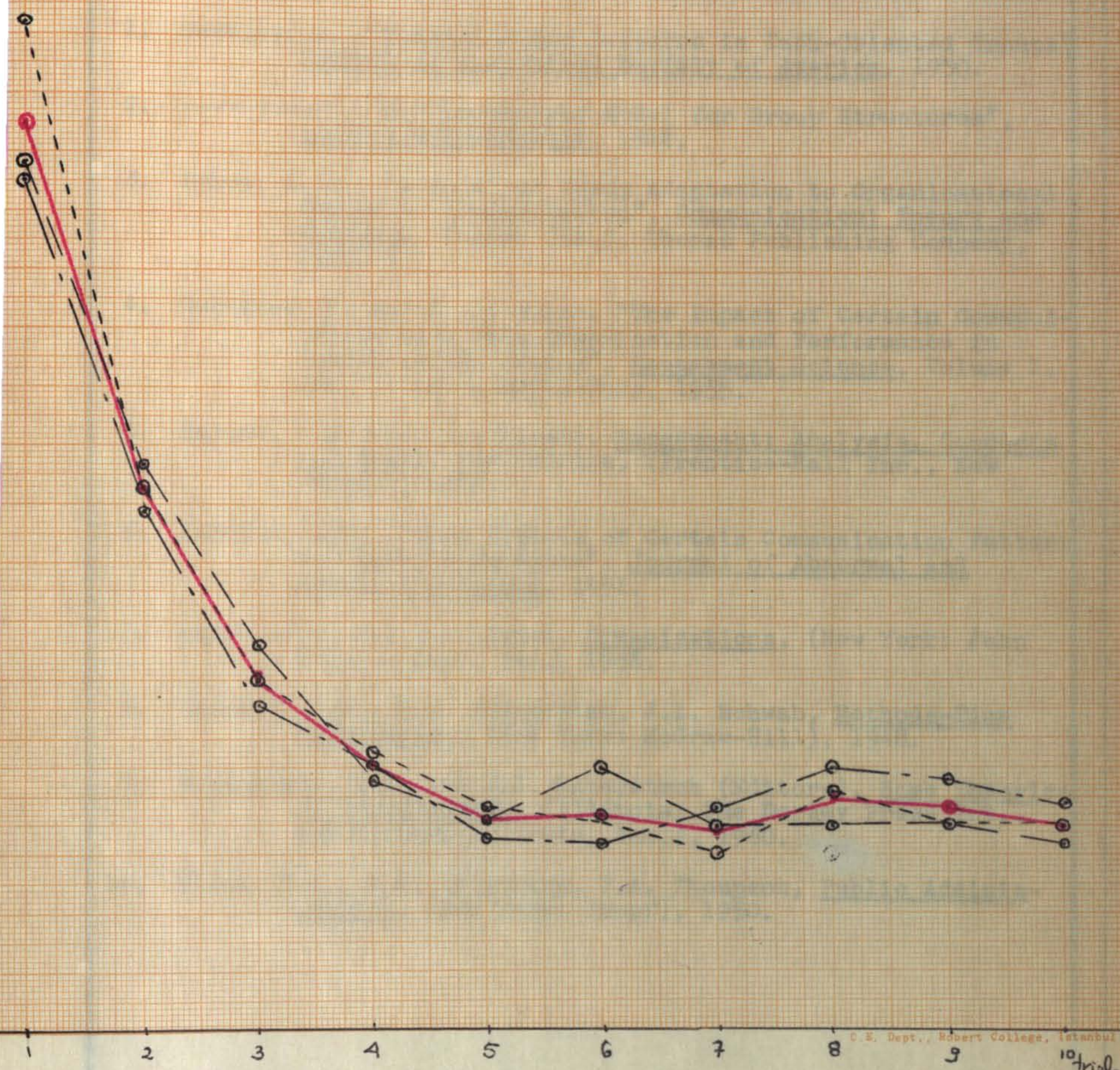


AVERAGE TIME PER TRIAL IN THE Y NETWORK

GRAPH VI

DATE

hor. 2cm = 1 trial   vert. 1cm = 10 sec   NAME   ——— AVERAGE FOR THE NETWORKS



AVERAGE TIME PER TRIAL IN THE WHEEL GROUPS

GRAPH VII

2 cm = 1 trial   1 cm = 10 sec   —— Average for the networks

BIBLIOGRAPHY

1. Bavelas, A., "Communication Patterns in Task-Oriented Groups", Journal of Acoustical Society of America, 1950.

2. -----------, "A Mathematical Model for Group Structures", Applied Anthropology, 1948.

3. Cohen, A. M., "A Model of Group Adaptation to Organizational Change in Communication", Communication: Theory and Research, Thayer (Ed.), Thomas Publishing Company, 1967.

4. Guetzkow, H. and H. A. Simon, "The Impact of Certain Communication Nets Upon Organization and Performance in Task-Oriented Groups", Management Science, Volume 1, Nos. 3 and 4, April-July, 1955.

5. Haynes, W.W. and J.L. Massie, Management: Analysis, Concepts and Cases, 2nd Edition, (Prentice-Hall Inc., New Jersey), 1969.

6. Leavitt, H.J., "Some Effects of Certain Communication Patterns on Group Performance", Journal of Abnormal and Social Psychology, 1951.

7. March, J.G. and H.A. Simon, Organizations, (New York: John Wiley & Sons, Inc.), 1958.

8. Maynard, H.B., G.J. Stegmerten, J.L. Schwab, Methods-Time Measurement, (New York: McGraw-Hill), 1948.

9. Rubenstein, A.H. and C.J. Haberstroh (Editors), Some Theories of Organization, (Illinois: The Dorsey Press Inc., and Richard D. Irwin, Inc.), 1960.

10. Simon, H.A., D.W. Smithburg, V.A. Thompson, Public Administration, (New York: Knopf), 1950.