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# CONTINUITY AND OPENNESS IN HIGH ENERGY PHYSICS GROUPS

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# CONTINUITY AND OPENNESS IN HIGH ENERGY PHYSICS GROUPS

Virtually all experiments in high energy physics are conducted by groups of experimenters, not individual investigators. Except for studies of cosmic rays, these groups gather their data using large machines which accelerate particles. The great expense of these machines requires that they be built at a few locations and shared by experimental groups. The necessity for physicists to combine in groups and share limited facilities has resulted in experimental groups with a number of different patterns of organizational affiliation.

Some groups are composed of scientists all affiliated with one organization. For instance, groups may be composed of staff members of an accelerator laboratory or they may all be faculty and graduate students of a single university who travel to the accelerator for the experiment. Other groups are composed of physicists from more than one organization. The sub-groups making up such a group may be from different universities or from a university and an accelerator staff.

The purpose of this paper is to explore some effects of organizational affiliation on high energy physics groups. The study reported here focuses on one structural variable: whether the groups were composed of members from one organization or from more than one.

Two research questions guided this exploratory study. The first was, "How does group structure affect whether or not group members tend to continue their collaboration?" The second research question was, "How does

group structure affect whether or not groups tend to admit new members?"

The answers to these questions have significance for research administrators as well as investigators of problem solving groups. Both continuity and openness in high energy physics groups seem desirable. If new groups form after every experiment, the productivity of physicists should be reduced. The large number of physicists expected to enter high energy physica in the next decade should be better utilized if they can participate in experienced groups. The results reported here are not dependent on this linkage between group characteristics and the total effectiveness of the effort in high energy physics, but their utilization by administrators will require some such assumptions.

The findings of this study suggest that group structure and both continuity and openness of the group are related. Some ways in which groups composed of organizational sub-groups must organize their work seem to promote continuity and openness. These findings need further verification and extension, particularly by considering group size and the type of experimental problem as independent variables. The initial results, however, suggest that administrators concerned with continuity and openness in high energy physics groups can affect those characteristics by altering group structure.

## METHODS

Data were gathered in two ways. Unstructured interviews were conducted in eleven groups working in five organizations. These inter-

views were with twenty-eight individuals, always including group leaders, and in two cases all the members of the group. The interviews focused on impressions of one experiment currently under way by each group. The interview transcripts are not analyzed in this paper, but rather are used as the source of explanations for the quantitative data.

Quantitative data were gathered by analyzing the publications of groups in the literature of high energy physics. A group is defined as the co-authors of a particular paper. By examining all the later publications of the co-authors it is possible to identify decisions to continue collaboration, to admit new co-authors, and to change organizational affiliations.

Two journals comprise a nearly exhaustive record of the successful experimental alliances of high energy physicists in the United States. The Physical Review Letters is an express journal in which most groups report progress or completion of an experiment. The editor of the Letters expects that publication there will be followed by more thorough reporting in The Physical Review. The most frequent exception to the rule of publication in the Letters are groups whose work is so widely discussed at professional meetings that the Letters editor considers express publication unjustified. This happens only rarely. The Letters, therefore, are used as the data source for this study.

## Subjects

The target population for the study was American high energy physics groups publishing in the past six years. Part of the analysis treats these groups as the object of study and a later part, intended to explain group

behavior, treats the members of the group as the object of study.

Groups were selected for study by first selecting the name of an individual from a list of all American high energy physicists with university tenure or equivalent status in 1965. A name was selected randomly and assigned a year from 1959 to 1962, also at random. Each name was used to search the Physical Review Letters, starting at the year assigned to the name, for the first paper involving that man as co-author of an experimental report. The co-authors of that paper were designated a group for this study.

Of the 102 names drawn from the original list, 26 led to the selection of groups for study. The criterion which most often eliminated a potential author was that the paper selected for defining a group be an experimental report. Many authors during the period from the date selected for the start of search through 1964, the end of the period of study, produced only theoretical papers or proposals for experiments.

One other sample was drawn to corroborate some of the findings. A random sample of thirty-six names was taken from a list of physicists who had recently conducted research in one large national laboratory. These high energy physicists were from universities and laboratory staffs. The names were used for a study of movement of individuals from one group to another. This sample is representative of all American high energy physicists in the sense that the national laboratory involved is host to groups from throughout the nation.

The Measure of Continuity

Continuity is the result of forces which bind a group together.* The measure for continuity used in this study is a number between zero and one. The number is the sum of actual choices of co-authors to repeat collaboration divided by the number of possible choices. The measure is calculated both for entire groups and for sub-groups who share a common organizational affiliation.

The numerator, actual choices, was calculated by examining all papers for each co-author published subsequent to the one defining the group. For each paper the co-authors were checked against the members of the group, and the number of agreements, minus one, were counted. These were then summed for all papers to give the actual number of choices to continue or renew collaboration.

The denominator was determined for the group by multiplying the number of co-authors on the paper defining the group, minus one, by the sum of the number of papers subsequent to the defining paper which had any group member as a co-author. This number then represented the possible choices for collaboration.

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* The measure of continuity here is related to "cohesiveness" as it is used in studies of small groups. Festinger, Schacter, and Back, in Social Pressures in Informal Groups: A Study of a Housing Project, New York: Harper, 1950, define cohesiveness in terms of "the total field of forces which act on members to remain in the group." It has been measured in various ways, one procedure being to ask each member to rate the degree to which he would like to remain a member. The mean rating is then taken as a measure of cohesiveness. The continuity measure used here is a measure of how much members do stay together, not of the forces acting on them. The two measures are related, but their relationship is not examined here.

Two corrections were applied. First, any group member who never published again was deleted from the denominator calculation. The reason for this correction was that if no one chose the man for collaboration, either his abilities or interests precluded his further association with the group. Thus, his failure to re-associate with the group was not indicative of the group's continuity but more his personal characteristics.

A second correction to both the numerator and the denominator was the elimination of papers published within three months of a previous paper and having two-thirds or more of the same co-authors. This procedure avoided the counting of papers prepared from the same data run. This correction assured that the continuity measure included only those papers which reflected distinct periods of experimental collaboration.*

The Measure of Openness

Openness is a measure of the willingness of the members of an existing group to take in new members. New members may replace old members who drop out or be part of a group expansion. The measure is a number describing the past behavior of a group in admitting such new members.

The measure was calculated only for groups, as defined above, whose members stayed together enough to justify the assumption that the group existed for its members. Thus, the measure was calculated by considering

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* The three-month and two-thirds criteria were developed by reading the content of the papers. All obvious multiple reporting of the same data runs was eliminated and no new papers dropped by applying these criteria. The numerical criteria should allow replication of this study without the necessity for analyzing the substance of the papers.

only those papers on which at least fifty percent of the original group and all the organizations appear.* The total number of new names on such papers was summed. This was then divided by the number of papers and by the number of co-authors on the original paper. Thus,

$$\text{Openness} = \frac{\text{New co-authors}}{(\text{number of papers})\ (\text{authors in original paper})}$$

The measure was applied to the original group of co-authors. Since a larger group had more potential drop-outs and therefore more possibility of a larger absolute number of replacements, the number of new members was divided by the number of original members. Also, the measure was made less sensitive to differences in productivity by dividing by the number of papers.

The Classification of Group Structure

The only characteristic of groups considered was whether or not all the members had the same organizational affiliation. Those groups with one organizational affiliation were called "single-organizational groups", and those with members from different organizations were called "multi-organizational groups." The parts of multi-organizational groups with the same organizational affiliation are called "sub-groups."

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* The 50% criterion is arbitrary but seems a conservatively low figure for the point where group members consider the group to endure. It is doubtful this criterion excludes groups whose remaining members would say, "this is the same group as before." Despite the 50% criterion, the continuity and openness measures remain independent. The continuity measure ignores any addition of new authors. While the openness measure is only calculated for groups showing at least a certain level continuity, the openness score only relates number of individuals entering the group to the number of original authors. Continuity is ignored.

Organizational affiliation for members of the group was taken as listed in the heading of the article used to define the group. Footnotes which give additional information, such as where a co-author was located at the time of publication or that he was on leave for some other organization, were ignored. If all the co-authors listed the same two organizations, e.g., a university and a national laboratory, the group was designated as single organizational. Distinctions between departments at universities were ignored.

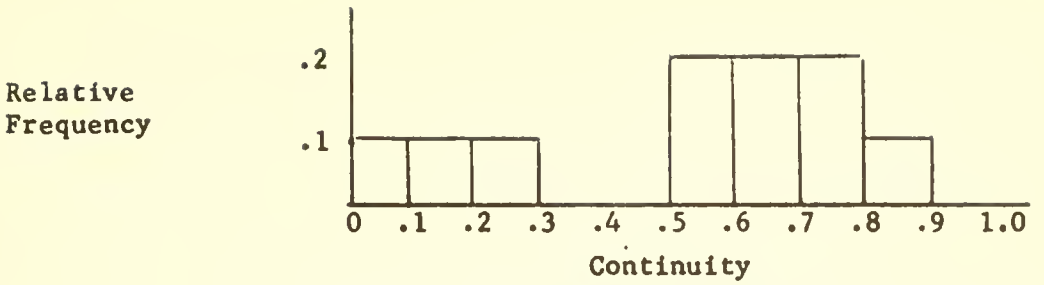
The purpose of the classification was to identify groups whose members were attached to the same or distinctly different organizations. It falls short of this objective in at least one way.

Authors from abroad may list home universities and yet never leave the host laboratory in this country during the entire period of collaboration. In this study no groups happened to contain such co-authors who did not also have co-authors with affiliations clearly justifying designation as multi-organization groups.

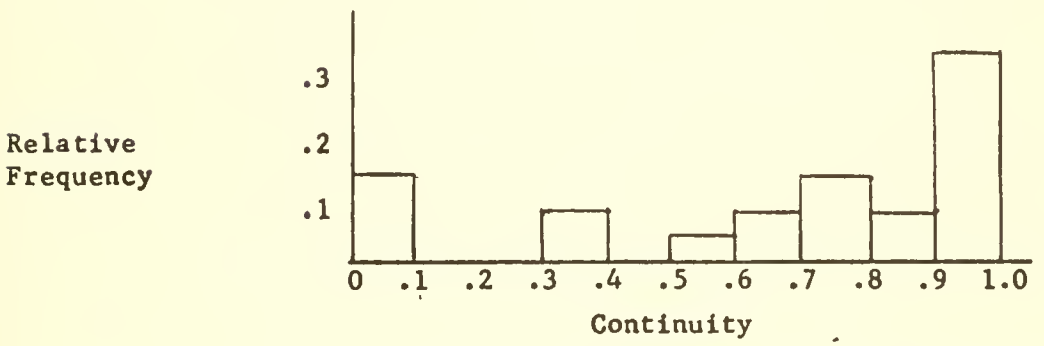
This classification system for groups allows an analysis of relationships between group structure, continuity, and openness. Further, by examining behavior of individuals changing from a group of one structure to another of different structure, it is possible to find patterns which help explain those relationships.

## RESULTS

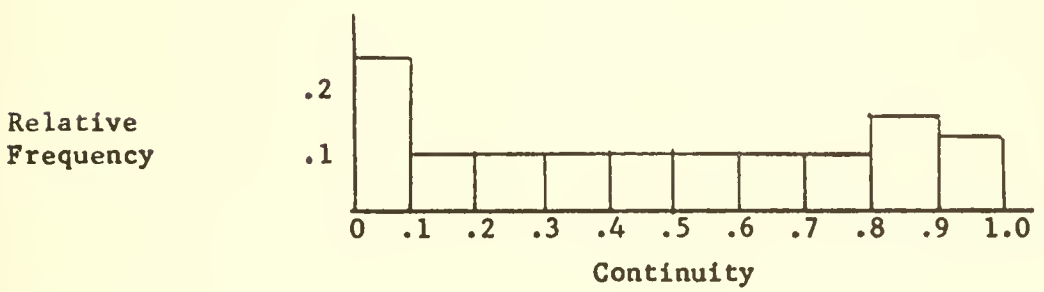
Figure 1 gives the distributions of measures of continuity for single organizational groups, multi-organizational groups, and their sub-groups sharing a common organizational affiliation. Sub-groups within multi-




A. Entire Multi-Organizational Groups (10 groups)




B. Sub-Groups of Multi-Organizational Groups (20 groups)




C. Single Organizational Groups (16 groups)

Figure 1. CONTINUITY AND GROUP STRUCTURE

organizational groups are significantly more constant than single organizational groups ($p < .05$, one-tailed test). A statistical test was not applied to the differences between continuity for sub-groups and multi-organizational groups because the measure for continuity makes the samples related. It is apparent, however, that the sub-groups tend to be more constant than the entire multi-organizational groups. There is no significant difference in continuity between the multi and single organizational groups.

The Mann-Whitney U test was employed in order to avoid the assumptions underlying the t test. The Mann-Whitney U test requires only ordinal measurement, not interval scaling.[1]

Figures 2 and 3 give the relationships between continuity and openness for single and multi-organizational groups, respectively. In single organizational groups, continuity is inversely related to openness.

On the other hand, multi-organizational groups seem to show a positive relationship between continuity and openness. The small number of groups and the narrow spread of openness scores, however, require the more conservative statement that multi-organizational groups do not show an inverse relation of continuity and openness. Comparison of the two figures shows that the means of the two distributions are not significantly different.

If group structure, continuity and openness are related, it seems reasonable to expect that individual physicists might show preferences for

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[1] For a discussion of the Mann-Whitney U test, other non-parametric statistical tests used in this study, and the issues involved in choosing non-parametric tests, see Sidney Siegel, Nonparametric Statistics for the Behavioral Sciences. New York: McGraw-Hill Book Company, Inc., 1956.

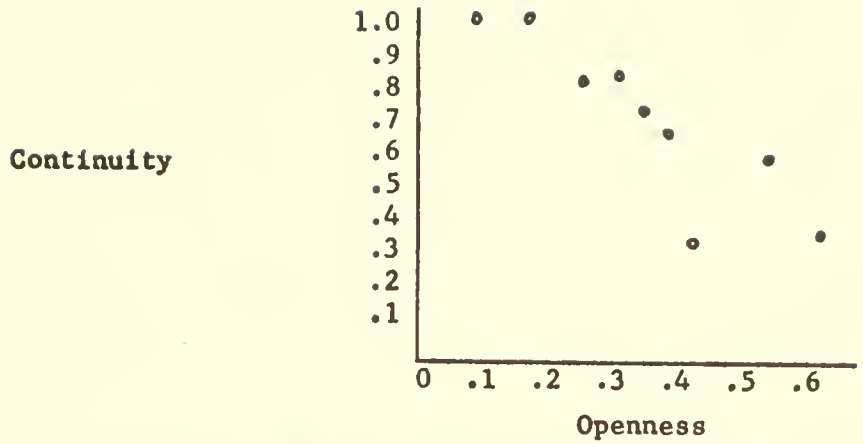


Figure 2. CONTINUITY AND OPENNESS FOR SINGLE ORGANIZATIONAL GROUPS

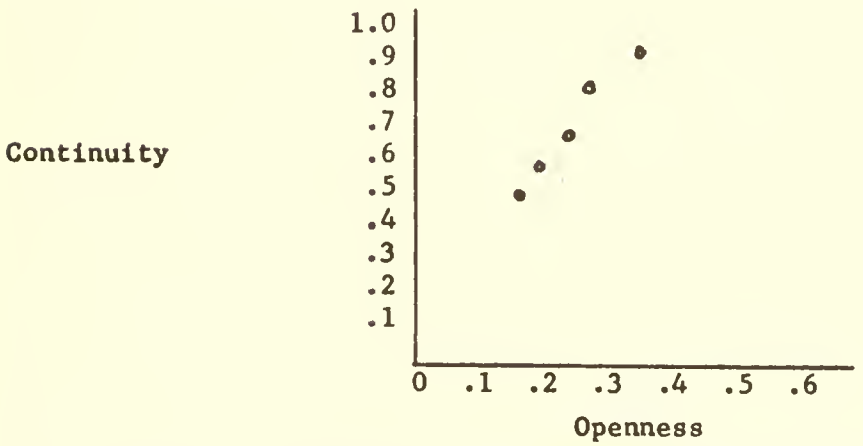


Figure 3. CONTINUITY AND OPENNESS FOR MULTI-ORGANIZATIONAL GROUPS

groups they perceive as more open when changing organizations.

Table I shows how individuals tend to make shifts to multi-organizational groups and organizational changes at the same time. The data were gathered for forty-five high energy experimental physicists drawn randomly from the Physical Review Letters between 1959 and 1964. The incident taken was the first instance where the author changed from one group structure to another on succeeding papers. The type of change was noted and the question answered: "Did he also change organizations?"

The data in the table show that only 20 percent of the shifts are from single- to multi-organizational groups when an individual did not change organizations, while 60 percent of the shifts were in that direction when he did change organizations. Thus, when individuals go from single- to multi-organizational groups, that switch tends to occur when the individual also changes organizational affiliation.

## EXPLANATIONS FROM THE INTERVIEW DATA

The findings from analysis of co-author relationships show that sub-groups are more constant than single-organizational groups and that more constant single-organizational groups are less open. Continuity and openness are not inversely related for multi-organizational groups. Further, individuals tend to change organizations when shifting from single to multi-organizational groups.

Part of the intent of this exploratory study is to formulate explanations for these relationships. Some explanations must be attempted both to allow the generation of hypotheses for testing and to suggest the consequences of management action on group structure aimed at changing

Table I. INDIVIDUAL MOBILITY AND SHIFTS BETWEEN GROUPS OF DIFFERENT STRUCTURE

| Type of Shift in Group Structure | Organizational Change? | | | |
|---|---|---|---|---|
| | NO | | YES | |
| | Number | Percent | Number | Percent |
| Single to Multi | 7 | 20% | 6 | 60% |
| Multi to Single | 28 | 80% | 4 | 40% |
| Totals- | 35 | 100% | 10 | 100% |

$X^2 = 4.32$, $p < .025$.

continuity or openness. The interviews with group members and leaders suggest some explanations.

Distinct Characteristics of Multi-Organizational Groups

The interviews revealed some special problems which multi-organizational groups had to solve. The leaders and members of such groups react to these problems with some common patterns of behavior which are clearly distinguishable from those described for the single organizational groups. These responses may also explain our empirical findings.

The members of multi-organizational groups tend to have more difficulty getting together than members of single groups or of sub-groups of multi-organizational groups. This is true despite the fact that during part of the experiment the members of all groups spent time at the experimental site.

One leader of a single organizational group expressed the difficulty arising in his group when it became multi-organizational:

> "We were all here at Brookhaven for the first experiment. Then two of the guys left to go to universities. That series of experiments was never finished. In fact, we never wrote up the first experiment. We couldn't seem to get our calendars together.

Physical separation of members of the group reduces personal interaction. The importance of such contacts to the formulation of solutions to experimental design problems is illustrated by a description by one physicist of his relations with another physicist who was nearby:

> He is the type of physicist who works by talking. Each time I saw him he was telling me about problems and I was making suggestions. We would just gas around. I don't know which other guys in the group he was talking with during that early period in the experiment. I'm sure there were others.

The multi-organizational groups not only had difficulty because such interaction was less, but where it was attempted, special problems arose. One group leader related an experience:

> You have real communications problems between the sub-groups from different organizations. I think a lot of it comes from incidents where things get repeated second-hand or even third. The mis-communication difficulties are primarily in the lower echelons of the groups. They get together generally at the experimental site when equipment is being set up.

Part of the difficulty in multi-organizational groups, in addition to less extensive and effective personal interaction, comes from the financial requirements of separate organizations. Each organization contributes funds for experimental apparatus. Since the equipment is not expended during the experiment, some method of determining disposition is necessary. One group leader described the problem:

> Each sub-group from a school has a specific part of the equipment which they fund, build, and own. It has to work that way for legal reasons. If we had joint ownership of everything and the experiment were finished, I couldn't give the equipment to the other university because it was partly paid for with my university's funds. Each sub-group has to own specific items.

Not only must the multi-group conduct the experiment so as to retain organizational investment, but the group members are paid by separate organizations. The fact that salary systems are different was cited by several interviewees, both technicians and senior scientists, as the cause of inter-personal friction.

A third difficulty for multi-organizational groups stems from perceived status differences in the organizations. One example of such a problem and the attempt to resolve it were described by the leader of a sub-group:

> There was some friction between the sub-groups. First, we are big and their school is small. People who hear about the collaboration may consciously or unconsciously assume that we are largely responsible. The other leader is especially aware of this. At the time we were doing the experiment, he was trying to get a National Science Foundation grant.
>
> We made a great effort to give him at least full credit for his school's contribution. We let him give the paper describing the plans as well as another giving the first results. We only spoke at some meetings in Russia where he wasn't invited.

The status issue was real enough that several sub-group leaders described their efforts to gain dominance over the sub-group from the other institution. Whether the effort was to maintain the balance of power or to tip it, the status differences were clearly of importance to leaders and to group members.

Responsive Behavior to the Problems

At least two patterns of behavior were observed in the interview data which are logically responsive to the multi-organizational groups' problems of reduced opportunities for interaction, separate financial systems, and perceived status differences.

The first pattern is greater division of labor. If members in different sub-groups cannot work on each other's problems and if equipment must be separately owned, then the design work must be allocated to sub-groups. It was clearly the opinion of the interviewees that subdivision of tasks occurred not only between sub-groups but within the sub-groups and was greater there than in single-organizational groups:

> One characteristic of multi-groups is that the work has many divisible skills, such as electronics, boolean algebra, and computer programming.

> It is even likely that multi-organizational groups will divide up the analysis of the data. In bubble chamber groups, which are often multi-organizational, you can divide the pictures.

The greater degree of division of labor in multi-organizational groups makes informal control of the group's activities and shared problem solving more difficult. One Nobel laureate joked about his experience with this phenomena:

> I used to feel better because my long-time colleague could always explain to me what a graduate student was doing if I couldn't understand. Now they have become so specialized that even he doesn't know what they are all doing. Physics is ruined.

Both the need to allocate the experimental tasks and the perception of status differences makes reasonable another pattern apparent in the interviews: The sub-groups have more centralized leadership than do single organizational groups.

Each sub-group has either a single man or two men who are recognized by themselves and the group members as responsible for negotiating with other sub-groups on work assignments, for assigning tasks within the sub-group, and for assuring recognition for the sub-groups. In none of the multi-organizational groups was there an expression of the desire to maintain diffused leadership. This desire was expressed in several of the single-organizational groups where the members tried to make joint decisions and to avoid becoming specialized. The desire for diffused leadership and sharing or rotating of tasks are linked together.

The Responsive Behavior Related to Continuity and Openness

If multi-organizational structure creates a tendency toward division of labor and a clear leadership structure, then the findings for continuity

and openness are explainable in terms of some earlier research findings.

Heincke and Bales[2] reported findings indicating that groups in which the status hierarchy is stable have less disagreement, tension, and antagonism. More clearly defined leadership and task roles in the sub-groups of multi-organizational groups should thus promote continuity. This could explain the higher continuity observed in the sub-groups of multi-groups as opposed to single organizational groups.

The division of labor may also promote continuity. Where tasks are differentiated, the chance for direct comparison between members is reduced. This may promote continuity among physicists if they are as competitive as one group leader asserted:

> I think you shouldn't consider the members of a group or sub-group as working primarily for a joint reward. They are really competitive. I think they are particularly aware of how they are doing as compared with other members.

Our finding that single-organizational groups are less open when they are more constant also becomes explainable in the light of the interview data and some earlier research. Slater[3] examined some correlates of group size in a sample of 24 "creative" groups. He observed that members of the smaller groups are inhibited from expressing their ideas freely through fear of alienating one another and thus destroying their group.

Figure 4 shows that in our sample the single-organizational groups are smaller than the multi-groups. The members of the single-organizational groups should then exhibit the effect observed by Slater more than

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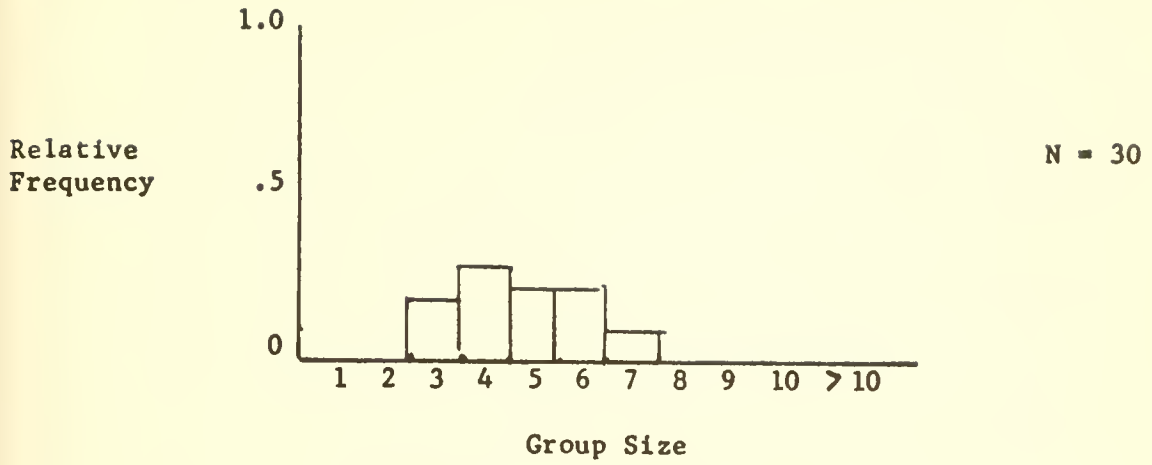
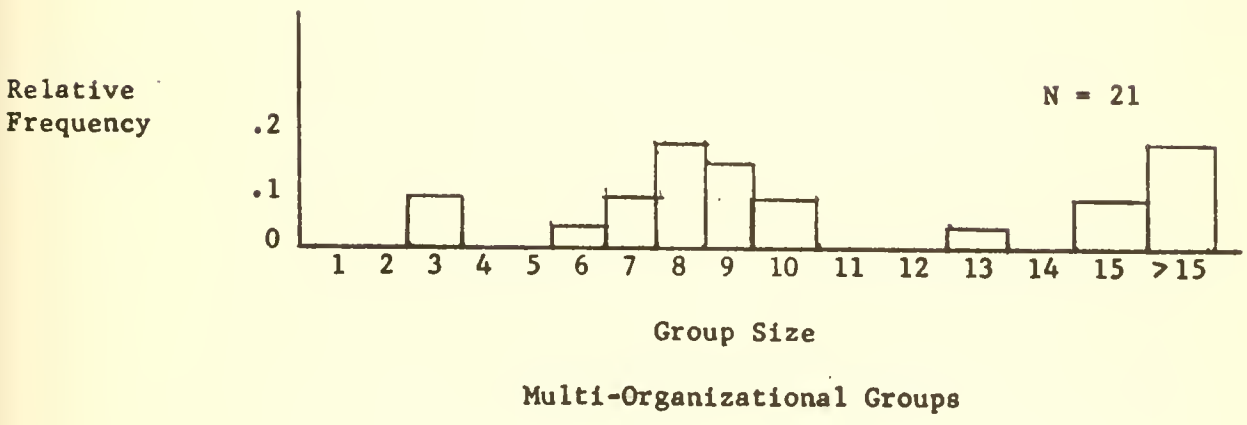
[2] Heinicke, C., and R. F. Bales, "Developmental Trends in the Structure of Small Groups", Sociometry, (16), 1953. pp. 7-38.

[3] Slater, P. E., "Contrasting Correlates of Group Size", Sociometry, (21), 1958. pp. 129-139.




Single Organizational Groups




Multi-Organizational Groups

Figure 4. GROUP SIZE

members of multi-organizational groups. Single-organizational groups also maintained diffused leadership and shared tasks. Members would reasonably fear that the introduction of new members might destroy this group atmosphere. Single organizational groups who admitted new members might increase tension and reduce continuity. Multi-organizational groups with stable roles and clear leadership hierarchy could accept new members with less threat to the group's continuity.

Finally, the individual physicist would reasonably tend to enter multi-organizational groups when changing organizations. From his point of view, the greater division of labor and more clearly defined leadership structure reduce the difficulties of learning a new role in a strange organization. Also, the members of the multi-organizational group at the other organizations would be less threatened by his joining. One sub-group leader said:

> The other sub-group may add some people to the papers. We don't care... No, it isn't generosity. Letting them have their names on the paper doesn't cost us anything, and they like it.

Another group leader expressed the same attitude, but attributed it to the lack of commitment he felt to continuity in a multi-organizational group:

> On the second run, they added three people. Their joining was informal and didn't raise much discussion. We and they felt no constraint to continue together.

The new man in an organization, therefore, would adapt to the new role more easily and encounter less resistance by joining a multi-organizational group.

## DISCUSSION

This exploratory study has proposed relationships between division of labor, leadership hierarchy, organizational structure, and group continuity and openness. These relationships suggest possible action by high energy physics policy makers. They also suggest further research questions.

### Implications for Policy

The tentative findings of this study suggest that greater continuity of research relationships and easier entry by newcomers might be achieved by encouraging the formation of multi-organizational groups. At least one judgment and the answer to one empirical question are necessary before recommending such a policy.

First, continuity and openness may be more or less important to the high energy physics policy maker than other objectives. Since relating these two variables to a quantitative measure of research output is presently undemonstrated, the judgment must be subjective. Second, are other variables -- particularly group size and type of research task -- equally potent in affecting continuity and openness in groups? At least some answers must precede recommendations for policy.

Should judgment and further research support the recommendation, means now exist for achieving emphasis on multi-organizational groups. On occasion, the scheduling committees of laboratories encourage groups proposing experiments to collaborate with other groups. The encouragement carries with it the implication that the required beam time may depend on such collaboration.

Another opportunity to encourage multi-organizational groups will occur at the founding of the proposed 200 BEV laboratory. The staff physicists could be selected and organized with the intent that they serve as sub-groups for collaboration with outside users. By not accumulating sufficient staff members for internal, single-organizational groups, the laboratory might both encourage multi-organizational groups and spread research talent to more universities for the training of undergraduate and graduate students.

Implications for Research

Some group characteristics postulated in this study deserve testing. Particularly important to the arguments advanced here is proving the proposition that single-organizational groups tend to seek greater interchangeability of skills. A second assumption in the explanations is that division of labor and continuity are positively related. This also needs formal verification in high energy physics groups to add plausibility to the arguments.

Another relationship of interest is that of openness and status differences between sub-groups in multi-organizational groups. Sub-groups may be more open to people joining other sub-groups the greater they perceive a status difference between their own sub-group and the others. Even though the multi-organizational structure makes newcomers less threatening, a newcomer to a sub-group should be perceived as diluting the credit attributed to sub-groups of equal status. Entry to a clearly lower status sub-group might be resisted less by the higher status sub-group.

Further study should be aimed at explicating the effects of group size and the nature of the task on continuity and openness. Since the sub-groups and single organizational groups had virtually identical distributions of size, the finding for continuity presented here was not affected. But differences in openness between single-organizational groups and multi-organizational groups may be significantly affected by differences in group size.

Single-organizational groups may undertake different research problems than do multi-organizational groups. Several interviews with group members, particularly those in small, single-organizational groups, indicated that members perceive differences in the types of research attempted. Single-organizational group members seem to perceive their work as "esthetic" and that of multi-organizational groups as "brute force."

Investigating this variable and determining its relation to group size, continuity and openness will require categorizing types of research tasks. The effort seems justified despite obvious difficulties. No recommendation to emphasize multi-organizational groups could safely ignore the effect of such a policy on the physics undertaken.