*Netherlands Institute for Preventive Medicine at Leiden
and State University at Utrecht*

GROUP-STRUCTURE AND GROUP-PERFORMANCE * 1

BY

MAUK MULDER

INTRODUCTION

In a number of laboratory experiments on communication-structures (networks), one of the two most important dependent variables has been the task-performance of groups [2]. The original publication in this field is by Bavelas: in interpreting Lewin's topological concept of "shortest path" (intended to be a dynamic concept) in a purely *positional* sense, he developed a measure of position-centrality in the net (4).

Since the first publication (in 1948) elaborate research has been carried out, in which researchers were basing themselves more or less on this idea of position-centrality: Leavitt, Heise and Miller, Shaw and Guetzkow performed laboratory experiments, using the *topological structure* as an independent variable.

In these experiments groups of 3, 4 or 5 subjects [3] could interact only by means of written messages. This communication was necessary to solve group-tasks. Each group-member possessed a certain amount of information and the combination of all the information was needed to solve the group-problem.

In those groups some of the communication channels (or links) between the members can be blocked, so that they cannot be used. In this way the experimenter can easily introduce varied structures, in which the positions differ in "centrality". Centrality reflects the extent to which one position is strategically located in relation to other positions in the pattern. The *most central position* in a network is the position *closest to all other positions*.

Let us consider the two "structures", depicted here as wheel and circle.

The letters represent persons, the connecting lines represent the channels through which the communication is possible.

A clear difference exists between these two structures: in the wheel the group-member C is in a central position; every inter-communication (= communication from one group-member to another) has to go through the central position.

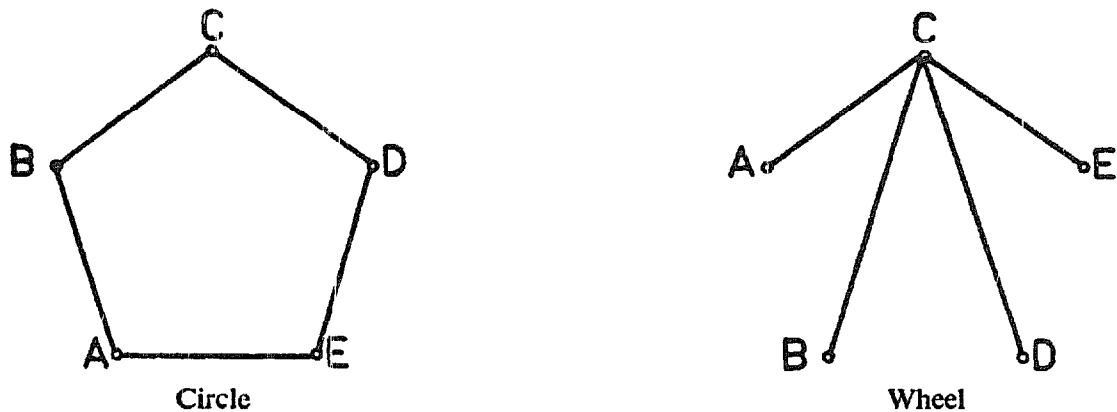Circle   Wheel

Fig. 1
5-position-structures.

The central person himself can communicate directly with each of the others. In the circle no differentiation exists between the five positions; all persons have equal communication-possibilities. Leavitt performed laboratory experiments with groups of five persons (34).

It may be useful to state the task used in this research. Each S, labelled by color, was given a card. On this card was a set of five (out of six possible) symbols. Each S's card was different from all the others in that the symbol lacking, the sixth one, was a different symbol in each case.

Thus, in any set of five cards there was only one symbol in common. The problem was to find the common symbol.

To accomplish this, each member was allowed to communicate by means of written messages with those other members of the group to whom he had an open channel (a link in our diagram). Every member had to know the common symbol.

Leavitt [4] found, that the wheel-groups worked faster than the circle-groups, when he analysed the "fasted single correct trial" (other time-measures yielded no significant results).

Furthermore, the wheel-groups needed a smaller number of messages to solve the problems and they made less errors.

According to Leavitt, the topological structure determines the better performance of the wheel-groups. Especially "*centrality*" as a *measure of "closeness" of all other positions in the structure,* is thus a measure of the

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[4] Not all the findings of other researchers can be reported here; the most relevant ones are selected.

"availability of all information", which is necessary for the solving of the group-problem.

The most central position in the wheel (C), closest to all other positions, is most likely to get the answer first. This answer-getting potential is very different from the one in the circle, where all members have an equal opportunity to collect all information and to solve the problem.

Two predictions (on time and amount of communication), theoretically derived from the topological structure, are not validated by the reported facts, thus Leavitt has to refer to the development of the group's organization (34, pp. 40, 42, 47, 49).

Here we are confronted with the same tendency, as in the research on satisfaction: the tendency to attribute performance-phenomena directly to characteristics of the topological structure. But as we formulated already (42), *the topological structure does not determine, what really happens, but only what is possible*. According to us, it is important, who actually sends messages to whom, and which content these messages have: *the dynamic structure must be determined* [5].

From this viewpoint the following data of Leavitt are relevant: he used four different topological structures. But the problem-solving times were not a function of these topological structures, but fell apart in two groups, as is clear in the following table.

Leavitt's data	C	Ch	Y	Wh
structure-centrality	25.0	26.1	26.2	26.4
structure-peripherality	0.0	7.4	9.8	13.6
time	.84	.89	.59	.53
messages	5.6	3.7	2.9	2.9
total-errors	16.6(7.6)	9.8(2.8)	2.6(0)	9.8(0.6)
definite errors	6.4	6.2	1.6	2.2

Although the smallest difference in "centrality" exists between the chain- and Y-structures, the wheel- and Y-structures are grouped together in the behavioral data. This remains unclear when we concentrate in our explanatory efforts only on the *topological* structure-qualities.

It appears from Leavitt's data on the "organization of work", that in all wheel- and Y-groups the central person collects the information, then solves the problem and sends out the answer ("central method").

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[5] When the relations, existing between group-members with regard to a dimension, show a certain durability or stability, we speak of a dynamic structure (12).

In the chain, it occurred in a number of cases, that persons other than the most central one, found the solution and passed the answer to the others. In the circle the information-messages were sent in two directions, till someone made the answer or received it from a neighbour. Thus it seems, that the "better" performance in regard to "time" and "number of messages" of the wheel- and Y-groups may be accounted for, not by the topological structure, but *by a special type of Interaction-Structure*, which develops itself on the basis of it.

In the Netherlands, we replicated Leavitt's experiment with 5-position-groups, using the wheel- and circle-structure. Subjects were students of the University of Amsterdam, in their first year. Ten circle-groups and nine wheel-groups were run. The wheel-groups worked faster (measurements: "mean time per problem" and "fastest single correct trial"), used fewer messages, and made less errors (cf. 43, p. 118-121).

In 67 % of the wheel-groups, a work organization envolved after the fourth problem, in which all "peripheral" members sent their information to the central person, who made the solution and sent out the answers.

Thus Leavitt's results are confirmed in this experiment with Dutch subjects.

An interesting phenomenon will be reported here, although it is not *directly* relevant. Bavelas and Leavitt (5, p. 503 and 34, p. 45) raised the question whether in certain communication-structures the probability of effective utilization of *insight* is greater than in others. They referred to the "method of elimination", whereby S instead of taking time to write all his symbols, wrote just the missing symbol, thus saving considerable time. From Leavitt's material the question could not be answered.

From our material it appears that the initiative to such insight occurs as often in wheel-groups as it does in circle-groups. However, the *acceptance* of it occurs more often in circle- than in wheel-groups, the difference being significant (.02 $< p <$ .03, two sided test).

Heise and Miller (24) used three-persons-groups, and several tasks. One of them was a stereotyped exchange of isolated words (task I); task II consisted of a sentence-construction.

The wheel-groups worked faster with the sentence-problems, but the circle-groups with the words problems. The communication activity was equal for both "structures" in task II, in task I the wheel used more messages. In task I, the Wheel made less errors (task II was nearly errorless).

Task I can be solved by machine-like behavior, and does not lead to an impression of a "group at work". The information flows through the channel-system, *along* the positions.

Task II, however, is different; to quote the writers themselves: "These problems were less rigidly structured and provided more scope for initiative". Especially the results of task II are therefore interesting; and from those, Heise and Miller concluded the wheel to show a better performance. The writers state: "Apparently the reconstruction of sentences requires more integration of group activity; the central man can co-ordinate and place in the proper context the words that the subjects contribute ... Conversely, the situation can become chaotic in the circle, for no one organizes the individual contributions" (24, pp. 322, 333).

For each of the structures a minimum-time and a minimum-number of messages were calculated.

It is interesting that in Task I, where machine-like behavior is exhibited by the subjects, time- and communication-data are according to expectation.

But in Task II they totally fail to do so (24, pp. 331, 333). From the description this task seems to be a simple task for the S's (they made no mistakes in it!) and thus it is comparable with the problems of the Leavitt-type.

The results of this experiment then also support the opinion about the relatively small importance of the topological structure for the prediction of *group*-behavior.

Very important is the research, done by Guetzkow and Simon (18, 19). The starting-point of these investigators has been the same as ours; for that reason we will report their findings now, before proceeding with the experiments and theories of Shaw. Guetzkow and Simon emphasize the effect of the communication-structure upon the *group's ability to organize itself* for performance of the task.

They designed an experiment with 5-position-groups and with three topological structures: wheel, circle and all-channel (in which all positions can communicate with all others). The problems were "simple" ones, of the Leavitt-type, but the experimental situation was modified, so that there was ample opportunity for S's for planning an organization [6].

The writers hypothesized that not the communication network, but the organization which develops, affects the speed of performance of the group-task.

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[6] Still further with promoting the organizational development went Flament (15) who instructed the groups explicitly to organize themselves centrally. His all-channel, chain, and wheel-groups (5-position-groups) required identical times to solve their Leavitt-type problems.

A time-study-analysis [7] of the task was made, the result of which indicated, that for these tasks the topological structures will *not* create differences among the groups with respect to the *time* needed to solve the problem, *when an optimal organization will be used.*

Optimal organizations are the "two-level-hierarchy" or the "three-level-hierarchy". A two-level-hierarchy exists, when the peripherals in the wheel send their information to the central person, who makes the decision and returns the answers to the peripherals. In a three-level-hierarchy, two neighbours send their information to their opposite neighbours, who in turn relay this information with their own to the fifth member; this person can solve the problem, relay the answer back through the "relayers" to the "endmen".

It appeared that seventeen of the twenty all-channel-groups, all fifteen wheel-groups and three (of the twenty-one) circle-groups developed such two- or three-level-hierarchies, and the "mean times for three fastest trials" did not differ then between the three networks, nor did they show a difference with the theoretical time, based on the M.T.M.-analysis.

Research, carried out at the University of Wisconsin, has shown results, which contrast the ones reported in the foregoing pages.

Shaw (47) used problems of the following type:

A small company is moving from one office building to another. It must move four kinds of equipment: (1) chairs, (2) desks, (3) filing cabinets and (4) typewriters. How many trucks are needed to make the move in one trip?

Items of information needed to solve the problem:

1. The company owns a total of 12 desks

2. „ „ „ „ „ „ 48 chairs

3. „ „ „ „ „ „ 12 typewriters

4. „ „ „ „ „ „ 15 filing-cabinets

5. One truck will carry 12 typewriters and nothing else

6. „ „ „ „ 3 desks „ „ „

7. „ „ „ „ 5 filing cabinets „ „

8. „ „ „ „ 24 chairs „ „

The statement of the problem was typed completely on each of four separate cards and each item of information was typed on a separate card. Each subject was given one of the problem cards and two of the information cards.

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[7] The procedure was the Methods Time Measurement, used in American industry (Maynard, Stegmerten and Schwab: Methods-Time Measurement, New York, McGraw Hill 1948).

In 4-position-groups, he found his wheel-groups working slower in the last (= third) problem, than his circle-groups, although they used fewer messages. There were no error-differences (and a smaller "corrective power" in the wheel- than in the circle-groups). These results were different from Leavitt's findings.

Shaw then designed a critical experiment, with so-called complex tasks from the type of which we gave an example, and so-called simple tasks of the Leavitt-type (48, p. 212).

In 3-position-groups, the wheel-groups required in the last (= fourth) problem less time for the relatively *simple* problems than the circle-groups (although the difference failed to reach statistical significance). The circle-groups however are (significantly) faster in the fourth *complex* problem than the wheel-groups. For both simple and complex problems the wheel needs fewer messages than the circle.

In the simple problems, there is no difference in number of errors between the two structures, but in the complex problems, the circle-groups make less errors.

Shaw (48, p. 217) writes: "The present experiment was designed to test the hypothesis that a communication net in which all S's are in equal positions (the circle) will require less time to solve relatively complex problems but more time to solve relatively simple problems than will a communication net in which one S is placed in a central position (the wheel). The outcome of this experiment generally supports the hypothesis".

The performance of the wheel is better for the more simple tasks, the circle is superior for the relatively complex problems. Shaw states that the simple problems merely require S's to identify a symbol held in common by all S's of the group, but the "complex" ones require S's to perform simple arithmetical computations such as addition, subtraction, multiplication and division.

In his theoretical explanation Shaw suggests that the differences found between the structures are due to the *availability of information* and to the *possibility of contributions from all members of the group*.

"When simple problems are to be solved the availability of information is of primary importance. All S's are equally capable of identifying common symbols. ...Thus, with simple problems the wheel should be faster than the circle because information is just as available to the person in the central position in the wheel as it is to any one position in the circle, and because the wheel pattern has the added effect of designating which S will perform the function of identifying the common symbol.

As the complexity of the problem increases, however, the possibility of contributions from all members of the group becomes much more important. Th s

is true because some S's are more capable than others of solving such problems quickly, and because part solutions can be delegated to various positions, thereby compensating in part for the effects of "saturation". With complex problems, then, the wheel should be slower than the circle because the central person becomes saturated (i.c. because he must do most of the work, either the actual solution or relaying information, the optimal output level is exceeded) and because it sometimes forces the weakest person in the group to function in the leadership role" (48, p. 216) [8].

This *"participation"-theory* has been quoted "in extenso", because our own experiment has been designed to test an opposing theory; in the next paragraph some theoretical considerations function as an introduction to this theory.

THE CENTRALIZED DECISION STRUCTURE

Three objections may be risen against Shaw's theory and the experiments, by which he tried to confirm it.

The first one concerns the *problem-complexity*.

It seems to us that Shaw's "classificatory" difference between two "substantially" different types of problems, simple and complex problems, is not completely justified: in both types of problems the essential feature seems to be that information, distributed over all group-members, needs to come together for the problem-solution. The *gradual* differences, we see between them, do not prepare us beforehand for the complete reversal of the results, which appeared in Shaw's findings.

One question is: is it possible to explain the seemingly quite contrary findings of Leavitt and Shaw in one theory, without using the "substantial" [9] concepts "complexity" and "simplicity" of problems as basic in such a theory?

The second objection is an experimental-methodological one. Shaw's "experimental situation" differs in two aspects from the situation in Leavitt's experiment. These two aspects were recognized by Shaw, but according to us, he underestimated them.

a) *number of problems*. While in Leavitt's experiments the groups solved 15 problems, Shaw's groups did only 3 or 4. This is an important

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[8] Another theory of Shaw is that when S's work with simple problems they should be willing to accept the decision of another S much more readily than in the case of the more complex problems. But the analysis of the used method of solution made clear, that the expected difference in method, used for the two types of problems, did not show up (48, p. 216).

[9] Lewin rejected in 1931 (35) the use of dichotomous classifications in psychology.

difference between the two experimental situations, on which we will come back.

b) *number of positions*. In an experiment with four-position-groups Shaw found results, contrary to the Leavitt-data. With the purpose of demonstrating, that circle-groups show a better performance than wheel-groups when solving complex problems, he then designed an experiment with three-position-groups, instead of with five-position-groups (as Leavitt had done).

However, there is a clear *topological* difference between groups of five and three positions. The "centrality"-differences for instance between individual positions are far greater in 5-position-groups than in 3-position-groups.

From the *dynamical* point of view the difference is much more striking. A circle-structure with three positions is not a typical circle, but a "totally interconnected structure": eventually it may function as a hierarchy with two levels. If all group-members send their "information" to all others, and each position makes his own problem-solutions (and this is exactly what happens in all Shaw's three-position-circlegroups) (48) the processes can be most adequately described as the simultaneous functioning of three wheel-groups. In the first phase, each position acts as a peripheral, who sends his own info to the others; in the second phase each position acts as central position, who after receiving all relevant info, makes the problem-solution [10].

All disadvantages, ascribed by Shaw to the wheel (cf. p. 363), are in this situation realized for the circle; the advantages of the circle, with which Shaw explains the superiority of this structure, are not realized in the three-position-circle, as it functions in Shaw's experiment. Our conclusion is, that the three-position-circle is inadequate to test Shaw's Participation-theory.

The third criticism is the most fundamental one: in the theorizing of Leavitt and Shaw the importance of the topological structure is strongly emphasized. "Availability of information", "contributions from all group-members", and "saturation" are directly derived from the topological structures. But predictions, based on characteristics of the topological structures, were not corroborated by the actual data, as we have seen (p. 358, 360). And in Leavitt's data, other variables appeared to be eventually more determining with regard to group-performance (p. 358).

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[10] The same reasoning holds for a more recent experiment of Shaw, in whic. "all channel-groups" are compared with wheelgroups (52).

Thus the dynamic aspect seems to be neglected to a certain degree in these earlier studies [11].

That is to say: it is understood that the topological structure leads, via other variables, to the final group-performance. But, especially for the prediction of the performance in situations, different from those, studied in the communication-structure experiments, these *dynamic intervening variables* must be clearly identified [12].

From this point of view, an answer may be suggested on the question at the end of the foregoing paragraph: how to explain the seemingly contradictory results of Shaw and J eavitt.

Therefore we start with defining the concept: *"interaction-structure"*. This concept in general refers to status gradients, reciprocal role relations, control relationships, etc. In this publication it has a more restrictive meaning: it refers to *"who communicates with whom"*.

On the basis of the topological structures (purely positional networks of links and knots) more dynamic interaction-patterns grow: for instance in the wheel it is necessary that every "inter-communication" goes to, from or via the central position. From these inter-communication-processes, the interaction-structure may be abstracted, when the *content* of the communication is neglected.

But, with regard to this "content", an important distinction may be made. In task-performing groups, studied by Leavitt et al., there occurs *exchange of information;* the information-items, required for the problem-solution, are distributed over all group-members, so they must be sent to others. But also, several *"decisions"* can be made: the decision not to pass the information, but first to collect all needed information; the decision to make the problem-solution for one's self; the decision not to accept the solution of another group-member, etc. These decisions result from the task-requirements of "making the problem solution" and "exchange of problem-solutions". These "processes" could be clearly identified sometimes in direct observation during the work-period in our own experiment (p. 359), but do not lend themselves to easy measurement.

To emphasize this "content" of the interaction (communication) the construct *"decision-structure"* may be introduced, and defined as: *"who takes decisions for whom"*.

Now this decision-structure may also have a centre; and to emphasize the

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dynamic character of the interaction-, and decision-structures (compared with the topological structures), we speak about a centralized structure (or: degree of centredness).

The core of our theory is, that *groups with a more centred decision-structure will be capable of better group-performances, because the contributions of the individual group-members can be integrated by the person in the centred "position" (the leader position)*. The theory is restricted to situations, in which 2 or more persons perform a group-task; in our experiment information, divided over all group-members, must be used to solve the group-problem.

Implicit in our concept of the *dynamic centred decision structure* is the idea, that it must *develop* itself.

This is in itself only logical, but we want to clarify the exact consequences.

A *more centred structure* is in general characterized by *"vulnerability"*: a disturbance in the functioning of the central position will have a radical effect, because this effect will be spread quickly through the total group and it will be very difficult to send the information-flow via other positions or to make the decisions in other positions.

Examples of such disturbances, as they may happen in our experimental set-up, are: insufficient capacities of persons in central positions; pressure from the "environment", as in the case when the central person is asked, which data a certain group-member has, if he will send a certain piece of information, if he wants to explain why he acts as he is acting (for instance why he is holding back data), etc. In this way, the vulnerability of the more-centred structure is to a considerable extent a function of the relation between the *pressure* from the environment and the *resistance* against this pressure of the person in the central position in the structure.

It is our opinion, that this vulnerability will lead to effects, when the centred *interaction*-structure, is not developed sufficiently toward the strongly centred *decision*-structure. Then the central position is not yet sufficiently resistent against pressure exerted on it.

In experiments, as Leavitt's, Shaw's and ours, groups are newly formed and start on new tasks; the moment they start they have no experience in solving such problems with such groups; under these circumstances we may expect that *in the beginning of the "work" more centred groups perform not better, but eventually worse, than less-centred groups.*

There is support for this theory in the available data. In Leavitt's time-data (34, p. 42) the wheel-groups are slower in the first problem and in the secon. problem wheel and circle need equal time. In the first problem the circle-grou;

use the same number of messages as the wheel-groups, but in the second they use already far more messages.

In this context it is also interesting that Leavitt found in one of his wheel-groups a great number of errors, because the central person accepted information-messages as answers. This happened in the first part of the experiment!

Mulder and Eikeboom also found in a replication of Leavitt's experiments with Dutch subjects (43) that the circle was faster in the first problem and slower in the second and next problems. In number of messages the wheel was already superior in the first problem.

The data of Simon and Guetzkow do not show a time-difference in the first problem. But S's were extensively trained, so that they knew how to solve the problems; it was made clear to them that they could accept solutions from other group-members, and special communication techniques were illustrated. The researchers state: "The task was reduced to a mere routine".

In research, performed by Luce, Macy and Christie the wheelgroups also are slower in the beginning, faster at the end of the workperiod, compared with the circlegroups (39, p. 10).

Shaw's data are not very clear in this respect. One gets the impression, that *Shaw's experimental groups do not develop such centred decision structures* as the groups in the experiments of Leavitt, Simon and Guetzkow and ourselves. In the latter ones, *all wheel-groups* develop into strongly-centred decision structures in which the central person makes the solution and sends it out. In Shaw's experiment with 4-position-groups, only 37 % of the wheel-groups use such a central method, in an experiment of Gilchrist and Shaw this figure is 28 % (16), and in Shaw's 3-positions-experiment it is 50 %. (And it does not make a difference, whether it concerns simple or complex problems in this experiment!) [13].

From the viewpoint of our theory then, other findings of Shaw could be related to these data on the work-organization. For instance the fact that the difference between circle- and wheel-groups in *times*, needed to solve the simple problems, is *not significant* (conf. p. 362). Furthermore, there is *no difference in errors* between wheel and circle with simple problems. Thus these data do not show the wheel to be very *clearly* superior for simple problems, although in the experiments by Leavitt, Guetzkow, Heise and Miller and ourselves it appeared to be so.

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[13] The satisfaction differences between persons on central positions and the others, the so-called peripherals, are very weak too in the Wisconsin-experiments, as compared with the other experiments. Earlier we demonstrated (42) that an important determinant of the relatively high satisfaction of "central persons" is the exertion of power over others. This power-exertion goes with more centred decision structures.

The small satisfaction differences could eventually be attributed to the lacking of more centred decision-structures.

In our opinion, an explanation of this striking discrepancy could be that the centred decision structure did not develop to a considerable degree. An essential point in Shaw's design may be emphasized: while the groups of Leavitt and Guetzkow performed at least 15 problems, Shaw's groups did only 3 or 4. Shaw noticed this difference, but did not give much weight to it (48, p. 211). According to our theory this is a most critical difference the *topological* structure is "given" and does not change; the *dynamic decision structure* however, must have opportunity to grow, must develop into centredness. In Shaw's experiments this opportunity is decisively smaller than in the other studies, because of the very small number of problems, to be solved [14].

The difference between the findings of Leavitt and Shaw, we would suggest, is not that the wheel allows for better performance with the simple problems, the circle groups with the complex ones, but that the more centred decision structure, which has developed in Leavitt's 15 problems, enabled a better performance. In Shaw's experiment, the groups did not develop strongly centred structures. (And the *gradual* difference between simple and complex problems has an effect in so far that the "vulnerability-phase" of the more centred decision-structures requires more time (= problems) with the complex than with the simple problems).

The answer, suggested for the question on p. 363, is that the contradictory results may be explained by one theory: *a theory on the degree of centredness of the decision-structure, as this has developed itself during the performance of the tasks,* with which the group has been confronted.

THE CENTRALITY-INDEX OF THE DECISION STRUCTURE

Now, an *operational definition* of the decision-structure will be given; this definition is strictly *a priori*, it is constructed without knowledge of our own experimental material (but with knowledge of the possibilities in the experimental situation in general) [15].

In the topological wheel-structure, a centred interaction-structure develops, in which the central person may function as a mere *"relayer" of information* (he sends out to all others what he receives, when he receives it or when someone asks for it, so that each of the group-members receives all information-items *in a number of separate messages, and may make then*

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his own problem-solution. He does not function as a strong leader, when leadership is conceived as the degree, to which a person contributes to the final group-performance (10).

Or he may function as an *"integrator"*. He may make the decision not to pass the messages, he receives, but to withhold them till he has all the necessary information, so that he himself can make the problem-solution, and then he may

I. send the solution to other group-members;

II. send the solution plus all the necessary information in one message to other group-members;

III. send all necessary information in one message to other group-members.

Although three "types" of integration activity are distinguished, in all of them the central person makes decisions which have consequences for the total group-activity.

Consequently, the *"centrality-index" which measures the degree of centredness of the decision-structure,* is based on communication-acts of all three types [16].

The "decision centrality index" (D.C.I.) is computed in this way: As a first step, for each person in the group must be computed how many persons are supplied by this person with messages of type I, II or III.

In this operation, type II- and III-content, although in *principle different,* are given the same weight (= 1), because when all information is put together on one sheet, the solution *of this experimental task* can be read-off easily. Type I-content is weighted double (= 2) because here the person who sends out the solution does not allow for any participation in the solution by the "receiver".

Second, the scores of all "positions" in the group are summed up.

Third, the *proportion* of every "position" is calculated by dividing his individual score by the sum-total.

The last step is to calculate the *difference* between the "position" with the highest proportion and the "position" with the next highest. Thus the "decision centrality index" (D.C.I.) gives a measure of the centredness of the decision-structure on *one* "position" (the "leader"). It may vary from zero to 1.00.

Although it bears upon *detail*-considerations and *post-hoc analysis* of data, the following points may be made: In the D C.I., as it is operationally defined, the sequence of acts is not included. An example will clarify this:

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[16] In the experiment to be reported, no instructions were given to S's as to the different existing possibilities of communication-content, and the message-sheets were not precoded.
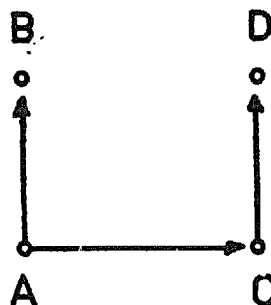
B   D

A   C

Fig. 2

When the arrows represent type I-, II- or III-messages from A to B, A to C, and C to D, it is uncertain if C has accepted the solution from A or that C has made his own solution. The latter possibility exists, because very often an intensive *information*-exchange occurs in the experimental groups.

Thus we do not know if C has passed to D the solution, received from A, or his own solution.

In the D.C.I. computation the distinction between these two possibilities is neglected: Even if C only passes A's type I, II or III-content to D, *he must have made the decision to do this*; in the D.C.I. computation, C is also in principle conceived as a "centre" for one decision. The *effect* of A's decision for C is not incorporated in the D.C.I.

The implication is that circle-groups have a disadvantage in developing a high degree of decision-centredness; it is impossible for one position in a four-position-circle to make decisions for the total group.

Now this could seem inadequate for those cases in which A is indeed the initiating centre and C waits for A's "solution" to pass it to D; one could take this solution to be A's decision, as it very often is in real life situations. However, *post-hoc* analysis of the data made clear, that this objection is not too serious in this experiment: in all (25) circle-groups, a situation similar to the one in figure 2, where C passed a received solution, *without having made his own solution*, did not happen.

For comparison, a second illustration is given:

B   D

A   C

Fig. 3

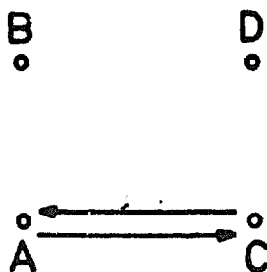Here again we do not know if A sent first a "decision" (type I, II or III) to C or if the reverse happened: again the sequence of acts is neglected, both positions are equally thought of as centres for one decision. This is very adequate because from the material it appeared (conforming to the a priori expectation) that this behavior of sending back one's "own" solution (rationalized as "checking") indicates

non-acceptance of the decision of the other. Here the "effect" of decisions, that is the acceptance or non-acceptance of someone's decisions by someone else (the power-structure) reflects itself to a certain degree in the D.C.I.!

In this connection the following experimental data are interesting: in the circle-groups, 65 % of the subjects make their own solution (from information, received in a number of messages) [17]. But 81 % of the circle-subjects receive type I, II or III messages!

Then only 19 % of the circle members make their own solution (without benefit of Type I-, II- or III-messages). Thus 46 % (65—19) make their own solution after having received also Type I-, II- or III-messages, or they make their own solution and receive afterwards Type I-, II- or III-messages.

In the wheel-groups the processes are quite different: 35 % of the subjects make their own solution; 79 % received Type I-, II- or III-messages. Thus 14 % make their own solution, while also receiving Type I-, II-or III-messages. In this case too, the problemsolving may have been done before reception of Type I-, II- or III-messages, or afterwards; but the important point is, that in both cases more members of the group continue functioning as a "centre". With regard to this, there exists a clear difference between the figures for circle-groups (46 %) and wheel-groups (14 %). The total figures for "making own solution" are also clearly different (65 % in the circle versus 35 % in the wheel).

The conclusion may be that, although the D.C.I., as it is calculated here, does not encompass in a strict way the *sequence* of acts, the use of it is well justified.

In the foregoing the reason is implicated, why we use the concept "decision-structure", instead of power-structure. Power-structure we defined earlier (42, p. 13) as the determining to a certain extent of the behavior of another. Now the power-relation between A and C (in figure 2) is not known, because it depends on the sequence of acts. The decision-structure, in which this sequence is neglected, is less revealing concerning the group-behavior.

HYPOTHESES

The theory on "decision-centredness" may be summarized as follows: groups with a more centred decision-structure perform the tasks better, because the contributions from the individual members can be better integrated by the person situated in the centre.

The dynamic centred-decision-structure has to develop; this takes a certain amount of time (a certain number of tasks). The degree of centred-ness of the decision-structure is expressed in the Decision Centrality Index (D.C.I.), being a measure of the degree in which one person makes the decisions for the whole group.

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[17] The data are given for the last problem, the group had to solve.

Furthermore a greater "vulnerability" for more centred structures is presumed in the theory; this vulnerability making itself apparent especially in the beginning of the working period.

The theory is laid down in the following hypotheses:

General hypothesis I

To the extent that the decision-structure in groups is more centred, the groups will give a better performance of their group tasks [18].

The specific hypotheses are:

I A. To the extent that the decision-structure in groups is more centred, the group task will be performed faster.

Performance per time unit is measured by the time, the group needs to solve (correctly) its problem.

I B. To the extent that the decision-structure in groups is more centred, the quality of the task performance will be better.

The quality of the performance is defined here by the number of errors made by the group during the task accomplishment.

I C. To the extent that the decision-structure in groups is more centred, the group task will be performed more efficiently.

Efficiency is defined by the number of messages, the group needs to solve the problem [19].

General hypothesis II

To the extent that a structure is more centred, it is characterized by a greater "vulnerability". The vulnerability will demonstrate itself when the pressure exerted on the central position of the structure is greater than its resistance.

In our experimental design, this hypothesis can be tested specifically, because newly formed groups start working on new tasks. In the wheelgroups centred *interaction*-structures are starting then nearly immediately. The expectation is that in the beginning of the workperiod, the resistance of the centre in the more-centred groups will be smaller than the environmental pressure on it.

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[18] Our groups accept as their task to work as fast as possible. When the group-goal should be: "to work slowly and badly", more-centred groups should "better" perform this task. Cf. Schachter's clarifying study on productivity (45, 6).

[19] In general efficiency refers to a certain goal-valence and the costs of reaching this goal. The restriction to "number of messages" is arbitrarily (cf. 56, pp. 39, 180 etc.; 42, p. 94).

II A. To the extent that the interaction-structure in groups is more centred, the group task will be performed relatively more slowly during the beginning period of the work [20].

II B. To the extent that the interaction-structure in groups is more centred, the quality of the group task will be relatively less during the beginning period of the work.

II C. To the extent that the interaction-structure in groups is more centred, the group task will be performed relatively less efficiently during the beginning period of the work.

> These hypotheses can be tested in the experiment, by comparing the performance of more centred groups and less centred groups, during the first part of the work-period (for instance the first two problems) and in the last period of the work (last two problems).

> Shaw has found that the "corrective power" is greater in wheel-groups than in circle-groups. This is in agreement with the concept of vulnerability, so the specified hypothesis can be formulated:

II D. To the extent that the interaction-structure is more centred, the "corrective power" of the group will be smaller.
> The "corrective power" is determined by comparing the number of corrected errors with the total number of errors.

To test these hypotheses, an experiment is designed in which four-position-groups had to solve *five* complex problems, of the type, Shaw had used. We should have preferred more problems to allow for the development of the decision-structure but in relation to the time, the subjects had available, this was a maximum [21].

On p. 363 it was suggested that in Shaw's experiment the change in number of problems could be important and in connection with the theory on the (developing) decision-structure, the above hypotheses were formulated. But a second relevant point seemed to be the number of positions in his groups (3 or 4; see p. 364).

In the theory on centredness of decision-structure it is assumed that the

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[20] With this formulation is meant, that we do not mean the task performance of more centred groups to be necessarily worse, but that the superiority of the more centred groups is reduced, *eventually* so much reduced that it means inferiority, compared with the less centred groups.

[21] The problems of the Shaw-type required much more time than Leavitt's problems.

more centred groups perform better than less centred groups because the "central person" can integrate the contributions of all members. If this is true, one can expect that such an *integration is more urgent, when the number of group-members is greater.*

Thus, we have the following *general hypothesis.*

The greater the number of members in a group, the greater will be the effect of the degree of centredness, of the decision-structure.

Specified hypothesis:

E. The greater the number of persons in groups, the sooner will the performance-inferiority of the less-centred groups show, as compared with the more-centred.

An experiment was designed with 5-position-groups, who had to solve 3 problems (again the numbers of members and problems are not ideal, but the results of a compromise, in connection with the available time of S's) [22].

Thus hypothesis E is proved when the superiority of the more centred groups appears at a relatively earlier phase of the workperiod in 5-position-groups than in 4-position-groups.

All foregoing hypotheses are concerned with the performance-variables. This section will be concluded with some hypotheses on recognition of leadership and satisfaction of group-members.

F. To the extent that in groups the interaction-structure develops into a centred decision-structure, the recognition of leadership will be more pronounced.

The expectation, formulated in this hypothesis, is that the group-members will tend to perceive the objective situation in a correct way. This leader-recognition will be measured by direct questions.

The last hypothesis is concerned with morale, or as we prefer to mention it, with satisfaction. In agreement with a theory on determinants of satisfaction in task-oriented groups, published elsewhere (42) the formulation is:

G. To the extent that in groups the interaction-structure develops into a centred decision-structure, the satisfaction of the group-members in the central "position" will be higher, of peripheral members lower.

Satisfaction is measured by a job-liking rating on a scale from unpleasant (= 0) to pleasant (= 10).

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[22] More "positions" lead to more time, needed for the solving of a problem

EXPERIMENT WITH 4-POSITION-GROUPS (5 PROBLEMS)

In the present study two topological structures were investigated: wheel and circle, both of four positions.

The apparatus. The S's were seated around a circular table, so that each was separated from the next by a vertical partition from the center to the tables' edge.

The partitions had slots permitting subjects to push written message cards to the persons on either side of them.

To allow for communication to the other members of the group, a five-layered pentagonal box was built and placed at the center of the table. The box was placed so that the partitions just touched each of the five points of the pentagon. Each of the five resulting wedgeshaped workspaces was painted a different colour [23]. The S's were supplied with blank message cards whose colours matched that of their workspaces. Any message sent from a booth had to be on a card of the booth's colour. On the left wall of each partition, 5 large cards, representing 5 trials, were hung in loose-leafe fashion. The cards were placed in order with the numbered backs turned to S. At the starting-signal, S could pull down the first card and go to work.

The 5 problems were the same "complex" ones, Shaw had used ("moving company"—cf. the example on p. 361—; "time of arrival of a plane"; "amount of gasoline, required for motor-vehicles"; "number of workers for constructing a building"; "amount of money for buying tombola-prizes").

Subjects: the subjects were students of Leiden University in their first year. They were naive with respect to this type of social psychological experiments [24] and were given the instruction to work as fast as possible (as a group).

Twenty-six groups of four persons were run, 13 for each "structure". The subjects of a given group usually were not acquainted with each other prior to the experiment; the instruction to the experiment was given them, when they were seated together. They were told, who could communicate with whom, but the structure was not made explicit to them.

When the group had solved the problems, each S was asked to fill out a questionnaire, in which mainly satisfaction- and leadership-measurements were made. The most important data in this experiment, however, were time-scores, communication-units and errors. These could be directly observed during the session or analysed from the material afterwards.

Results will be reported of analyses of circle- versus wheel-data, bearing especially on the development-hypotheses (II A., II B., II C.) but also on I A., I B., I C.

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[23] In this experiment only four of the five available workspaces were used.

[24] This experiment was introduced as meant to investigate how fast groups can solve certain abstract problems.

Furthermore analyses will be performed, based on the degree of centredness of the decision-structure during the last phase of the work. Only hypotheses I A., I B., I C. will be tested in these analyses.

THE RESULTS

The *Decision Centrality Index*. Before the findings concerning the dependent variables are reported, it is necessary to mention some data concerning the decision-structure (the D.C.I.). The mean D.C.I. for the wheel-groups = .47, for the circle-groups = .28. The difference is significant (one-sided test, with the Mann-Whitney U-test leads to $.01 < p < .02$). When we calculate the D.C.I. separately over the first two problems, and over the last two problems, the figures are for the wheel respectively .40 and .51, for the circle .31 and .24.

In the first part of the workperiod no difference in D.C.I. exists between circle- and wheel-groups, neither when the first problem is separately considered, nor when the two first problems are taken together.

The differences in the last phase are significantly different: for the fifth problem $.01 < p < .02$; for fourth and fifth problems together $.001 < p < .005$ (one-sided test). When for each group the difference between the D.C.I. of the last two problems and the D.C.I. of the first two is calculated (D.C.I. last problems minus D.C.I. first problems), this measure is greater for wheel- than for circle-groups ($p < .07$).

It may be stated that in the wheel-groups centred decision-structures develop to a greater extent than in the circle-groups.

The topological wheel-structure appears to promote the development of a more-centred decision-structure, and although the difference is not very great, the distinction between the topological structures will be maintained in the following analysis.

In this connection a relevant question is, if also the *interaction*-structure shows differences in development between the wheel- and circle-groups.

When calculating the degree of centredness of the interaction-structure, it appears that there is no increasing centredness of the interaction-structure in wheel- or circle-groups. The wheel-interaction-structure is very rigid in this experiment, and does not show a development.

SPEED OF THE WORK-PERFORMANCE (TIME TO SOLVE)

Time to solve was defined as the time required for the total group to learn the answer. The results are shown in Table 1.

TABLE 1

Mean times per problem in minutes (4-position-groups)

	first problem	second problem	third problem	fourth problem	fifth problem	total
Circle	13,95	8,70	6,60	6,55	7,25	8,61
Wheel	16,27	9,92	6,13	5,85	5,88	8,81
Circle minus Wheel	—2,32	—1,22	+0,47	+0,70	+1,37	

The wheel starts slower, but is faster in the later problems. The increasing "advantage" of the wheel appears clearly from the data on the last row. This interaction between structure and problem-sequence is significant (Kendall's tau $= 1,0$, $p = .01$ with one-sided test) [25].

Restriction to "times" of the *correctly solved* problems shows the same results, the circle- and wheel mean differences being in the 5 problems respectively —0,63, —0,30, +0,76, +1,03, +1,75.

But the differences in the last period between circle and wheel are not significant; when the fourth' and fifth' problems were taken together, the lowest p-value, obtained with the U-test, was $.05 < p < .10$, in the case of the times for correctly solved problems.

Hypothesis II A. is strongly supported from this material; hypothesis I A. is not, although the results are in the predicted direction.

QUALITY OF THE WORK-PERFORMANCE (ERRORS)

Any incorrect answer reported by a member of the groups is an error; a further distinction is possible between corrected errors and definite errors.

TABLE 2

Errors (4-position-groups)

	definite errors	corrected errors	total errors
Circle	28	29	57
Wheel	40	13	53

[25] The data satisfied few of the assumptions of analysis of variance and other "normal distribution"-methods; therefore the following distribution free methods are used: for fourfold tables, the usual Chi-squares eventually with correction for continuity, and with Fisher's exact method for: $f_{th} < 5$ (30); for 2 × K tables and K × L tables the Likelihood Ratio Test of the Independence hypothesis (cf. f.i. 41, p. 257 seq.); furthermore the Mann-Whitney U Test (61, 40, 59, 25), the Sign-Test (54) and Kendall's Tau (31, 28).

Results will be stated for a one-tail test, since they are testing directional predictions.

The error-"totals" are not different, but in the circle a far greater proportion of errors has been corrected, than in the wheel. The difference is significant ($p < .005$). Thus the corrective power of the circle-groups is greater; hypothesis II D. is strongly supported by these data.

In Table 3 are shown the distributions of the errors over the five problems, thus the development in the quality of the performance can be analysed.

TABLE 3

Errors per problem (4-position-groups)

	first problem	second problem	third problem	fourth problem	fifth problem	(sum)
Circle	9	15	8	7	18	(57)
Wheel	20	12	11	4	6	(53)

60 % of all the wheel-errors are made in the first two problems; in the last two problems 19 %. For the circle these figures are respectively 40 % and 44 %. The difference, shown in the 2 × 5 table, is significant (likelihood ratio test $.01 < p < .02$). The errors of the wheel-group appear to be concentrated in the beginning of the work-period. This results in fewer errors in the last two problems (or in the last problem) for the wheel-groups than for the circle-groups (with Chi-square the p values, corresponding with one-sided test, being $.01 < p < .05$).

When the analysis is restricted to definite errors, the results go into the same direction, but are statistically not significant.

Hypotheses II B. and I B. are strongly supported by our findings.

EFFICIENCY OF THE TASK-PERFORMANCE (AMOUNT OF COMMUNICATION)

With efficiency we mean the relation between the value of the goal and the costs of attaining this goal. The goal, the problem-solution, is in all cases identical, thus the way to the goal is here essential.

Any message transmitted by one subject to another, is considered one "communication" (so the fact is neglected that one message may contain several separate "items"; analysis of "items" gives the same results as the here reported message-analysis).

The mean numbers of messages, per problem per position is smaller for the wheel-groups ($= 4,7$) than for the circle-groups ($= 6,6$), the difference being significant (U-test, $p < .005$). Here also, the *development* is relevant for us, and it is shown in Table 4.

TABLE 4

Number of messages, per problem, per position (4-position-groups)

	first problem	second problem	third problem	fourth problem	fifth problem	(mean)
Circle	8,20	7,08	5,88	5,75	6,28	(6,64)
Wheel	7,15	5,68	3,63	3,43	3,38	(4,65)
Circle minus Wheel	+1,05	+1,40	+2,25	+2,32	+2,90	

Again, the superiority of the wheel is increasing steadily from first to last problem (Tau $= 1,0$, $p = .01$). The difference in the first problem is not significant, in the last it is very significant (U-test: $.0001 < p < .001$).

The hypotheses I C. and II C. have found strong support in the data.

An efficiency-problem is the distribution of the total amount of communication over the different "positions". The central person sends out per problem a mean of 8,7, the "peripherals" 3,3 and the *question is if the central person does not exceed the optimal output level* (p. 363).

May be that he does so in the beginning (where his mean number of messages $= 13,6$), but definitely not at the end, when the figure for the last problem $= 6,2$. And this is, as table 4 shows, not different from the communication-activity of the circle-members [26].

DEPENDENT VARIABLES, IN CONNECTION WITH DEGREE OF CENTREDNESS (D.C.I.) OF THE DECISION-STRUCTURE

In the foregoing it appeared, that differences exist in "time to solve", number of errors and amount of communication, between wheel- and circle-groups. And several of the hypotheses have found support in those data, although there does not exist an extremely great difference qua Decision Centrality Index between wheel and circle. The greatest objection against the analysis on the basis of wheel- and circle-groups is, that the D.C.I. which characterizes them, is an overall D.C.I.: it is computed over all five problems.

But in the theory, the *development* of the more centred decision-structure was emphasized; thus we are not so much interested in the overall D.C.I., as in the *achieved* centredness, in the D.C.I. of the last problem. And we may sharpen our analytical tool, so that it is in harmony with the theoretical intention, in the following way:

For every experimental group, the D.C.I. of the last problem was

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[26] That the "time" is shorter for the wheel, does not invalidate the argument, because for that very reason the central person could take more his time.

computed; then the wheel-groups were divided into two "classes", containing the 6 more-centred and the 6 less-centred groups [27] [28].

The same was done with the circle-groups. The result is shown in Table 5.

TABLE 5

D.C.I.-last problem (4-position-groups)

more-centred wheel-groups: (W_I) = .85
less-centred wheel-groups: (W_{II}) = .17
more-centred circle-groups: (C_I) = .54
less-centred circle-groups: (C_{II}) = .07

In this table there appears to exist heterogeneity within the wheel- and within the circle-groups: the D.C.I.'s of the less centred wheel-groups (W_{II}) and the less centred circle-groups (C_{II}) are so low, that the conclusion is that these groups did not achieve a considerable degree of centredness [29]. But the W_I- and C_I-groups did; the most striking fact in the table is that the C_{II}-groups even show a higher D.C.I. than the W_{II}-groups (the difference is significant (two-tail test) $.01 < p < .001$).

Although in wheel-groups necessarily a centred *interaction structure* exists, and consequently a centred decision-structure may in general develop more easily the decision-structure (as we define it) appears to be clearly distinguished even from the interaction-structure (and so the more from the topological structure).

CENTREDNESS AND SPEED OF TASK-PERFORMANCE (TIME TO SOLVE)

On the basis of these four classes the time-data have been analysed. In Table 6 the data for the last problem are shown.

When the *most*-centred groups (W_I) are compared with the least-centred groups (C_{II}), the latter appear to need more than two times as much time as the former to solve the problem. The difference is significant (Mann Whitney U-test: one sided $p < .01$). Within the topological structure the differences are also significant: W_I-groups are faster than W_{II}-groups $(p = .001)$ and C_I-groups faster than C_{II}-groups $(p = .03)$.

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[27] The preference for the D.C.I. of the last problem and the classification in two classes were, as the D.C.I. computation itself, strictly a priori; no trial and error with the material has taken place.

[28] Because there are 13 groups, the one with the median value of the D.C.I. has been discarded.

[29] More- and less-centred has exclusively to do with the degree of centredness within the wheel-groups or within the circle-groups.

TABLE 6

Last (fifth) problem (4-position-groups)

	n	D.C.I.	time to solve
more-centred wheel-groups (W$_I$)	6	.35	4,01
less-centred wheel-groups (W$_{II}$)	6	.17	7,88
more-centred circle-groups (C$_I$)	6	.54	5,79
less-centred circle-groups (C$_{II}$)	6	.07	8,84

However the most important datum is that more-centred circle-groups needed considerable less time than less-centred wheel-groups; this difference too is significant ($p = .03$).

From these findings it may be concluded that the decision-structure is the *primary determinant* of the performance-speed: the more centred the decision-structure, the faster is the group-performance: Hypothesis I A. is strongly supported by the experimental results.

Results will now be reported of a different time measurement, the "fastest single correct problem", used earlier by Leavitt and Guetzkow. The means for wheel-groups and circle-groups do not differ; they are both = 4.87. But when we analyse these data on base of the decision-structure, achieved in the last problem, we find differences, as shown in table 7.

TABLE 7

Fastest single correct problem (4-position-groups)

	n	D.C.I.	fastest correct problem
more-centred wheel-groups (W$_I$)	6	.85	3,28
less-centred wheel-groups (W$_{II}$)	6	.17	6,47
more-centred circle-groups (C$_I$)	6	.54	4,47
less-centred circle-groups (C$_{II}$)	6	.07	5,27

The following differences are significant: W$_I$ versus C$_{II}$ ($.001 < p < .01$); W$_I$ versus W$_{II}$ ($p = .001$) and C$_I$ versus W$_{II}$ ($.01 < p < .02$). The difference between C$_I$ and C$_{II}$ leads to a p-value $= .09$.

The general direction in these data is the same as in Table 6, with the exception that the W$_{II}$-groups are not faster than the C$_{II}$-groups.

The small differences in both tables between W$_{II}$ and C$_{II}$ may be explained by the very small difference between these groups qua D.C.I.

CENTREDNESS AND QUALITY OF TASK-PERFORMANCE (ERRORS)

Now the D.C.I. analysis is performed on the error-data.

In Table 8 data are given for the last period of the experimental session which the D.C.I. is pertinent.

TABLE 8

Errors (4-position-groups)

D.C.I.		fourth problem			fifth problem			fourth and fifth problem together		
		correc-ted	defi-nite	total	correc-ted	defi-nite	total	correc-ted	defi-nite	total
V'_I	.85	0	1	1	0	0	0	0	1	1
W_{II}	.17	1	1	2	0	5	5	1	6	7
C_I	.54	4	1	5	1	3	4	5	4	9
C_{II}	.07	1	1	2	10	2	12	11	3	14

In the last two problems, the most-centred groups (W_I) made in total one error; in C_{II} this number is 14. (The difference is significant: $.01 < p < .02$). Restriction to the last problem gives the same result. Although W_I-groups in all problems together make 23 definite errors (C_{II}-groups: 10), the W_I-groups do not make errors in the last phase of the problem-solving. In the last problem the number of errors decreases with increasing D.C.I. (this relation is significant: $p < .05$), though the difference between C_I and W_{II} is negligeable). The results give support to hypothesis I B.

CENTREDNESS AND EFFICIENCY OF TASK-PERFORMANCE (AMOUNT OF COMMUNICATION)

In Table 9, the mean numbers of messages, used in the last problem, are reported.

TABLE 9

Number of messages, per position, in last problem (4-positions-groups)

	D.C.I.	mess· s
more-centred wheel-groups (W_I)	.85	2,46
less-centred wheel-groups (W_{II})	.17	4,21
more-centred circle-groups (C_I)	.54	4,88
less-centred circle-groups (C_{II})	.07	7,46

The difference between most- and least-centred groups is extremely large: the latter ones need three times as many messages to reach their goal, the solution of the problem ($p < .001$). Within the topological structure, an increasing D.C.I. leads also to a decreasing amount of communication (p-values $< .01$).

But C_I-groups do not need fewer messages than W_{II}-groups. Here, where we are concerned with the pure amount of communication, the interaction-structure seems to have more influence than on the other dependent variables.

Hypothesis I C. is supported, as far as the differences in the degree of centredness (indicated by the D.C.I.) are large; when they are not very large, the centredness of the interaction-structure exerts some influence on the amount of communication.

In Table 10 results are reported of an extremely important analysis: the analysis of the communication-activity *within* the wheel-groups.

TABLE 10

Number of messages, per position, in last problem (4-position-groups)

W_I central positions = 4,67	W_I, peripheral positions = 1,72
W_{II} central positions = 7,17	W_{II} peripheral positions = 3,22
Circle positions = 6,17	

Persons in the centre-position of the decision-structure in W_I send out less messages than central persons in W_{II} ($p < .05$) and than circle-positions ($p = .08$). They also receive less messages than central persons in W_{II} ($.001 < p < .005$) [30].

Thus Shaw's Saturation-theory (cf. p. 8) must be rejected: when centred decision-structures develop, the communication-activity of the central position even decreases.

PERCEPTION OF GROUP-STRUCTURE

After the task-period, S's filled out a small questionnaire. Some data, not bearing on performance, will be reported now.

One question was: *Did your group have a leader? If so, who?*

Results of the first part of this question are given in Table 11.

TABLE 11

Leadership-question (4-position-groups)

	yes	no	uncertain	no answer
Circle	5	30	9	8
Wheel	35	4	0	13

The difference between the two structures is large and significant ($p < .00001$). In the wheel-group, a leader is very often recognized, while this is rare in the circle-group. In the second part of the question, the subject is asked (eventually) to make a choice; the distribution of choices is shown

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[30] A correction for the differences in "time" does not change these relations (cf. 43, p. 170).

in Table 12, where are tabulated the choices on position "white"—in our experiment in the wheel-groups the central position—and the choices on the other (three) positions.

TABLE 12
Leader-choices (4-position-groups)

	Choice on white	Choice on other
Circle	4	10
Wheel	48	1

The distribution within the circle does not differ from the one, to be expected on the basis of the 0-hypothesis. In the wheel, there is a significant deviation herefrom ($p < .00001$).

When we use as *leadership-ratio* the *highest* number of choices on one position, divided by the total number of possible choices, the ratio is for white in the circle .08, in the wheel .92. In the wheel the recognition of the central person as the leader is nearly complete.

An analysis based on the D.C.I.-differences, does not give spectacular results. In the more-centred circle-groups, 7 subjects give a (somewhat) positive response on the question, if the group had a leader; 2 do so in the less-centred circle-groups. In the more centred circle-groups, 10 choices are made (in the second part of the question), in the less-centred only two (of the 24 possible ones).

This last difference is significant ($p < .01$). Thus, the differences between more- and less-centred circle-groups are small, and in the wheel-groups the central person of the topological w-structure is always chosen.

The interaction-structure seems to determine the recognition of leadership, as it is measured in our question. Only a slight influence of the decision-structure could be demonstrated, thus hypothesis F. is only weakly supported by our data.

This leadership-question was in our questionnaire immediately preceded by the following question: "Describe shortly the structure of your group, that is, who could communicate with whom". This question, which aims clearly at the interaction-structure, could have influenced the responses of our S's in the leadership-question.

SATISFACTION OF GROUP-MEMBERS

S's are asked to rate their job-satisfaction on a scale from unpleasant (= 0) to pleasant (= 10). The mean satisfaction of circle-members = 7.3, of central persons in the wheel = 8.6, of "peripherals" in the wheel = 6.2. The differences of the central persons with peripherals ($.0001 < p < .001$),

and with circle-members (.02 < p < .03) are significant, as is the difference between circle-members and wheel-peripherals (.03).

These findings are in agreement with results of other studies (cf. however p. 367 in this publication, footnote 13).

More interesting is the result of a D.C.I.-analysis, as shown in Table 13.

TABLE 13

Satisfaction (4-position-groups)

	central positions[31])	other positions
more-centred wheel-groups (W$_I$)	9,28	5,41
less-centred wheel-groups (W$_{II}$)	8,17	6,96

It appears from this table, that in more-centred groups, the central persons are more satisfied with their work in the group, than in less-centred groups, while the relation is reversed for the other group-members. The differences are clearly in the predicted direction, but no statistical significance could be demonstrated (the lowest p-value was found for the difference of the "peripherals", $p = .09$).

When the *difference* between central person and peripherals for each group is determined, this difference is significantly greater in W$_I$-groups than in W$_{II}$-groups ($p = .04$).

It may be concluded that to a certain degree hypothesis G. has found support in these data.

Some data are relevant in this connection which were obtained by a rating of the *group-performance* by the group-members.

TABLE 14

Performance-rating (4-position-groups)

	central positions	other positions
more-centred wheel-groups	5,75	5,58
less-centred wheel-groups	6,42	5,00

When we compare Tables 13 and 14 it is evident, that the *satisfaction-differences are not a result of the belief of S's that they had attained a high achievement-level* [32]; the differences go exactly in opposite directions: the central persons, who "score" higher in satisfaction in the more-centred

[31] In all wheel-groups the central person of the decision-structure is during the last problem in the central topological position!

[32] An achievement-hypothesis has been tested by Shaw (52); his result was also negative.

groups, rate their groups' performance lower; and the reverse holds for the peripherals.

SUMMARY OF EXPERIMENT WITH 4-POSITION-GROUPS, 5 PROBLEMS

This experiment was designed to test the general theory, that groups which develop a more-centred decision-structure, will perform their tasks better than groups with a less-centred decision-structure.

More-centred structures are characterized by vulnerability, resulting from an environmental pressure, which exceeds the resistance of the "central position".

The first part of the theory (the core of it!) is tested in hypotheses I A., I B., I C.

The analysis is based on differences in Decision Centrality Index (D.C.I.) in the last problem.

Speed of Group-performance (Time to Solve)

To the extent that the group's decision-structure is more centred, the group-task appears to be performed faster. This is true even when circle-groups are more centred than wheel-groups, although the last ones are characterized by a centred interaction-structure. Thus hypothesis I A. is confirmed.

Quality of Task-performance (Errors)

Groups with a more-centred decision-structure make less errors in the last part of the workperiod. Hypothesis I B. is also corroborated by the experimental data.

Efficiency of Task-performance (Amount of Communication)

Groups with the centred decision-structure use fewer messages than less-centred groups, but the interaction-structure has also influence. With this reservation, hypothesis I C. has been supported.

The second part of the theory, which aims at an analysis of the developmental process itself, is tested in hypotheses II A., II B., II C. Furthermore, the vulnerability is directly investigated, as it is expressed in hypothesis II D. The analysis of the data is on basis of wheel- and circle-structures.

Speed of Group-performance

The wheel-groups work slower in the beginning of the task-period, but show at the end of it more speed than the less-centred circle-groups. The

groups with the more-centred interaction-structure thus appear to have the disadvantage that in the beginning of the work-period the pressure on the central position exceeds its resistance, with the consequence of a worse group-performance. Hypothesis II A. is confirmed by the data.

Quality of Task-performance

In the comparison of wheel- and circle-groups, hypothesis II B. is also confirmed. In the more-centred groups a greater proportion of the errors is made in the beginning of the workperiod, a smaller in the end of it, compared with the distribution of the errors in less-centred groups.

Efficiency of Task-performance

The wheel-groups show in the first problem an amount of communication, which is nearly equal to the communication required by the (less-centred) circle-groups, but in every following problem the wheel-groups are working in a more efficient way than the circle-groups, as is indicated by the increasing difference in the amount of communication, in favour of the wheel-groups. Thus hypothesis II C. is confirmed.

Corrective Power

Hypothesis II D. bearing on a special aspect of the "vulnerability" of centred groups, is also confirmed by the data: the correction power of the wheel-groups is smaller than that of the circle-groups.

Division of Labour within the Group

It could be demonstrated, that in groups with a more-centred decision-structure the persons in that central position do not exceed an "optimal output level"; on the contrary their activity is, qua sending and receiving, decreasing when the centredness of the decision-structure increases. From this viewpoint too, the more-centred groups are not less efficient, as was suggested by other researchers (cf. p. 363).

Recognition of Leadership and Satisfaction

The experiment was not designed to test hypotheses F. and G. For hypothesis F. the experimental support was very weak; hypothesis G. has found support in the data.

The general conclusion from the experimental findings is that hypotheses I A., I B., I C., II A., II B., II C. and II D. are confirmed.

EXPERIMENT WITH 5-POSITION-GROUPS (3 PROBLEMS)

This experiment was designed to test a special application of the theory on a determinant of group-performance. In this theory it was hypothesized that more-centred groups perform their group-tasks better, because the central position can integrate the contributions of the various group-members. Now the hypothesis is that such an integration is more urgent in greater groups.

In the five-problem-experiment (4 positions!) it has been shown already that the performance of the more centred groups, compared with the performance of the less-centred groups, is better in the fourth and fifth problems, but worse in the first and second problems.

The special theory, tested new in an experiment with *five*-position-groups is: the greater the number of group-members, the faster the inferiority of the less-centred groups will manifest itself (hypothesis E., p. 374). In this experiment the group's workperiod contains only three problems: if hypotheses I A., I B. and I C. can be also confirmed in *this* experiment, then hypothesis E. finds strong support.

Two topological structures were investigated, the wheel and the circle. The set-up was the same as the one in the preceding experiment.

The problems were "moving company", "time of arrival of plane", "amount of gasoline, required for motor-vehicles".

Subjects: the subjects were students of Amsterdam University in their first year. Twenty-four groups of five persons were run, 12 in each structure.

THE RESULTS

The Decision Centrality Index. First, the data on the centredness of the decision-structure of wheel and circle will be reported. The mean D.C.I. for the wheel-groups is .56, for the circle-groups .12 ($p < .0001$). The development of the decision-structure is shown in Table 15, where the D.C.I. is computed for first and last problem.

TABLE 15
Decision Centrality Index (5-position-groups)

	D.C.I.-first problem	D C.I.-last problem
Circle	.11	.11
Wheel	.48	.62

The circle-groups in general do *not* develop a more-centred decision-structure, while the wheel-groups do. Again it is meaningful to start the analysis of the data on the basis of the topological structures.

TIME TO SOLVE

The times, which the groups required to solve the problem, are given in Table 16.

TABLE 16
Mean time per problem, in minutes (5-position-groups)

	first problem	second problem	third problem	total
Circle	23,78	14,05	11,45	16,43
Wheel	25,07	12,27	9,82	15,72

The wheel-groups need more time in the first problem, but in the second problem they are already faster. But in comparing the data for the last two problems together (or the last one separately), no significant difference could be demonstrated to exist between circle- and wheel-groups. Analysis of the correctly-solved problems leads to similar results.

QUALITY OF TASK-PERFORMANCE (ERRORS)

Like in the experiment reported earlier, a distinction is made between definite errors and corrected errors, together they make the total number of errors.

TABLE 17
Errors (5-position-groups)

	definite errors	corrected errors	total
Circle	23	33	56
Wheel	34	18	52

The error-totals do not differ, but the corrective power of the circle-groups is greater than that of the wheel-groups $(.001 < p < .01)$.

The distributions of errors over the three problems are not different for circle and wheel (therefore they are not reported here).

EFFICIENCY OF THE TASK-PERFORMANCE (AMOUNT OF COMMUNICATION)

The number of messages per problem per position is smaller for the wheel-groups (mean $= 6,2$) than for the circle-groups ($= 9,9$). The difference is significant $(.0001 < p < .001)$.

The development of the communication-activity is shown in Table 18.

TABLE 18
Number of messages per problem per position (5-position-groups)

	first problem	second problem	third problem	total
Circle	10,84	9,20	9,50	9,85
Wheel	9,26	4,84	4,44	6,18

In the first problem, there is a small (but significant: $p = .04$) difference between wheel and circle, but in the last problem this has grown very large $(.001 < p < .01)$.

The central person sends out 10,4 messages in the last problem; this does not differ significantly from the mean of the circle-members in that problem, thus the same reasoning holds as has been carried out on p. 379.

DEPENDENT VARIABLES, IN CONNECTION WITH THE DEGREE OF CENTREDNESS OF THE DECISION-STRUCTURE (D.C.I.)

In the preceding the data of wheel- and circle-groups have been compared after a difference in the decision-structure (D.C.I.) between them had been demonstrated. But the D.C.I. was computed over all three problems.

Now we will analyse the data on the basis of the *achieved* decision-structure (that is to say the D.C.I. of the last problem) like we have done already in the 4 position experiment (p. 379 seq.).

CENTREDNESS AND TIME TO SOLVE

Again four D.C.I.-classes, each containing 6 groups, are formed. The D.C.I.-difference between W_{II} and C_{II} is significant; W_{II} and C_I do not show a significant difference.

Time-results are given in Table 19.

TABLE 19
Time in last problem (5-position-groups)

	D.C.I.	time
more-centred wheel-groups (W_I)	.93	8,82
less-centred wheel-groups (W_{II})	.31	10,82
more-centred circle-groups (C_I)	.20	10,46
less-centred circle-groups (C_{II})	.01	12,44

Although the most-centred groups (W_I) are clearly faster than the least-centred groups (C_{II}) and in general the D.C.I.-differences when not too

small, lead to corresponding time-differences, no significance could be demonstrated (the lowest p-level is .12).

In Table 20 the results of the "fastest single correct problem" are shown.

TABLE 20

Fastest correct problem (5-position-groups)

	n	D.C.I.	time
more-centred wheel groups(W_I)	5	.93	8,23
less-centred wheel-groups (W_{II})	6	.31	13,36
more-centred circle-groups (C_I)	6	.20	11,40
less-centred circle-groups (C_{II})	6	.01	12,23

The differences are not significant; W_I versus C_{II} leads to $p = .09$; W_I versus W_{II} : $p = .07$.

CENTREDNESS AND QUALITY OF TASK-PERFORMANCE (ERRORS)

In Table 21 the total number of errors (corrected plus non corrected errors) is shown, and between parentheses, the separate figures for the definite errors, as they are distributed over all three problems.

TABLE 21

Errors (5-position-groups)

	D.C.I.	first problem	second problem	third problem	total	(total definite errors)
more-centred wheel-groups (W_I)	.93	12(7)	0(0)	0(0)	12	(7)
less-centred wheel-groups (W_{II})	.31	20(8)	11(11)	9(7)	40	(26)
more-cent ed circle-groups (C_I)	.20	29(11)	9(2)	2(2)	40	(15)
less-centred circle-groups (C_{II})	.01	6(1)	6(5)	4(1)	16	(7)

The total numbers of errors (corrected plus non-corrected) in all problems together do not give a systematic coherent picture: more centred wheel-groups make fewer errors, than less-centred wheel-groups, but for the circle-groups the situation is reversed. The data for the definite errors are similar.

In the last two problems no error at all is made by W_I-groups, against 20 by the W_{II}-groups (.0001 < p < .001), against 11 by the C_I-groups (.01 < p < .02) and against 10 by the C_{II}-groups (.01 < p < .02).

The great number of errors, made by the W_{II}-groups (compared with the circle-groups) may be explained by the vulnerability of these groups with their central interaction-structure and a small degree of centredness of the

decision-structure. When the differences in D.C.I. are great, groups with a more-centred decision-structure make less errors.

CENTREDNESS AND EFFICIENCY OF TASK-PERFORMANCE (AMOUNT OF COMMUNICATION)

TABLE 22

Number of messages, per position, in last problem (5-position-groups)

		D.C.I.	messages
more-centred wheel-groups	(W_I)	.93	3,80
less-centred wheel-groups	(W_{II})	.31	5,07
more-centred circle-groups	(C_I)	.20	8,77
less-centred circle-groups	(C_{II})	.01	10,23

The differences between W_I and C_{II} ($p < .00001$), W_I and W_{II} (.05) and W_{II} and C_I ($.00001 < p < .0001$) are significant, but the difference between C_I and C_{II} is not ($p = .10$).

When the differences in D.C.I. are not too small, more-centred groups appear to require less messages than less-centred groups. But here also (cf. p. 383) the interaction-structure has influence.

PERCEPTION OF GROUP-STRUCTURE

Results were precisely similar to the findings of the experiment with 4 position-groups; therefore they are not reported here.

SATISFACTION OF GROUP-MEMBERS

The mean satisfaction of circle-members = 7,6, of central persons in the wheel = 8,4, of peripherals = 6,0. The difference between central and peripheral wheel-members is significant ($.001 < p < .01$), that between central persons and circle-members is not significant. Circle-members are more satisfied than wheel-peripherals ($.001 < p < .01$).

Again we find data in connection with hypothesis G (p. 374) which are shown in Table 23.

TABLE 23

Satisfaction (5-position-groups)

	central positions	other positions
more-centred wheel-groups (W_I)	8,95	5,10
less-centred wheel-groups (W_{II})	7,97	6,64

Again we find (cf. p. 385), that in more-centred groups the central person likes the work in the group better than the central person in less-centred groups. For the peripheral persons, the situation is reversed. Statistical significance could be demonstrated between more- and less-centred groups, when the *differences* between central person and peripheral persons were analysed within groups.

SUMMARY OF EXPERIMENT WITH 5-POSITION-GROUPS (3 PROBLEMS)

Two analyses have been done: a comparison of the result of wheel-versus circle-groups and an analysis, based on the D.C.I. during the last problem.

Time to Solve

The data are in the predicted directions: in the second problem, the more-centred groups (the wheel-groups) are already faster, so that the mean time over all three problems is smaller for more-centred than for less-centred groups (with the 4 position-groups the reverse was demonstrated, see p. 377).

Analysis on the basis of the D.C.I. (last problem) shows increased differences in the expected direction. But no *statistical* difference could be demonstrated, although the "fastest correct problem" time measurement shows p-values, approximating the .05-level.

Thus some support is found for hypothesis I A. in the material of this experiment.

Quality of Group-performance

In the analysis of the material on the basis of D.C.I.-differences it appears that when large differences exist in degree of centredness during the later phase of the workperiod (that is, in problems two and three), more-centred groups perform better than less-centred groups. Hypothesis I B. is supported by these findings, and consequently hypothesis E. is confirmed as far as the quality of performance is concerned.

Efficiency of Task-performance

In the first problem already, the wheel-groups use a significantly lower number of messages though the difference is not very large, and in the second they send roughly half the number of messages, the circle-groups need. The superiority of the wheel-groups thus manifests itself earlier than it was the case with the 4 position-groups (cf. p. 379). In the 4 position-

groups no significant difference exists in the first problem and only in the fifth problem the relation between wheel and circle is similar to the one which appears here (in the 5 position-groups) already in the second problem.

Thus hypothesis E. has found strong support, as far as the efficiency of task-performance is concerned.

The results of this experiment generally support the hypothesis E. (although *time*-differences, going in the predicted direction, failed to reach statistical significance); with an *increasing* number of group-members, groups with a more-centred decision-structure *manifest their superiority* over less-centred groups in regard to speed, quality and efficiency, earlier.

Conclusions

Shaw formulated the theory that "availability of information" determines the performance of groups, when "simple" problems are solved, but with more complex problems "the possibility of contributions from all members of the group becomes much more important".

This opportunity for participation of all members is greater in the circle-groups; consequently so-called circle-groups should perform more complex tasks faster, than wheel-groups, where the central person becomes saturated. Thus this theory is based on a "substantial" difference between complex and simple problems.

In our opinion however the essential point is not the *gradual difference in problem-complexity*, but the *need for integration:* when two or more persons work on the same task, so that the work of each of them is only a part of the "total", the integration of their activities is a basic condition for a good end-performance.

Strict integration is secured to an optimal degree by a *strongly centred decision-structure*. When the interaction-structure of a group is considered to refer to "who communicates to whom", the decision-structure bears upon "who takes decisions for whom".

Equal participation of all members in the decision-processes seems to us detrimental for the group-performance; but in the group with a strongly-centred decision-structure, the central person can integrate the contributions of the individual members, so that these contributions lead to maximum profit.

Our theory is a dynamic theory on group-structures: groups, which have developed a more-centred decision-structure function better than less-centred groups, in regard to *speed* of task-performance ("time to

solve"), *quality* of task-performance (errors) and *efficiency* of task-performance (amount of communication). The theory was strongly supported by our experimental data, obtained with groups who solved complex problems of the type, Shaw had used to test his theory; so the "participation"-theory can only be refuted. Especially the explanation by means of the *saturation* concept (cf. p. 363) proves to be incorrect, because in groups with a more-centred decision-structure the central position is not characterized by a greater input or output but even by smaller "communication-pressure" than the central position in groups with a less-centred decision structure (p. 383).

Thus our theory is quite the reverse of Shaw's theory.

Shaw's empirical findings however, may be in harmony with our theory, which emphasizes the fact that the centred-decision-structure must *develop*; in Shaw's groups strongly-centred decision-structures do not seem to develop to such an extent.

In this context the remark must be made that we are uncertain about what Shaw calls "central method". In an analysis of Shaw's material [33] it appeared that central persons in the wheel-groups, adopting the central method, send as much messages as central persons in wheel-groups, not adopting this method. This result is unclear.

Furthermore our theory suggested a greater *vulnerability* of more-centred structures, this vulnerability manifesting itself when the centre is under too high pressure from the environment. In the experimental set-up as used by Leavitt, Shaw and ourselves, it can be expected that in the *beginning* of the task-period, when the centred interaction-structure (in the wheel-groups) has not yet developed into a centred decision-structure, this vulnerability will manifest itself most clearly: then, more-centred groups will perform relatively worse. This theory, as expressed in three hypotheses, has also found strong support in the data of our first experiment. The results of this experiment may be summarized as follows: in groups performing tasks, in which the individual contributions need to be integrated, the more-centred decision-structure leads to better performance, although this centred structure is characterized by a greater vulnerability.

Our second experiment demonstrates that this difference qua performance between groups with more- and less-centred decision-structures is more striking, when the groups consist of more members [34].

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[33] This was enabled to us by Prof. Shaw's kindness to send us quite an amount of his original data.

[34] Cf. 26, 27.

For the *practice* in industry or government, it is important that participation in decision-making deteriorates the group's performance; more-centredness in the decision-structure leads to a better performance even when the central persons are *not selected* and *not trained* as in our experimental set-up. The vulnerability of a leader-structure however, makes clear that training of leaders may be a much yielding procedure [35].

Also a crucial point in this context is the utilization of the insight-contributions by peripheral members in more-centred groups (cf. p. 359).

From a *theoretical* viewpoint it is important that during the very restricted time of the experimental session, groups develop a centred decision-structure: this opens a good perspective with regard to the generalization of the theory [36].

However, with regard to this generalization, two aspects are important. First it must be stated that centredness of the decision-structure is not identical to "closeness of supervision". The former refers to the requirements for integration of the contributions of all group-members, the latter, however, has to do with "how" each group-member is active, and the extent of supervision on this by the central person (1, 2, esp. p. 37).

The centredness of the decision-structure shows a certain agreement with the *concept* "authoritarian leadership" (60). Unfortunately this last concept is to such an extent negatively evaluated that even in the scientific literature results are sometimes misinterpreted [37].

The second aspect concerns the experimental situation.

In our experiment, anyone of the group-members could have accomplished the total task, as is shown in Shaw's circle-groups where both task-functions, information processing and decision making, are performed by each subject; the information is of one type and is available to the subjects when the group starts to work (so it is not coming in at irregular, unpredictable moments) and is systematically distributed (conf. 32, 33, 44, 51) and only one solution is correct (cf. 53). Even in this type of task-situation, the groups with the more-centred decision-structure are performing "better". But then we may notice, that in the short time, they had available in the experiment, the groups could not develop a very *strong* centredness of the decision-structure, as appears from the great number of S's who make their own solution; furthermore as was stated already the central persons were *not selected* and *not trained*. Thus the expectation can

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[35] Schutz investigated the possibilities of creating productive groups by selecting "compatible" group-members (46).

[36] With reference to the often heard objection against the abstractness of group-experimental studies it may be stated that here it is again demonstrated, that this method permits very adequately the analysis of the concrete development-in-time of the groups (cf. also 20).

[37] 17, p. 431 en 50, pp. 127, 128, 132.

be, that in situations, where this "centredness" is far more pronounced, even greater effects will result with regard to group-performance.

Thus participation in the decision-taking is ineffective in a group-task situation, in which integration is essential. This does not mean, however, that according to our theory participation in the opinion-processes is ineffective. On the contrary, a wide divergence of opinions leads to better decisions, as Torrance has demonstrated (58; cf. also 8, pp. 404 seq. and 53).

A fascinating problem is the *development* of the centred-decision-structure itself (cf. 21, 7).

In our experiments with more complex problems, 23 % of the peripheral wheel-subjects made their own problem-solution, in the fifth problem. In the experiment with simple problems (referred to on p. 359) it was found that no peripheral wheel-member made his own solution in the fifth problem. And also it appeared that only type-I messages were sent by the central person in this experiment with simple problems. Thus it is clear, that the more-centred decision-structure develops more easily in groups, solving relatively simple problems.

Shaw and Gilchrist (in personal communication) suggest the explanation, that with more complex problems, solutions of others are not so easily accepted. The difficulty, however, is that acceptance or non-acceptance of solutions, is not independent (in the wheel) from central persons, who may withold the information-items, and send out only solutions. Further research in this direction to identify variables, which determine the development of certain structures, is promising, as is evident from recent publications.

We have done laboratory-experiments in fieldsituations (to be published) with interesting data on the attitudes of the peripherals, the "followers". Very promising are results of studies by Guetzkow (22) and Friedler (14), bearing on the attitudes of the central group-members. By all these different investigations the knowledge of the relation between group-structure and performance is now continuously increasing.

SUMMARY

...Hypotheses as to the group-performance have been tested in two series of experiments.

INVESTIGATION OF 4-PERSON-GROUPS, SOLVING 5 PROBLEMS

The influence of the structure of communication on group-performance has been investigated in the Bavelas-Smith-Leavitt research. The measurements of performance showed a relation to "positional" (topological) variables.

Shaw has put forward the theory that as far as the solving of more complex problems is concerned the topological structure, which allows contributions from all group-members (more participation from each individual), shows better results than the structure where one person is situated in the most central position; the latter being in danger of being "saturated".

In the earliest investigations of performance it appears that too great a significance has been attached to positional variables; the dynamic aspect having been much neglected, as Guetzkow and Simon, and Flament have proved for simple problems.

In order to explain the contradictory results found by Shaw for simple and difficult problems the following theory is put forward by the author: groups with a more centred decision-structure perform the tasks better, because the contributions from the individual members can be better integrated by the person situated in the centre.

This dynamic centred-decision-structure has to develop; this takes a certain amount of time (a certain number of tasks). The degree of centredness of the decision-structure is expressed in the Decision Centrality Index (D.C.I.), being a measure of the degree in which one person takes the decisions for the whole group.

Furthermore a greater "vulnerability" for more centred structures is presumed in the theory; this vulnerability making itself apparent especially in the beginning of the working period.

The theory is laid down in the following hypotheses:

General hypothesis I.

To the exten. that the decision-structure in groups is more centred, the groups will give a better performance of their group tasks.

General hypothesis II.

To the extent that a structure is more centred, it is characterized by a greater "vulnerability". The vulnerability will demonstrate itself when the pressure exerted on the central position of the structure is greater than its resistance.

The specific hypotheses are:

I A. To the extent that the decision-structure in groups is more centred, the group task will be performed faster.

I B. To the extent that the decision-structure in groups is more centred, the quality of the task performance will be better.

I C. To the extent that the decision-structure in groups is more centred, the group task will be performed more efficienctly.

II A. To the extent that the interaction-structure in groups is more centred, the group task will be performed relatively more slowly during the beginning period of the work.

II B. To the extent that the interaction-structure in groups is more centred, the quality of the group task will be relatively less during the beginning period of the work.

II C. To the extent that the interaction-structure in groups is more centred, the group task will be performed relatively less efficiently during the beginning period of the work.

II D. To the extent that the interaction-structure in groups is more centred, the group's "corrective power" will be smaller.

To test these hypotheses an experiment has been designed in which 4-person-groups have solved 5 problems (so called complex problems, as used by Shaw). S's were first year students of the Leyden State University; 13 groups worked according to the circle structure, 13 in the wheel structure.

The hypotheses dealing with performance (I A, I B, I C, II A, II B, II C, II D) are confirmed by the experimental results. As far as hypothesis I C is concerned a restriction should be made to the effect that the interaction-structure is also of influence. The author's theory is thus confirmed in full.

Shaw's participation theory is turned down herewith; especially also the hypothesis of too great a saturation of the central person, has proved to be incorrect; on the contrary: saturation of the central person is decreased by a more centred decision structure.

INVESTIGATION OF 5-PERSON-GROUPS, SOLVING 3 PROBLEMS

Also the number of persons in a group is important. It is expected that integration of the individual contributions by one person becomes more urgent as the number of group-members increases. This has been formulated in the hypothesis:

E. The greater the number of persons in groups, the sooner will the performance-inferiority of the less-centred groups show, as compared with the more-centred.

In order to test this hypothesis, an experiment has been designed where 5-person-groups had to solve three problems. Hypothesis E is confirmed when the superiority of the more centred groups occurs in a relatively earlier phase of the working period in these 5-position-groups, than in the 4-position-groups.

S's were first year students of the Amsterdam University. Problems were the same as those used in the four-position experiment.

Twelve wheel-groups and twelve circle-groups were formed. The results confirm hypothesis E as far as the quality and efficiency of the task performance are concerned. Results for speed of task-performance are in the predicted direction, but no statistical significance has been indicated.

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