Organization and Productivity in R & D Teams
A Report of Research Findings

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Working Paper 86-4
November 1986

This study was supported by the National Science Foundation—Grant ISI-804340.

The present report is a revised and updated version of the report presented to companies participating in the study in November, 1985. The analyses in the previous report were based on 160 to 190 teams. The analyses in this paper are based on the total sample of 224 teams.

Center for Sociological Research

Stanford University

SUMMARY OF FINDINGS

from the study of

THE RELATIONSHIP OF TEAM SOCIAL STRUCTURE TO TEAM PRODUCTIVITY

(Conducted under NSF Grant ISI-8304340)

The principal findings to date concern the effects on team productivity and innovativeness of four types of factors: Interaction among team members, team composition, team organization and team perceptions of the company.

1. On a scale from "Not at all Productive" through "About Average" to "Highly Productive," only 12 of the teams in the study were rated below "About Average." Results were similar for ratings of Innovativeness. These results hold whether the raters were external evaluators, team leaders or the team members themselves.

2. Teams which have a higher average interaction among members receive higher productivity evaluations from external evaluators, from team leaders and rate themselves higher as well. Average interaction among team members is negatively related to team size and the relationship between average interaction and external evaluations of productivity increase when the effects of size are taken into account.

3. Teams with a high rate of interaction involving requests for technical assistance have higher productivity ratings from external evaluators, team leaders and rate themselves higher as well. These relationships are also net of the effects of team size.

4. There is also a relationship between a high rate of interaction involving the exchange of information and evaluations of productivity from external or internal evaluators.

5. Teams for which a few members are receivers of all requests for technical assistance receive higher productivity ratings from external evaluators, team leaders and themselves.

6. Teams for which giving and receiving technical assistance are reciprocal relations, i.e. two people request and give each other technical assistance are rated more highly on productivity by external evaluators, team leaders and rate themselves higher.

7. In interaction based on the exchange of information, external ratings of productivity are unrelated to properties of that interaction such as whether there are few receivers of requests for information or whether the relationships are reciprocal.

8. Teams which are heterogeneous with respect to such factors as age, gender, and education level of members report more internal problems and rate themselves lower on productivity and innovativeness than teams which are homogeneous. But external evaluators rate heterogeneous and homogeneous teams approximately the same; if there is any difference, it is in favor of heterogeneous teams.

9. Teams with a form of organization ("Autonomous teams") in which members are only loosely connected to one another received the lowest productivity ratings.

10. In teams with a collegial form of organization, high rates of interaction were related to high evaluations of productivity. This relation did not hold for teams with other forms of organization.

11. In "collegial" teams, the performance of a "Bridge role", a role that facilitates team interaction, was associated with higher evaluations of productivity. This relation did not hold for any other form of team organization.

12. The performance by one person of a "Manager role" which included supervision, evaluation, task assignment and resource allocation was positively related to productivity evaluations in "collegial" teams. It was negatively related to productivity ratings in teams with a "Mixed" form of organization, part collegial and part leader-centered.

13. Some forms of team organization are more conducive than others for the performance of particular kinds of tasks. Some forms are more compatible with given task requirements than others. In working on "uncertain" tasks, decentralized forms of organization receive higher performance evaluations than centralized.

14. Where task requirements and the form of team organization are compatible, teams report fewer internal problems.

15. There is considerable agreement among different evaluators on more general, global evaluations. There is much less agreement on very specific, concrete perceptions.

16. Favorable team perceptions of characteristics of the R & D organization in the company, e.g., the company is quick to expand into new R & D areas, are associated with high external evaluations of team performance.

17. Team perceptions of the consequences of team success are associated with external evaluations of team productivity.

This investigation would not have been possible without the support and assistance of a great many people and over thirty organizations. First of all, we want to thank the team members, team leaders and team evaluators for the time and effort they spent in conscientiously completing our questionnaires. The thirty companies that cooperated with our study and the over thirty company liaison persons that did all the on-site work of preparing team rosters, distributing questionnaires and acting as the collection point merit our special gratitude. While such arrangements have supported research prior to this study, the complexity of the present research design called for yeoman efforts and without exception, these liaisons were equal to the challenge.

A group of people from industry and academia were extremely important in the development and design of the study. This group is our Project Advisory Committee. More than once, they prevented serious errors and their suggestions improved the study in many ways; one of these suggestions is responsible for one important respect in which the study is unique—they advised us that a complete census of team members was not only possible, but would be less disruptive to R & D organizations than sampling a few team members. The following have served on the Project Advisory Committee: Michael Anbar (SUNY-Buffalo), Robert Becker (American Cyanamid), John Doyle (Hewlett Packard), Ralph Kaitz (M.I.T.), John Kaplan (General Motors), Peter Keane (Proctor and Gamble), Ray Leadabrand (SRI International), Ernest Littauer (Lockheed Missies and Space), Boyd Poulsen (Syntex Research), Joseph Stevenot (Procter and Gamble), and Elmer Wheaton (retired, formerly of Lockheed Missies and Space.)

Needless to say, this study would not have been possible without the financial support of the National Science Foundation, grant ISI-8304340. But more than funding has come from the Division of Industrial Science and Technological Innovation through its program officer, William Hetzner. Bill, who is now with the Industrial Technology Institute, was not only willing to support a project that, from the point of view of the program represented somewhat of an unorthodox appraoch, but continually provided helpful suggestions. He contributed both substantively and procedurally to the project.

Ronald Kruse, who was a co-investigator in the early stages of the project, made a major contribution to the development of the four questionnaires used in the study. The research has benefited enormously from his rare talent for constructing answerable questions. Elizabeth Cohen, who studies teams in educational settings, has contributed theoretical insights and constructive criticism throughout the study.

Finally, we want to express our appreciation to the company representatives who participated in our conference where we discussed many of these findings. Their comments and suggestions and their enthusiastic response to our results have provided both new ideas and additional gratification to all of us.

Center for Sociological Research
Stanford, California
November, 1986

1. Introduction.

The main focus of this study is on the relationship between the organization of an R & D team and its productivity and innovativeness. Our view of team organization encompasses the formal and informal relations among team members as well as the relations between the team and the larger company component in which it is embedded. The basic premises underlying the research assert that the structure of a team (i.e., the formal and informal relations in the team) and the nature of its task affect interaction among team members and this in turn affects the productivity and innovativeness of the team.

By no means do we claim a simple linear relation between amount of interaction and productivity—for some forms of team organization and/or for some types of tasks, a high level of interaction may be counter-productive. Rather we ask the questions: Under what conditions does a high level of team interaction foster team productivity? Under what task conditions does a particular type of team organization enhance productivity either directly or indirectly through its effects on team interaction. Furthermore, it is not only the total amount of interaction that is of interest but also the nature of the interaction itself; we distinguish different types of interaction that serve different functions in a team—eg., exchanging information, providing technical assistance, evaluating ideas. These may be differentially related to team structure, nature of the team's task and productivity.

In addition to its primary focus, the research has pursued a number of additional avenues, some of which should be of particular interest to the companies that have participated in our study. We have examined whether or not differences in perspective among the participants in the study affect their responses—eg., when do team leaders and team members agree or disagree on their answers? We have investigated some of the effects of team composition, particularly heterogeneity of age, gender, educational level and technical specialities. We have analyzed some of the consequences of how team members perceive the organizational context as, for example, whether or not team perceptions of company incentives affect the team's productivity ratings. These and other lines of investigation capitalize on what is a unique and rich set of data.

This study and the data that have been generated are unique in many ways. For the first time, data from all members of a team have been collected in a study of a large number of teams. There have been studies of larger numbers of research units and there have been studies of larger samples of individual research workers, but never before has anyone attempted to gather d~~ata f~~rom all team members of over 200 teams. And the attempt has succeeded 91% of the members of the teams studied returned completed questionnaires. This high response rate is itself unusual since many researchers are delighted with rates of return in the 702 range in studies of this kind. Our rate of return is both a tribute to the efforts of the participants and a first indication of the quality of the data.

There are other respects in which the study is unique. It is the most extensive exploration of formal and informal relationships, especially of the networks of such relationships, that exist on R & D teams. Never before has it been possible to provide statistical descriptions of these networks and never before has it been possible to relate network properties to team outcomes such as productivity. One can compare the average number of links in a network based on the exchange of information with the same parameter for a network based on the exchange of technical assistance and test whether either of these parameters is related to ratings of team productivity.

Finally, we must note one additional respect in which this study is atypical. Considerably more time and effort went into the development of the questionnaires than is the case in most surveys. Construction of these instruments was based on intensive case studies of several R & D teams where team members were interviewed and observed on frequent occasions over a period of several months. In all, three years were spent in formulating and testing these questionnaires. The quality and richness of the data we have obtained provide a more than ample return on this investment.

Four questionnaires were employed in this study. The major instrument, the Unit Member Questionnaire (UM), was distributed to every team member including the team leader(s). The team leaders also filled out a short supplementary questionnaire (UL). The Unit Evaluation Questionnaire (UE) provided an external evaluation of the productivity and innovativeness of each team; two senior managers who were not part of the team but knowledgeable about the team's performance answered this questionnaire. These evaluators also completed a one-page Evaluator Profile (EP) which requested information about each evaluator's current position, previous training and job history in R & D.

Since there was some overlap in the questions asked of team members, leaders and evaluators—particularly those concerning evaluation of the unit's performance, we have the opportunity to examine some issues from a variety of perspectives to determine where people from different vantage points agree and where they disagree. In some of the analyses below, we will present results for Members, Leaders and Evaluators. Our ability to examine responses to the same issue from these three different sources is but one more illustration of the richness of the dataset.

A dataset such as ours presents endless analytic possibilities and the analyses we have completed thus far are only a beginning. While we have been able to evaluate some of the key ideas with which we began the study, much more can and will be done. There are many topic areas that we have not yet examined; and, in addition, there are alternative ways to approach the data which remained to be explored. For example, the analyses to date have focused almost exclusively on the team as the unit of analysis—the relationships we have found are between one set of properties of a team and some other set or sets of team properties. Thus we have explored the relationship between average level of interaction on a team and the productivity ratings the team received. We have not examined any relationships among individual characteristics such as, for example,

the relationship between an individual's level of interaction with others and that individual's evaluation of productivity or innovativeness of the team.

The analysis that we have completed, however, has been highly informative. We have found support for many of our central ideas and we have had some surprises. As we continue with the research, we foresee additional findings in support of the basic ideas of the study and also more unanticipated results. Even though we are at an early stage in digesting our findings, it seems appropriate to consider the implications of our results and to reflect on priorities for future analysis. To aid us in reflecting on these issues, we have prepared this report.

Despite the fact that we are at an early stage of data analysis, we have many more findings than we can present in a short report. We have chosen to present a sample of results in five different topic areas rather than pursue any one topic intensively. In this way we will illustrate the range of possibilities for analysis that exist in the data. This should provide a basis for discussion both from colleagues and from the companies that participated in the study. We have chosen these topics to cover a broad range of interests and because we believe they have both theoretical and practical implications.

Before turning to these topical areas, we shall present some basic facts about our sample. The body of the report then is divided into six sections:

Descriptive Facts about the Sample.
Different Perspectives on Team Performance.
Some Effects of Heterogeniety in Team Composition.
Consequences of Different Types of Interaction.
Team Structure, Type of Work and their Effects.
The Impact of Organizational Characteristics on Team Performance.

2. Descriptive Facts about the Sample.

Table 1 presents some chararacteristics of the 224 teams in the sample. These teams represent 30 companies from 8 different "lines of business." 2285 people belong to these teams and 2077 of them returned the Unit Member Questionnaire which is a 90.9% rate of return. Our data base also includes 260 Unit Leader Supplementary Questionaires from the leaders of 212 teams—2 Leader questionnaires were returned from 36 teams and 3 Leader questionnaires were completed in 6 teams. For 12 teams (5.3% of the sample), we have no leader information from either the Unit Member or the Supplementary Questionnaire. 406 Unit Evaluation Questionnaires were returned from 220 teams; the sample includes Evaluator Questionnaires from 2 Evaluators for 182 teams, 1 Evaluator from 36 teams and 3 Evaluators from 2 teams. We have no Evaluator data for 4 teams (1.8%).

The classification of Basic Research, Applied Research and Development was based on UM Questions 1 and 2. Question 1 asks:

> As your company defines it, which of the following best describes the general area of R&D in which this unit is working: CHECK ONLY ONE.
>
> Basic research to obtain new knowledge in a product area.
> Applied research to solve specific problems with a product or process
> Development of a specific product or group of products.
> Improvement of existing products.
> Improving manufacturing processes.
> Other. (Please specify:)

Where the team responses to this question are clear-cut, it alone is used. Some of the ambiguous cases are resolved using the response of the team leader. Table 1 shows that nearly half the teams are classified as Development, 25% as Applied Research and 20% as Basic Research.

Next we examine some characteristics of the composition of teams. Teams were classified according to UMQ.61 which requested information concerning the "highest degree received" and UMQ.60 gender. Table 1 shows that teams where more than half the members have Ph.D.s constitute 38% of the sample (84 teams). Thirteeen percent of the teams have no Ph.D.s and there are 10 teams composed solely of Ph.D.s. Forty-two percent of the teams (93) are all-male and 6% have female leaders.

Figure 1 shows the distribution of team sizes in the sample. This distribution is somewhat constrained since we indicated our preference for teams of between 5 and 20 people. The smallest team in the sample has three members while the largest has thirty-four. The average team size is 10.2 and 50% of the teams are size 9 or smaller. Contrary to what some people might expect, size effects on most of our measures are small or non-existent. The major exception, where size effects are not negligible, occurs with measures of member interaction. Figure 2 illustrates the effect of team size on average pairwise interaction among team members.

UMQ.12 asks a member to indicate for each other member of the team:

> "How often do you talk with other members of the unit concerning matters related to the unit's work?"

For each other person, the member can check one of five categories: Daily, 1-3 times a week, 1-3 times a month, less than once a month and never. For 87% of all the pairs in the sample, the two members of the pair agree within one category in characterizing the pairwise interaction—eg., if one person says "daily", then the other either says "daily" or "1-3 times a week." (Although it is easy to take 87% for granted, levels of agreement are not usually so high in this type of research—by chance one would expect 54% of the pairs to differ by one or zero categories—so we consider 87% agreement another indicator of the quality of our data set.)

Taking all pairs on all teams, the average pairwise interaction falls in the 1-3 times a month category. As Figure 2 shows pairwise interaction is significantly more frequent in smaller teams, averaging 1-3 times a week in teams of between 3 and 5 members and halfway between 1-3 times a month and 1-3 times a week for teams of sizes 6-10. This result is not

Table 1

Characteristics of the Sample

Number of Companies:	30
Number of Teams:	224
Number of Team Members:	2285
Number of Member Questionnaires Answered (includes leaders):	2077
Number of Leader Questionnaires Completed: (36 Teams with 2 leaders and 6 teams with 3 leaders)	260
Number of Evaluator Questionnaires Completed: (182 Teams with 2 Evaluators, 36 Teams with 1 Evaluator and 2 Teams with 3 Evaluators)	406
Number of Teams with No Leader Questionnaires Returned:	12
Number of Teams with No Evaluator Questionnaires Returned:	4

Note: One team did not return questionnaires from either leaders of evaluators and hence is excluded from most analysis.

Number of Basic Research Teams:	44
Number of Applied Research Teams:	58
Number of Development Teams:	101
(21 teams were "other" or not classifiable)	

Number of Teams with only Ph.D.s:	10
Number of Teams with 50% or more Ph.D.s:	84
Number of Teams with no Ph.D.s:	30

Number of all-Male Teams:	93
Number of Teams with 0-10% Females:	19
Number of Teams with More than 10% Females:	111
Number of Teams with Female Leader:	14

FIGURE 1: DISTRIBUTION OF TEAM SIZE

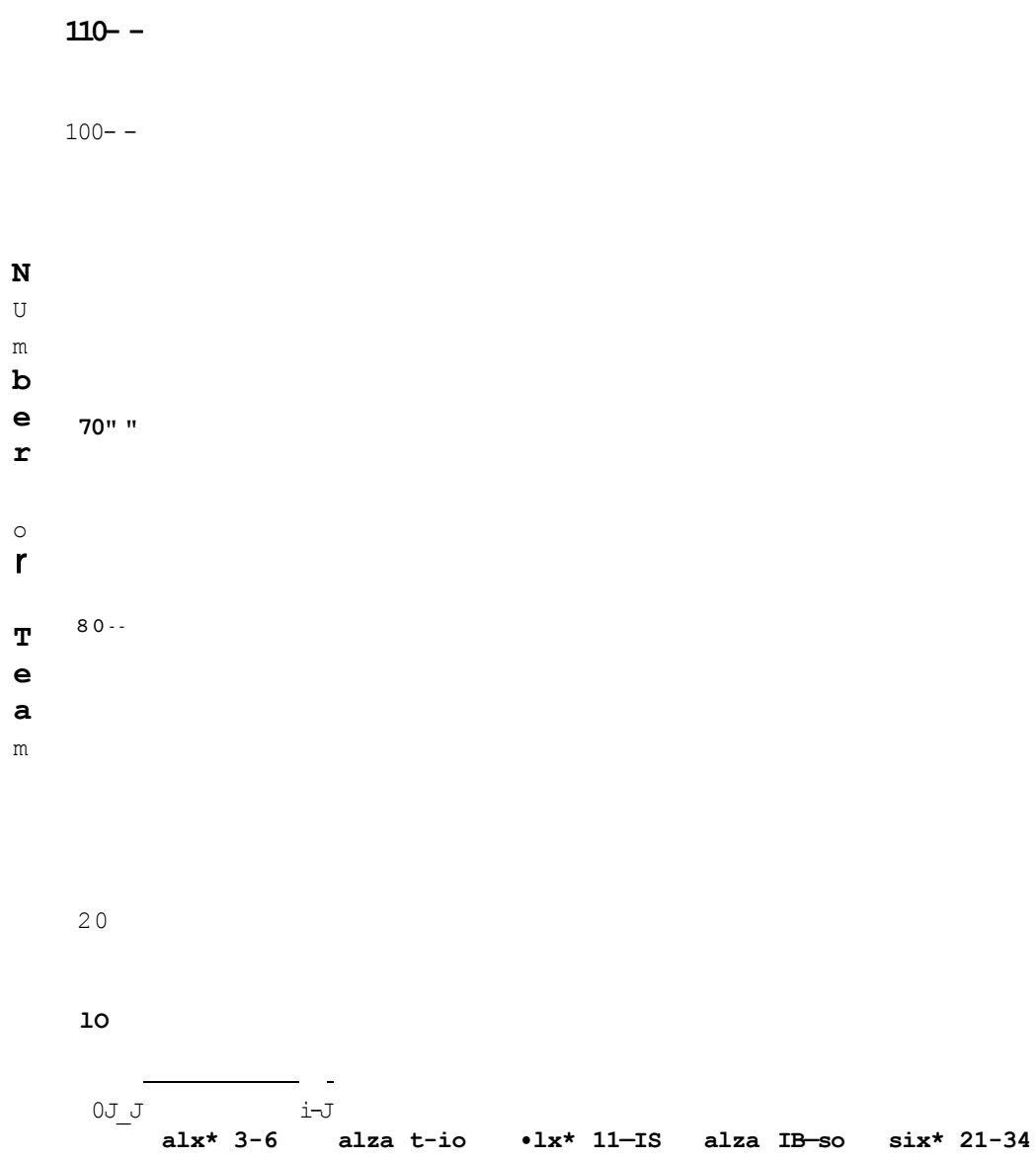
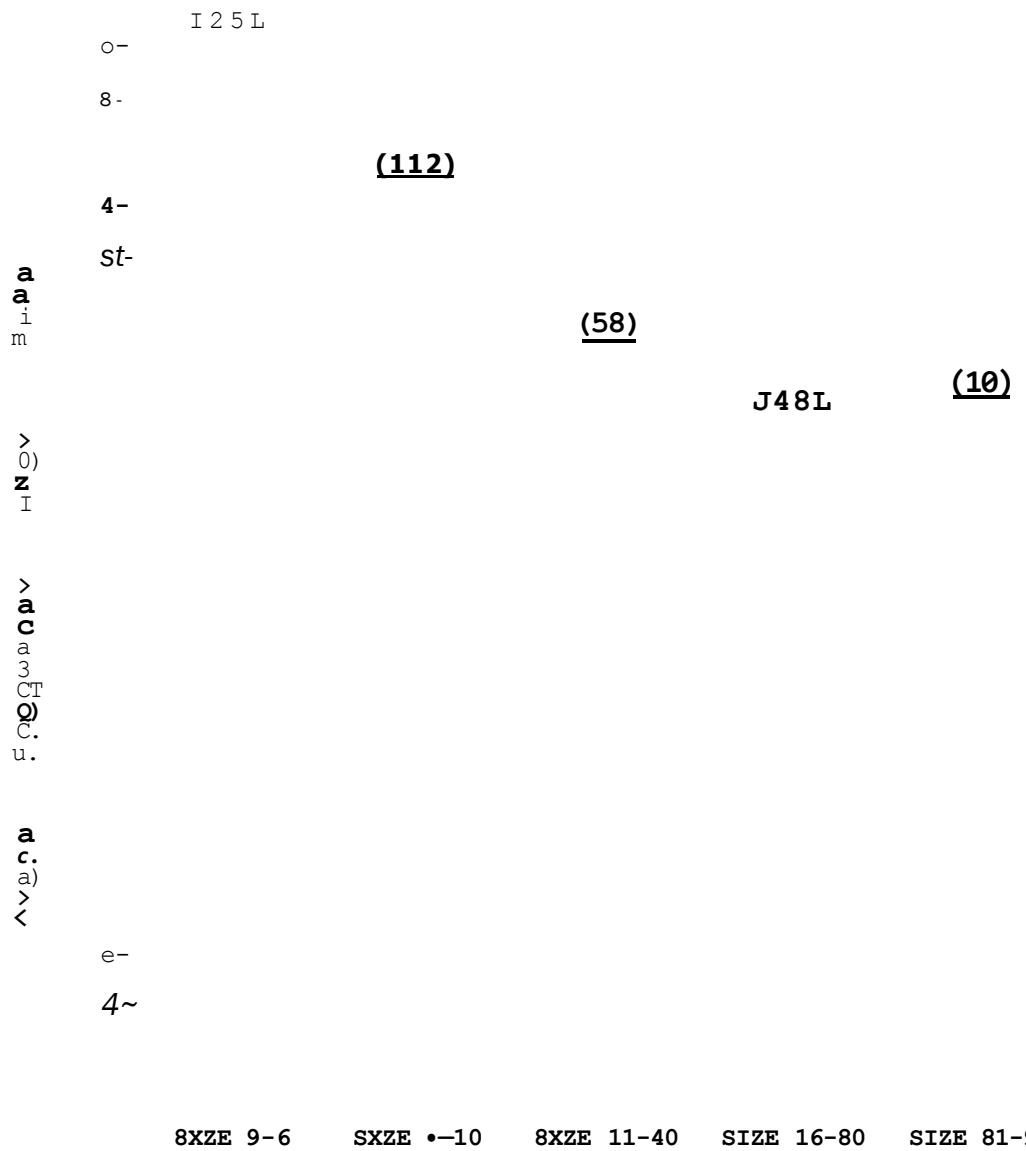


FIGURE 2: TEAM SIZE AND FREQUENCY OF PAIRWISE INTERACTION



Number of Teams in Parentheses.

surprising; after all, in a 20 member team a member could divide his time among 19 pairs whereas in a 5 member team, the same interaction time could be divided among, at most, 4 pairs.

Nevertheless, the relationship between size and our interaction measures requires that when we consider those factors which affect interaction, we remove the effects of team size. In the analyses we will present below, we will examine effects net of team size for those interaction measures that are related to size.

Since we focus on productivity and innovativeness as the most important team outcomes, we should examine how these outcomes are distributed among teams in our sample. We have a number of different possible measures of both productivity and innovativeness and the next section will consider some of the interrelations among these various measures. Most of our measures are highly correlated so results would be similar whichever of these interrelated measures we choose to present. We have selected the Evaluator ratings of productivity and the Evaluator ratings of innovativeness as our principal measures of these outcomes.

> UEQ.10: In your opinion how productive—in the sense of producing information, devices, materials, et.—is this unit?
> UEQ.11: In your opinion, how innovative—in the sense of generating new ideas, methods, approaches, inventions or applications in its field of work— is this unit?

For each question, the Evaluator was asked to circle a number on a seven-point scale ranging from Highly Productive (Highly Innovative) to Not at all Productive (Innovative). The middle number on the scale was labelled "About Average." For all teams where there was more than one Evaluator, the ratings on each of these scales were averaged to arrive at a team rating. Figure 3 shows the distribution of Evaluator ratings of Productivity and Figure 4 shows the distribution for Evaluator ratings of Innovativeness. Both figures reveal the same picture—the low end of either scale is almost never used; teams are distributed over 4 rather than 7 categories. All of our teams are above average, that is all but 1.6% on Productivity and all but 2% on Innovativeness. This result is not surprising because we are studying teams that are in the midst of their efforts and have not been terminated. An evaluator who gave a very low rating would be signalling that a team should be terminated and such a signal was probably premature for teams selected for the study. Despite the fact that range of ratings covers only half the scale, both figures indicate that there is still sufficient variation to enable us to test the effects of various factors on both productivity and innovativeness.

3. Different Perspectives on Team Performance.

Three of the questionnaires contain items that can be used to assess team performance. Table 2 presents a list of these measures. In addition to the Evaluator ratings of Productivity and Innovativeness, there are

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FIGURE 3: DISTRIBUTION OF EVALUATOR PRODUCTIVITY RATINGS

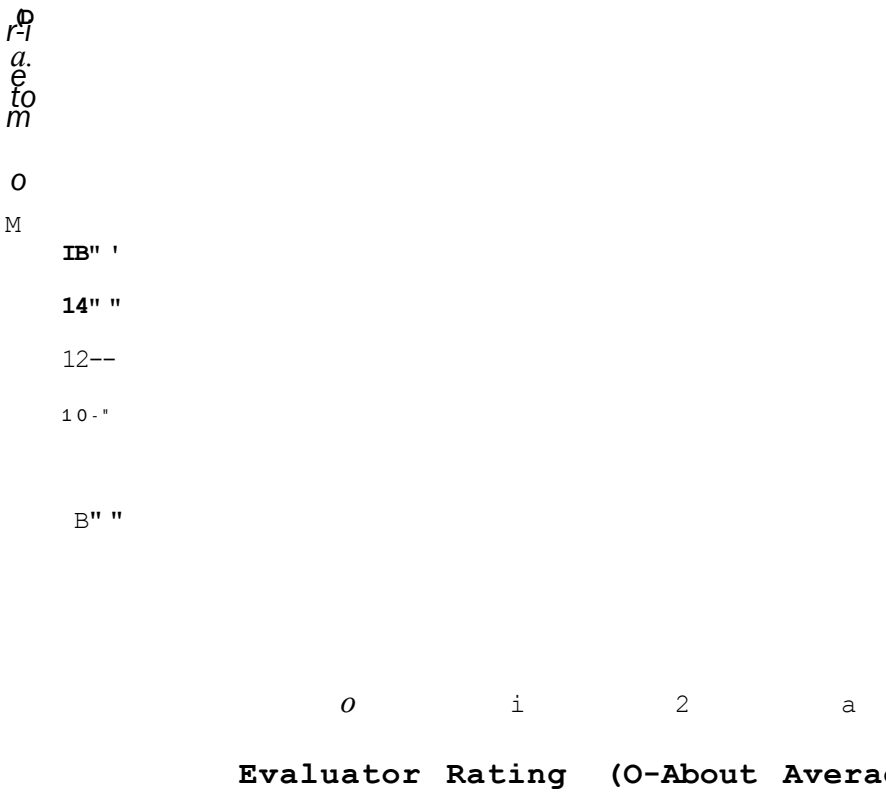


FIGURE 4: DISTRIBUTION OF EVALUATOR INNOVATIVENESS RATINGS

-i

Evaluator Rating (0-"About Average")

also team and leader ratings on these two scales. The two evaluators were asked to indicate which of a list of project objectives were important to the team and then were requested to evaluate the team's performance with respect to each of the objectives they considered important. The Evaluators also responded to three "Yes-No" questions (UE9a-9c) concerning 1) whether the team had stayed within budget; 2) whether the work of the unit has proceded according to schedule and 3) whether the team had expanded the scope of its work. Finally, Team Members and Team Leaders were asked (UMQ.29 and ULQ.10) to indicate which of 11 "tangible products" were produced as a result of the team's work. The list of these products is shown in Table 2.

First let us examine agreement between the two evaluators. Table 3 presents the degree of agreement for each of the 12 team objectives that the evaluators were asked to assess. In this table, we use two different criteria of agreement; 1) Both Evaluators choose the same category or differ by no more than one category, eg., one chooses "single most important objective" and the second chooses "an objective of major importance;" 2) Both Evaluators regard the objective as the single most important objective. The first column of the table shows the frequencies with which an objective was considered of some importance by at least one of the Evaluators, that is, it excludes those teams where both Evaluators agreed that a given item was not an objective for the unit. (By doing this, we understate the degree of agreement between Evaluators, but including these cases would overstate the degree of agreement—it is easier to agree that something is not an objective.) The second column of the Table indicates that, using the first criterion, there is a reasonable level of agreement among evaluators and for the last three objectives—Satisfying the requirements of government regulation, Expanding an existing scientific/technical knowledge base and Bringing a new scientific/technical knowledge base into the firm—there is very high agreement.

A very different picture emerges if we use the second criterion. For each objective, we select those teams where one Evaluator responded with category 1, "The single most important objective," and examine whether or not the second Evaluator also chose that category. Column 3 of the table shows the number of teams where at least 1 Evaluator chose category 1 and Column 4 shows the percentage of that number where the second Evaluator agreed. Column 4 of the Table indicates that using this criterion, agreement among Evaluators is uniformly low. For the objective of "Developing a New Product," where one Evaluator selects the objective as the "single most important" in a substantial number of teams, agreement reaches a high of 49%.

Two principal interpretations can be offered for the results in Table 3. Either Evaluators cannot consistently select "the single most important objective" from a set of important objectives, or the idea of a "single most important objective" is not applicable to the work situation of R & D teams. While the table shows considerable agreement using the less restrictive criterion, either interpretation rules out using a more stringent criterion of agreement.

Table 2

Measures of Performance Used in the Study

	Rated by:		
	Team Members	Team Leaders	External Evaluators
Global Ratings:			
Productivity		X X	X
Innovativeness	X X		X
Attainment of Unit Objectives (Aggregated over 12 Objectives)			X
More Specific Evaluations:			
Not Exceeding Budget			X
Proceeding According to Schedule			X
Expanding the Scope of Work			X
Stage o f Progress	X X		X
Tangible Outcomes:			
Position Papers	X	X	
Project Proposals	X	X	
Published Articles	X	X	
Patents	X	X	
Books	X	X	
Algorithms, Blueprints	X	X	
Reports within the Unit	X	X	
Reports Circulated Outside the Unit	X	X	
Experimental Prototypes of Devices	X	X	
Experimental Materials	X	X	
Prototype Computer Programs	X	X	

Table 3

Agreement between Evaluators on the Relative Importance of Team Objectives

Q.12. Please indicate the relative importance of each of the following R & D objectives to the work of this research unit. (l=The single most important objective; 2=An objective of major importance; 3=An objective of less importance 4= Not an objective for this unit.)

Objective	Total Mentions by Either as 1, 2 or 3	% Agreement (Difference <=1 Category)	Total Mentions as 1: "Most Important"	% Agreeing Objective is Most Important
Obtaining General Knowledge in a Product area	158	69%	14	**0%**
Developing a New Product	151	75%	97	49%
Providing New Features for an Existing Product	119	63%	24	**16%**
Improving Available Features of an Existing Product	121	**60%**	**22**	**0%**
Improving the Quality of an Existing Product	125	65%	17	**6%**
Reducing the cost of Producing an Exisitng Product	105	65%	**28**	**21%**
Reducing the Price of an Existing Product	76	63%	7	**0%**
Developing a New Process	142	**66%**	48	25%
Improving an Existing Process	120	**62%**	**20**	**0%**
Satisfying Requirements of Gov't regulation	95	**81%**		**0%**
Expanding an Existing Scientific/Technical Knowledge Base	174	**80%**	44	27%
Bringing a New Scientific/Technical Knowledge Base into the Firm	166	**80%**	52	15%

Figure 5 presents additional information on Evaluator agreement. In this graph we examine Evaluator agreement on three parts of UEQ.9:

> Which of the following statements accurately describe the performance of this unit to date? CHECK ALL THAT APPLY.
>
> a) The unit has not exceeded its original budget.
> b) The work of the unit has proceeded according to schedule.
> c) The unit has expanded the scope of its work (i.e., taken on new objectives.)
> d) The unit has changed objectives since it began the current project.

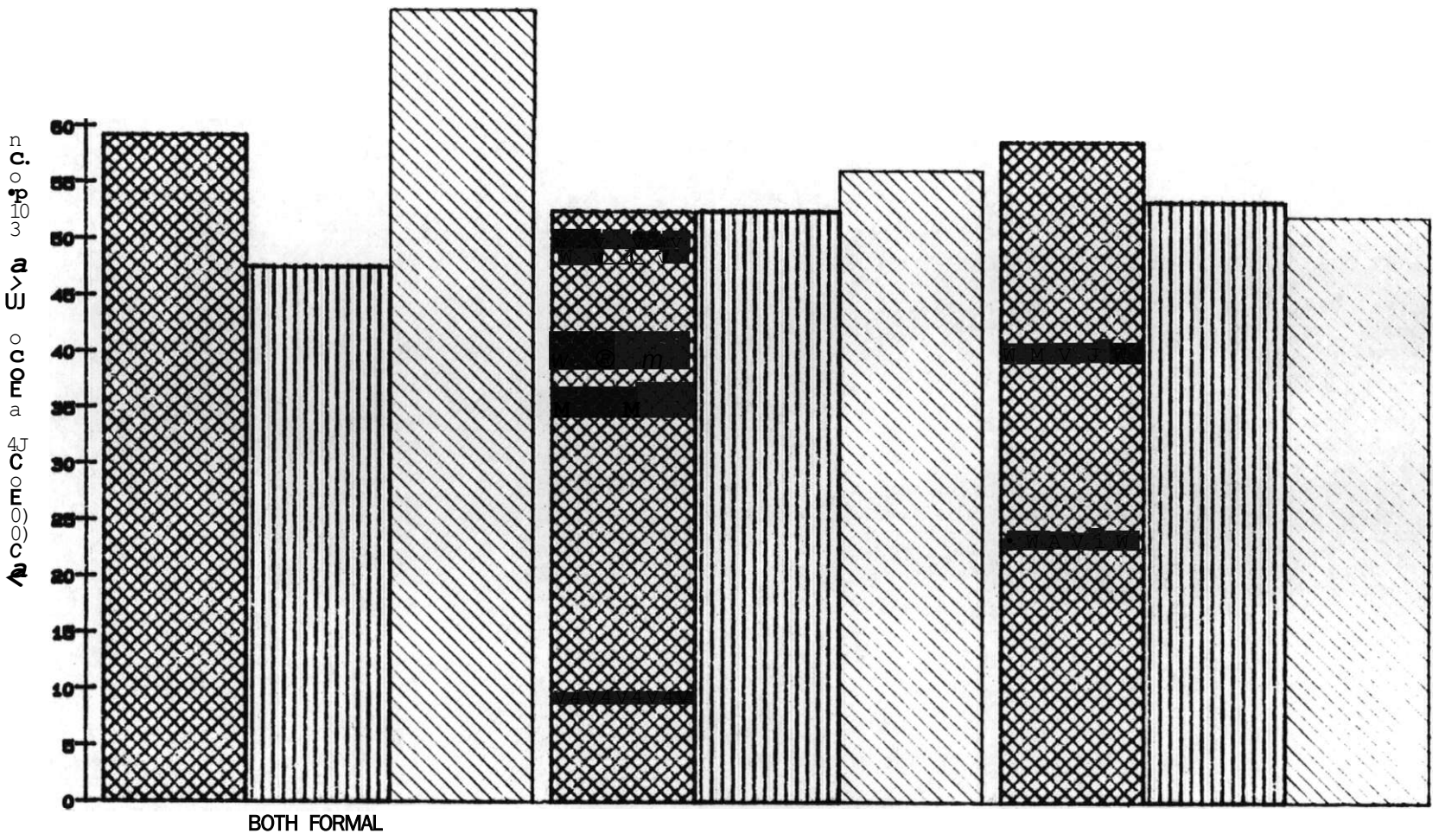
There were not enough choices of "d" for analysis; hence Figure 5 deals only with parts a,b and c. In this analysis, we have classified cases according to Evaluator responses to UEQ.2: Do you formally evaluate (i.e., in writing) the performance of this unit? We assumed that Evaluators who formally evaluated a team's performance would have more information than those who did not; we expected greater agreement where both Evaluators answered "yes" to UEQ.2. Teams were classified as: 1) Both Evaluators formally evaluated the team, or 2) One formally evaluated the team, one did not, or 3) Neither formally evaluated the team.

Figure 5 shows that the level of agreement is low and variable, ranging from 47% to 70%. None of these differences are statistically significant since the two extreme percentages—"both are formal evaluators" for 9b. Schedule and 9c. Scope of work—are based on only 27 teams. The safest conclusion, especially since the highest level of agreement and the lowest occur where both are formal evaluators, is that whether or not the Evaluators formally evaluate performance does not consistently affect the degree of agreement between Evaluators.

We are somewhat surprised by the results shown in Figure 5. We expected that since the questions were relatively specific, agreement among Evaluators would be high, and, for the reason mentioned above, would be highest where both Evaluators formally evaluated the team. Clearly, neither expectation is supported. It turns out that the less specific, more global, overall ratings of productivity and innovativeness produce greater agreement (using the criterion of 0 or 1 category difference as defining agreement) between Evaluators. This is shown in the first row of Table 4. The table also indicates that there is high agreement between Evaluators and Leaders and between Evaluators and Team Members for both Productivity and Innovativeness ratings. Team ratings are based on the median response of team members rounded to the nearest integer. The table also shows a similar level of agreement between Team Leaders and Team Members. Thus, the data indicate that global perceptions of productivity and innovativeness are shared across the different perspectives of the Evaluators, Leaders and Members.

Another approach to assessing team performance involves examining tangible products produced by the team. ULQ.10 inquires about the number of each of eleven types of products (from position papers to prototype computer programs). No measure of number of products calculated from this question correlated with any of our other performance measures for the

FIGURE 5: AGREEMENT AMONG EVALUATORS ON SPECIFIC TEAM PERFORMANCES



budget

schedule

scope of work

Table 4

Agreement on Productivity and Innovativeness Ratings

Agreement Between:	Productivity Ratings	Innovativeness Ratings
Two Evaluators	79%	78%
Evaluators and Team Members	88%	84%
Evaluators and Team Leaders	84%	78%
Team Leaders and Team Members	87%	87%

sample as a whole. Only for teams engaged in development do we find statistically significant correlations between number of products and, for example, evaluator ratings of productivity; while statistically significant, these correlations are still small.

On the other hand, if we construct an index based on the unit's performance with respect to the twelve objectives presented in Table 2, we obtain a correlation of .64 with Evaluator Ratings of Productivity. UEQ.12A is the basis of this measure and responses are aggregated over those items which the evaluator checked as "single most important" or "of major importance" in answer to UEQ.12. Scores for the two evaluators are then averaged to arrive at a performance measure for the unit. This measure will also be used in some of the analyses in Section 5.

We can briefly summarize our findings about different perspectives on team performance. We find considerable agreement among Evaluators, Leaders and Members as well as consistency across questions for those questions that ask for global judgments from the respondent. More specific, concrete questions yield low agreement or low consistency across questions.

4. Some Effects of Heterogeniety in Team Composition.

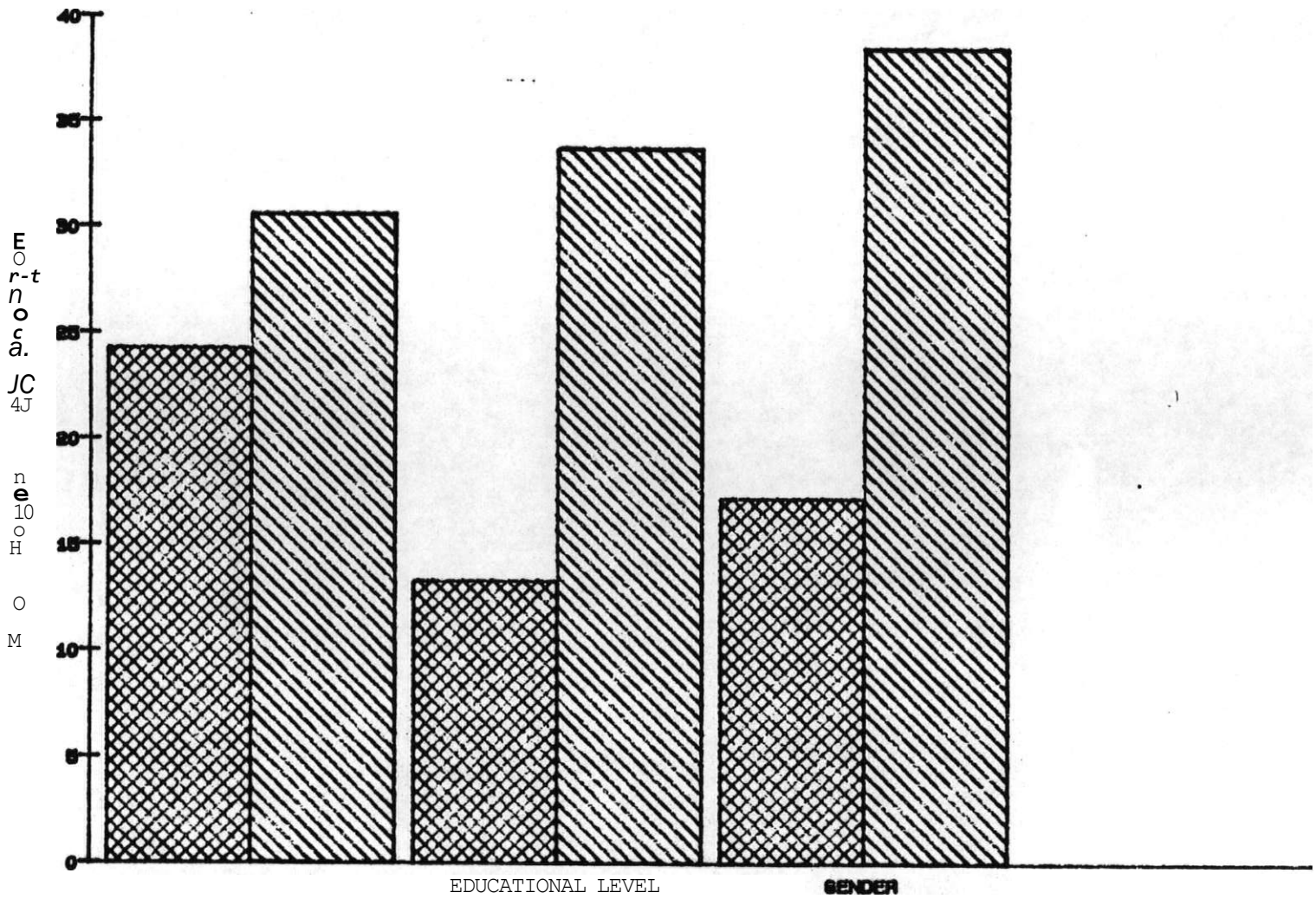
One of the basic ideas underlying this research emphasizes the importance of status heterogeniety in work team performance. Beliefs about competence, for example, are associated with different values of status characteristics like age, race, gender, educational level and even field of technical specialization. For example, Ph.D.s are expected to be competent at a wide variety of tasks. Whether or not these beliefs have any basis in statistical fact, they are often inappropriately and subconsciously used to form expectations about individual performances—not all Ph.D.s are smart. Status stereotypying also interferes with people getting sufficient information about one another to make sound judgments of each other's competence. Women in professional groups often complain that no one initially expects them to make an equal contribution. Close interaction over the long run can break through these stereotypes and produce accurate information. In the short run, however, where there is status heterogeniety that is not based on task expertise or formal responsibility, there is a status problem for the team to solve.

Despite the fact that all the units in the study have been in operation for at least three months and many have been in operation for several years, we still expected to find effects of status heterogeneity. We have examined three status composition factors—age, educational level and gender—and have compared relatively homogeneous with relatively heterogeneous teams with respect to six effects. Figures 6 through 11 present our results. Each figure presents the relationships of the three status factors to one effect measure.

To avoid overemphasizing a single individual's response, we decided that there was a team problem if 20% or more of the team members checked Q.35. For Q.57, our criterion was that 20% or more of the team members said the problem had a moderately negative or strongly negative impact on their work.

In Figure 6—responses to UMQ.35e "Internal problems in the unit threaten the achievement of the unit's objectives"—a higher proportion of status heterogeneous teams compared to status homogeneous teams report

FIGURE 6: STATUS HETEROGENEITY AND "INTERNAL PROBLEMS

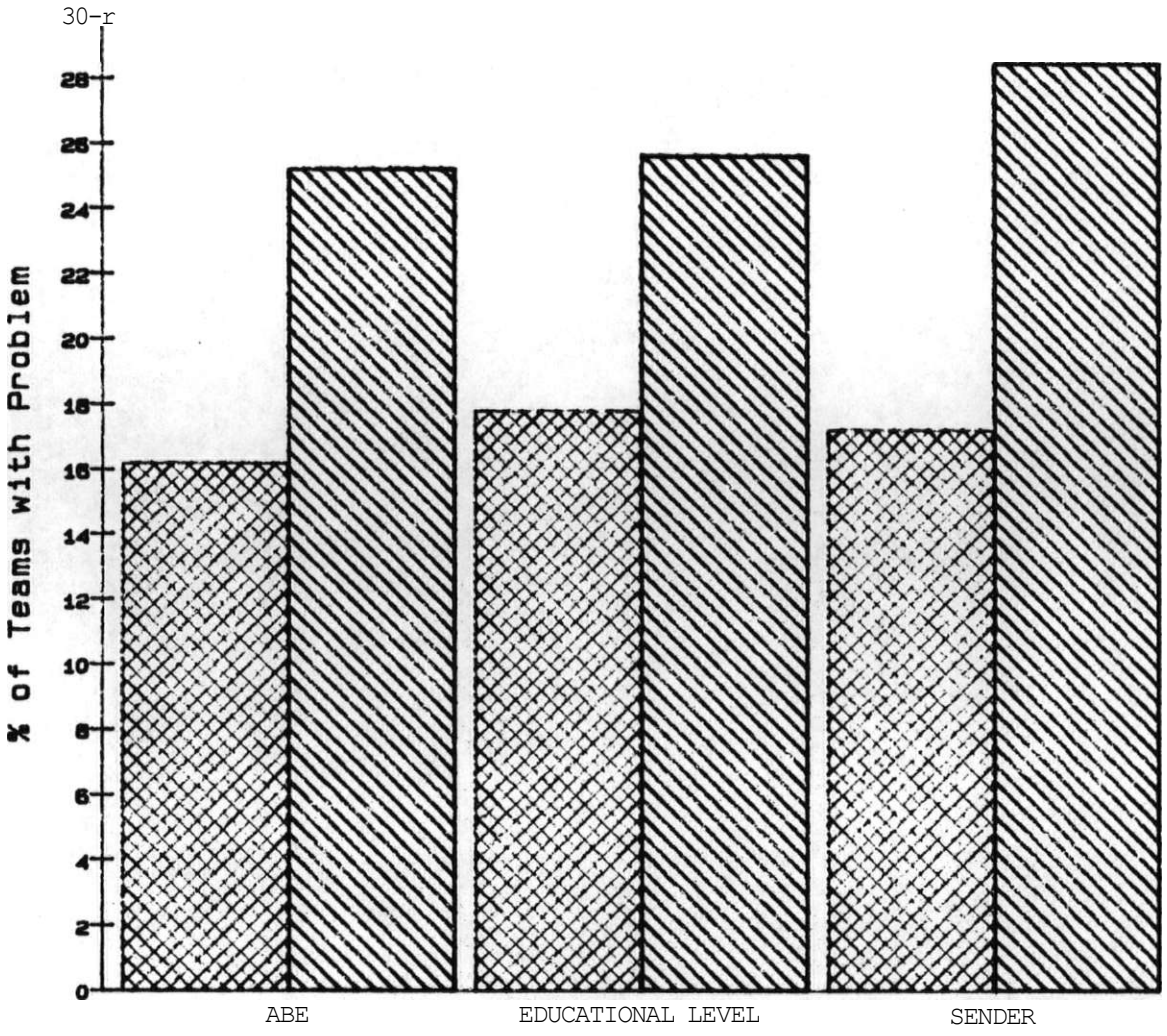


Status Characteristics

mm homogeneous

heterogeneous

FIGURE 7: STATUS HETEROGENEITY AND COMPLAINTS ABOUT FAIRNESS ANO RESPECT



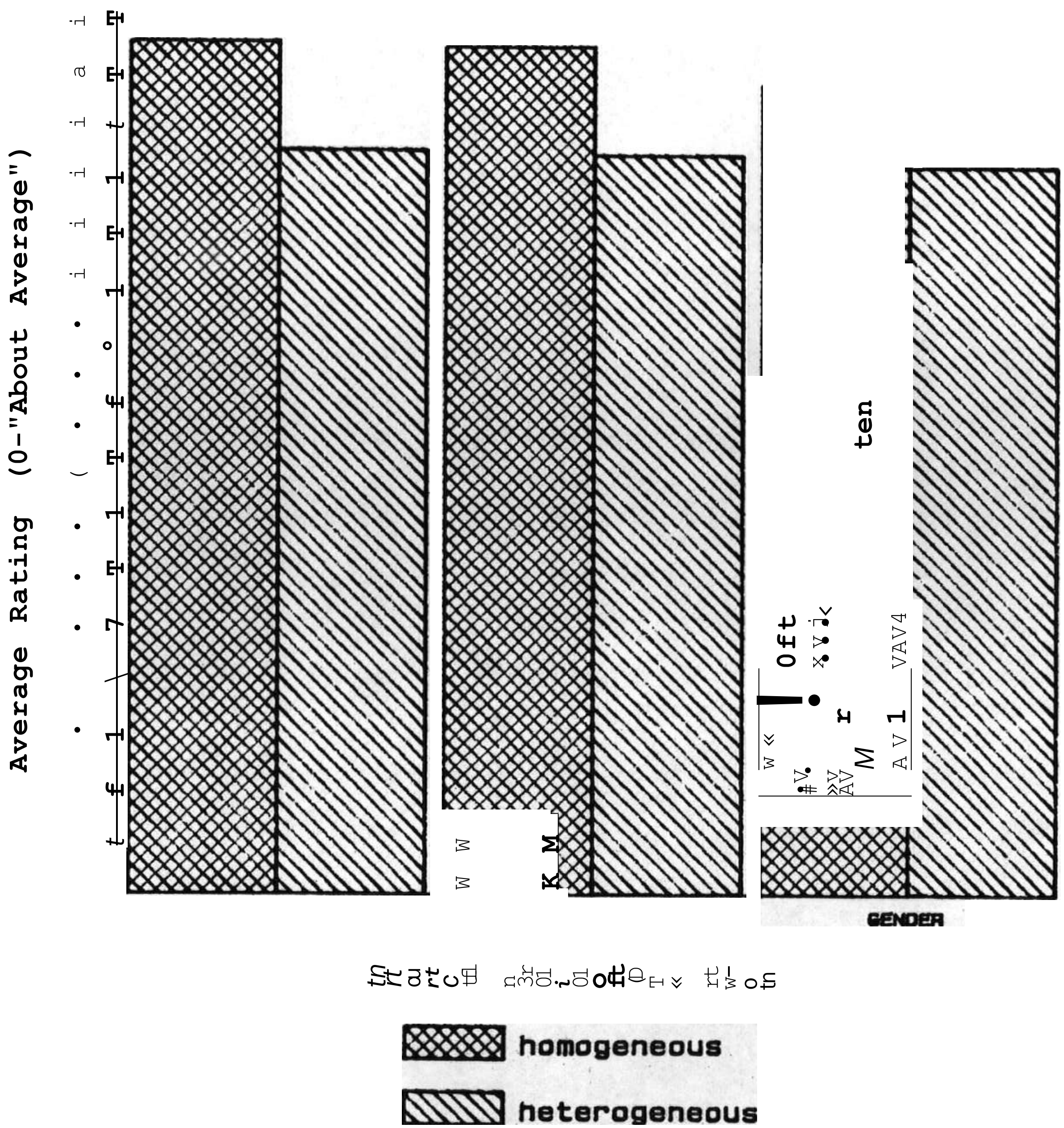
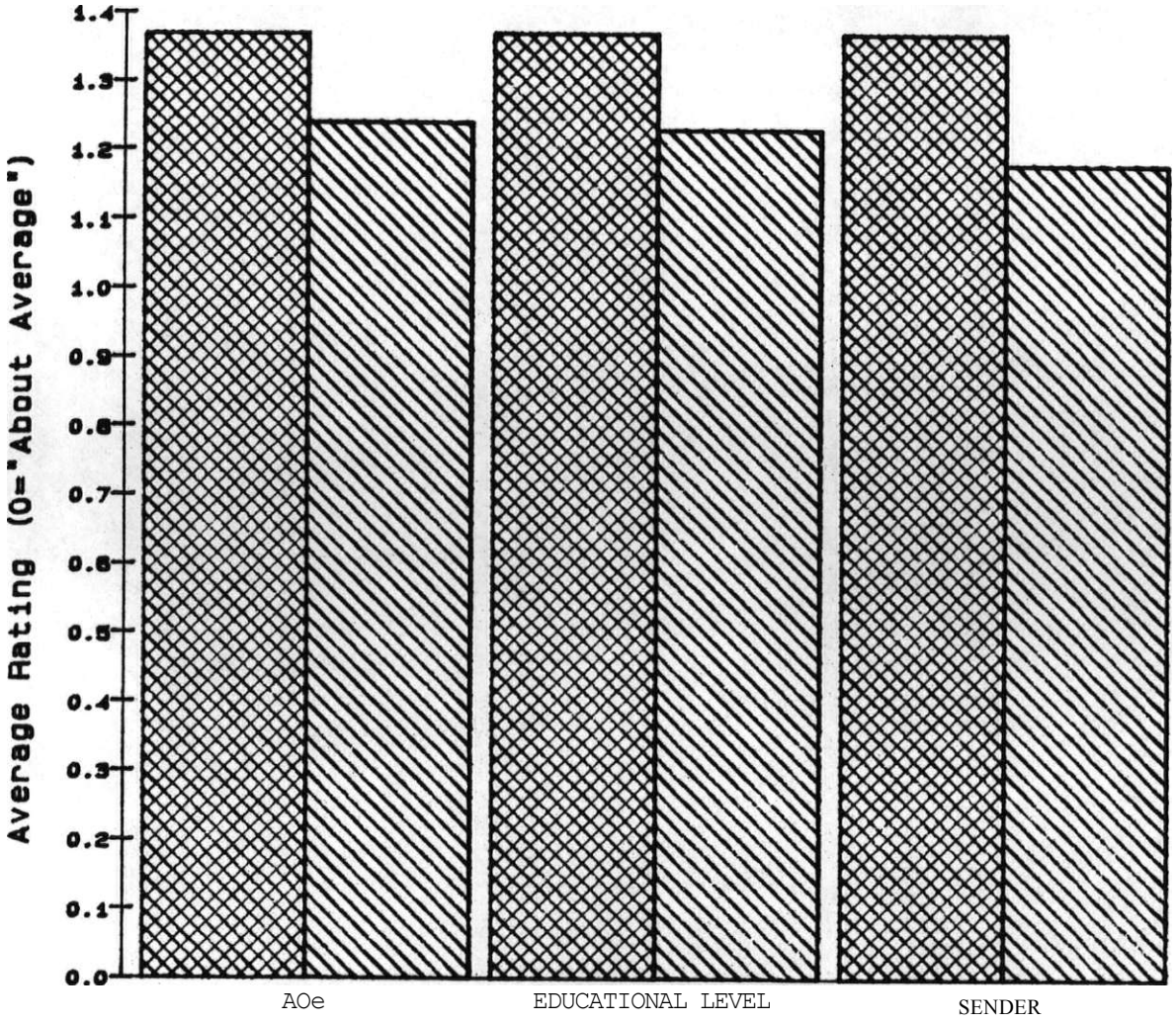

Average Rating (0-"About Average")
GENDER
homogeneous
heterogeneous

FIGURE 9: STATUS HETEROGENEITY ANO MEMBER RATINGS OF INNOVATIVENESS

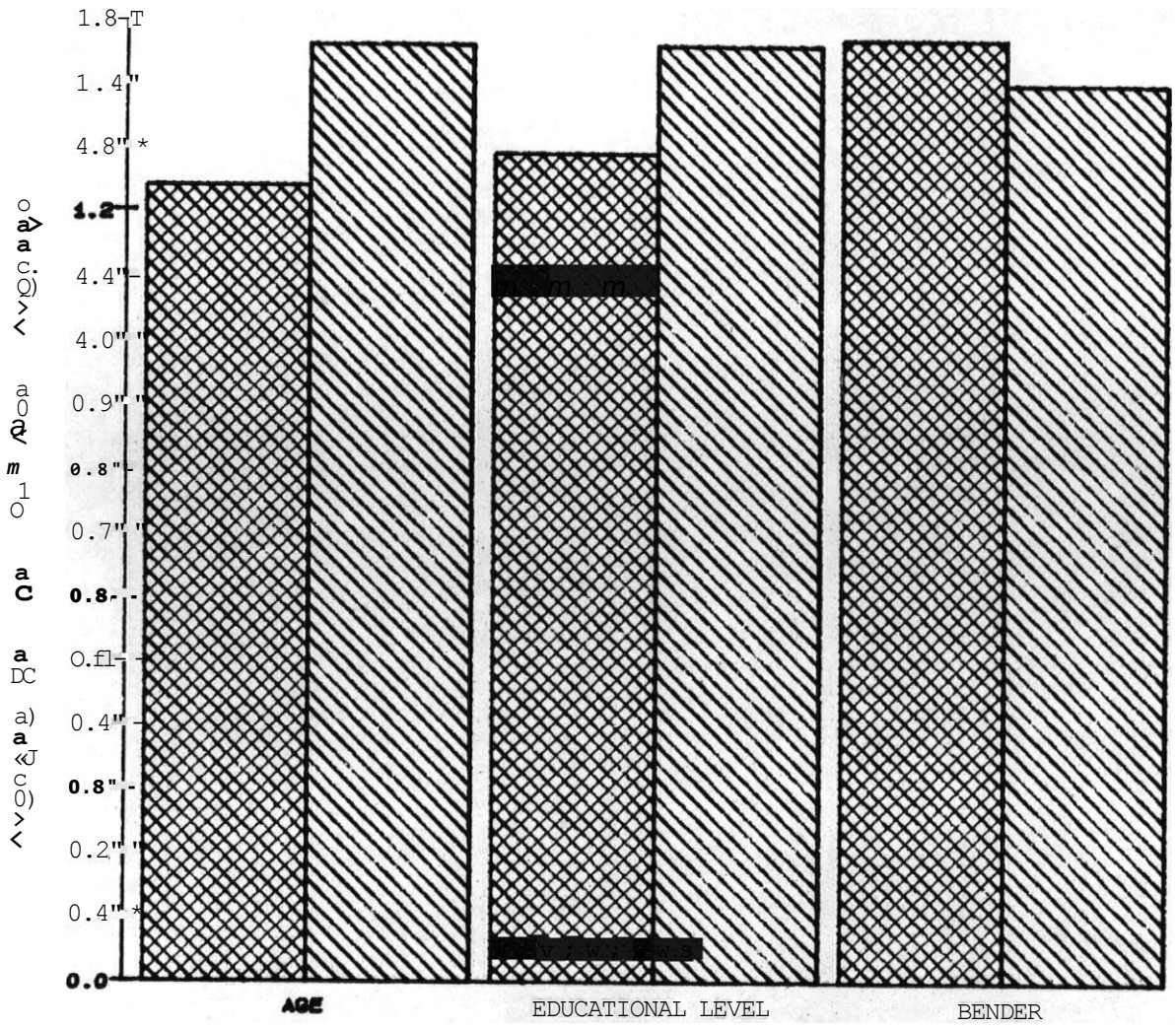


Status Characteristics

m m homogeneous

heterogeneous

FIGURE 10: STATUS HETEROGENEITY ANO EVALUATOR RATINGS OF PRODUCTIVITY

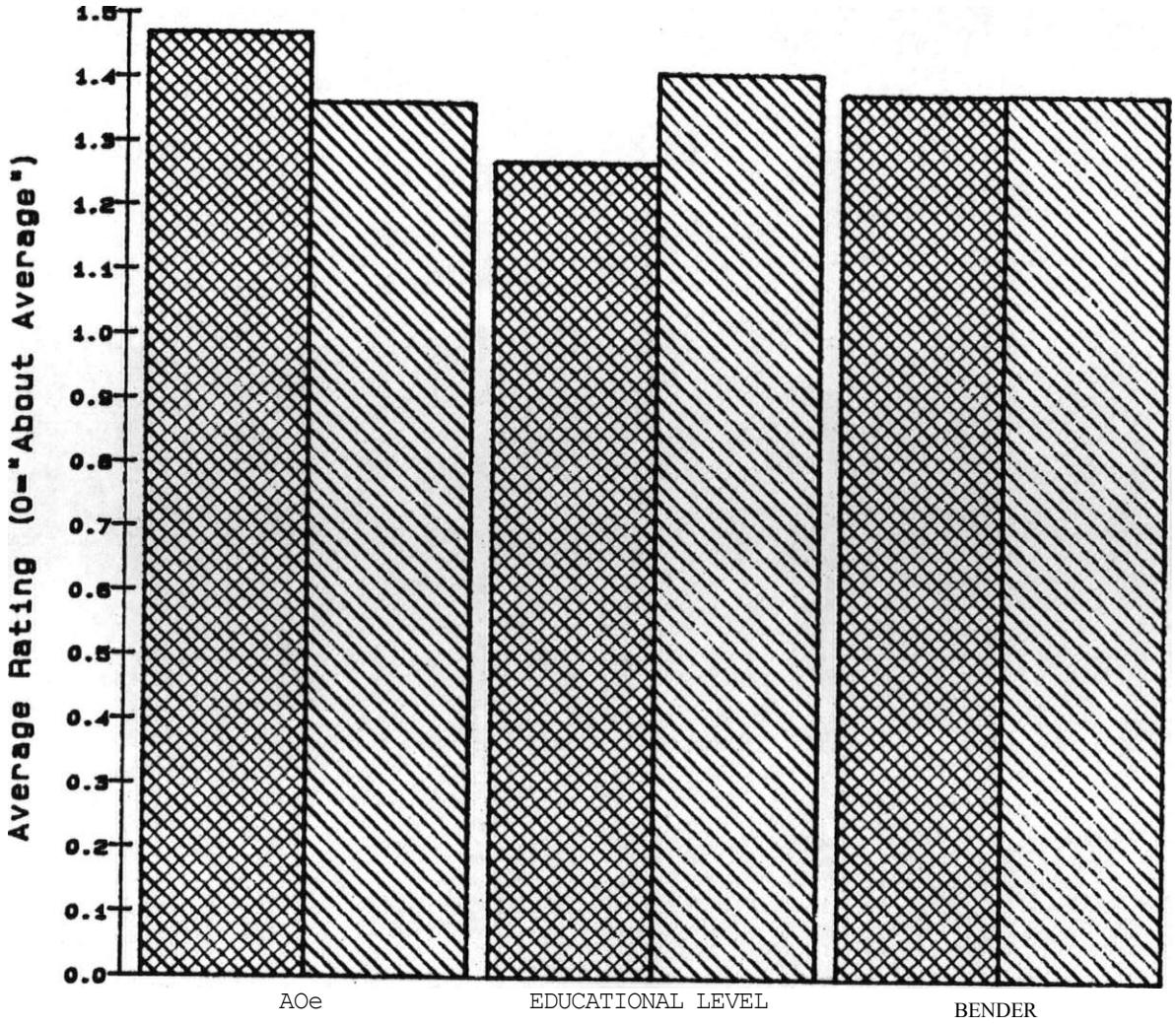


Status Characteristics

mm homogeneous

heterogeneous

FIGURE 11: STATUS HETEROGENEITY ANO EVALUATOR RATINGS OF INNOVATIVENESS



Status Characteristics

homogeneous

M ! heterogeneous

that internal problems threaten the team. For Age, the percentages are 30.6% of heterogeneous and 24.3% of homogeneous; for Education Level, 33.7% compared to 13.3%; and for Gender, 38.4% of the male and female teams compared to 17.2%.

Figure 7—UMQ.57 "Failure of some other members of the unit to treat me with fairness and respect"—shows a similar picture although the differences are smaller. The percentages are—Age: 25.2% and 16.2%; Educational Level:25.6% and 17.8%; Gender 28.4% and 17.2%.

In Figures 8 and 9, we show the average rating by Team Members of Productivity and Innovativeness (UMQ.31 and UMQ.32). Since all but six teams were rated average or above, 0 on the vertical axis represents average on the rating scale. Both graphs show that heterogeneous teams receive lower Team Member ratings in Productivity and Innovativeness. Although the differences are small, the direction is consistent: In six out of six comparisons, the heterogeneous mean is lower than the homogeneous.

For these four graphs, the results are clear-cut. In twelve out of twelve comparisons, heterogeneous teams either have more problems or have lower ratings than homogeneous teams.

A very different picture emerges when we examine Evaluator ratings of Productivity and Innovativeness in Figures 10 and 11. These two graphs do not show a consistent pattern. In three comparisons, the teams with heterogeneous status composition have higher mean ratings and in two comparisons have lower mean ratings than the teams with homogeneous composition; none of the differences shown in these graphs is large enough to be statistically significant. Thus we conclude that status composition of the team does not affect external evaluations of productivity or innovativeness.

The findings that team reports of problems and team ratings of productivity are affected by status heterogeneity while external ratings are not has a straightforward interpretation. The external evaluators are not part of the internal status system of the team and are much less affected by the status processes that go on within the team. Internal evaluations are based not only on the work of the team but also on the attitudes and feelings about, for example, the interpersonal relationships among team members. To the extent that status processes interfere with these relationships, they will affect the internal evaluations without having any impact on external evaluations.

Another possibilitity is that the team responses to status heterogeniety are early warning signals of difficulties about which the external evaluators are not yet aware.

One should not conclude, however, that the way to avoid internal problems is to compose teams that are homogeneous with respect to these status characteristics. In the first place, such homogeneous composition is very rarely possible; secondly, homogeneous teams can have other varieties of status problems. And finally, there are other ways to deal with the problems that status processes generate if team members and managers are aware of these problems.

5. Consequences of Different Types of Interaction.

We have examined both the amount of work-related interaction and the nature of the interaction relationships among team members. The

well-developed body of research on Social Networks has provided us with conceptual and analytic tools; these tools combined with the unique features of our dataset allow us to pursue these relationships in a depth that heretofore was not possible.

If one team member reports speaking to another, we say that a "Link" exists from the former to the latter. A Link is directional; it is a one-way connection from one team member to another. We can consider Links as present or absent or we can assign weights to them, for example, according to their frequency of usage. In our analysis, we examine the relationships between various properties of the total set of links for a team and, for example, the productivity ratings the team received. Properties such as the average weight of a link in a team or the proportion of links that are reciprocated—Member 1 claims a link to Member 2 and Member 2 also claims a link to Member 1—are straightforward, but some of the other network properties we will introduce are more complex. Before turning to these more complex ideas, let us illustrate the use of "average weight" and "reciprocation" in an analysis of overall work-related interaction in the team.

UMQ.12 asks: "How often do you talk with other members of the unit concerning matters related to the unit's work?" Next to the roster number of each other team member, the respondent is asked to check one of five categories: Daily; 1-3 times a week; 1-3 times a month; Less than once a month; Never. The categories are the weights assigned to each claimed link. The weights ranged from 5 for Daily to 1 for Never (for technical reasons, we used 1 rather than 0 for Never). If the weight of a link between Member 1 and Member 2 differed by no more than 1 from the weight of a link between Member 2 and Member 1, we considered that each link was reciprocated. For example if Member 1 reported that he spoke to Member 2 Daily and Member 2 said he spoke to Member 1 one to three times a week, both links were considered to be reciprocated. Over all teams, 87% of the 18,612 links where both members turned in a questionnaire were reciprocated.

Although we did not expect overall interaction to be related to productivity, we investigated the relationship between the average weight of a link based on UMQ.12 and ratings of productivity by Evaluators, Leaders and Team Members. The average weight was computed for each team to determine the average frequency of pairwise interaction in the team; this value was correlated with the three productivity ratings. The results are shown in the first column of Table 5. Contrary to our expectation, average frequency of overall work-related interaction is significantly related to Evaluator, Leader and Team Member Ratings even without controlling for team size. Not surprisingly, the average weight of a link is negatively correlated with team size. (See note to Table 5.) In larger teams, the average frequency of pairwise interaction is lower than in smaller teams. This follows from the fact that as size increases, the number of potential links over which a person can spread a fixed number of hours increases at nearly the square of the size.

Since teams vary in size from 3 to 34, it is important to look at these relationships unconfounded by variations in team size. To examine the relations net of size effects, we computed partial correlations

Table 5

Correlations and Partial Correlations

between

Average Pairwise Interaction and Productivity Ratings

Productivity Rating:	Correlations	Partial Correlations (Partialling out Size)
Evaluator	.12	.18
Team Leader	.14	.21
Team Members	.31	.27

Note: Correlation between Average Pairwise Interaction and Team Size = - .55.

All correlations with magnitudes greater than .12 are statistically significant.

(Based on 223 teams)

between average frequency of pairwise interaction and each of the productivity ratings, partialling out team size. These are shown in the second column of Table 5; the partial correlations between average pairwise interaction and both Evaluator and Leader ratings of productivity are larger than the correlations without controlling for size whereas the partial correlation with Member ratings is smaller, although these differences are not statistically significant.

One important property is whether a link is "acknowledged" or not. Acknowledgement seems to be similar to reciprocation so one must be careful not to confuse the two properties. If Member 1 reports that he consults Member 2 for Information and Member 2 says "Yes, Member 1 consults me for information," then Member l's link is Acknowledged. Member 2 may also consult Member 1 for information or he may not; if he does then Member l's link is Reciprocated; otherwise it is not, even though it is still an acknowledged link.

To measure whether a link is acknowledged or not requires asking two questions, one to determine the initiation of a link and the second to ascertain the receiver of the link. For a link to be acknowledged, initiator and receiver must agree that the link is present. The Member Questionnaire contains four such pairs of questions dealing with four different bases of links or different types of interaction: 17a and b, seeking technical assistance; 17c and d, seeking information; 17e and f, seeking evaluation of ideas; and 17g and h, consultation for planning future activities.

We are at an early stage in the analyses of these links so we can only present results with respect to links concerning exchange of technical assistance and those seeking exchange of information. Before turning to our results, we must introduce additional properties of these links. The links reported in these questions are either present or absent, that is, the only weights are 0 and 1. (It would have made the questionnaire inordinately burdensome if we had tried to obtain weight information for each of these relationships.) On each criterion, eg., exchanging technical assistance, each team represents a set of links or a "network"; we can examine several properties of these networks and relate these properties to other aspects of team performance such as ratings of productivity. Consider the following network properties:

a) Density: The total number of links compared to the maximum number of links possible in the team. In other words, the degree to which the network approaches saturation, i.e. every member linked to every other member.

b) In-degree Variance: The degree to which team members differ with respect to the number of links in which they are receivers. A high value of this property means that only a few people are receivers in most of the links.

c) Out-degree Variance: The degree to which team members differ with respect to the number of links in which they are initiators. This property is 0 when all members initiate the same number of links.

d) Reciprocation: The average number of links per person that were reciprocated.

The properties discussed so far are based on "direct", one-step links in the network, eg., Member 1 approaches Member 2 for information. But there are also "indirect" links where Member 1 has no direct link to Member 3 but obtains information from Member 3 because Member 2 is linked to Member 3 and he is linked to Member 2. In this example, we would say that Member 1 is "linked in 2 steps" to Member 3. It is possible to "expand" a network by including links of 2, 3 or even more steps. We shall only consider the Expanded Network that results from allowing indirect links of 2 steps. This gives rise to additional properties, and we will consider one of these:

e) Density gain: The difference between the Density of the Expanded Network and the Density of the Original Network. Allowing indirect links moves the system closer to saturation, but does it make any difference in other aspects of team behavior?

Table 6 presents results for the network based on the questions: "I frequently approach these people for technical assistance or guidance." and "These people frequently approach me for technical assistance or guidance," and also for the "Information Exchange Network" based on UMQ17c and UMQ17d. In Table 6 are the partial correlations (partialling out team size) between each of the five network properties and Evaluator, Leader and Member ratings of productivity. In ~~this~~ analysis, only acknowledged links were counted; this biases ~~the~~ data underestimating the number of links and perhaps their effects and gives greater credence to the person who denies the link than to the person who claims it. Nevertheless, it seemed preferable to undrestimate rather than overestimate these properties. All correlations for the Technical Assistance Network are statistically significant except for those involving Out-degree variance. What this table shows then is that ratings of productivity increase as: 1) The average number of links involving requests for technical assistance increases; 2) the number of these links that are reciprocrated increases; 3) the number of links that are added through indirect connections increases; and 4) the number of people who are receivers of requests for technical assistance decreases .

In short, when many people receive technical assistance from a few technical experts and/or technical assistance links are reciprocal, there are higher productivity ratings from Evaluators, Leaders and Team Members.

For the Information Exchange Network, the results are more complex. Only Density of the Network is significantly correlated with all three productivity ratings. On the other hand, all properties are significantly related to Leader ratings and all but Out-degree variance are significantly related to Member ratings.

The pattern of findings shown in Table 6, particularly the differences between Technical Assistance and Information Exchange with respect to Evaluator ratings, supports our view that we must analyze different types

Table 6

Partial Correlations between Network Properties

and

Productivity Ratings

(Partialling out size)

Property	Evaluator Rating	Leader Rating	Members Rating
TECHNICAL ASSISTANCE NETWORK			
Density	**.21**	**.20**	.31
In-degree Variance	**.21**	**.18**	**.21**
Out-degree Variance	**.08**	.09	**.06**
Reciprocation	.17	.23	.17
Density Gain	.14	.17	.19
INFORMATION EXCHANGE NETWORKS			
Density	.13	.17	.25
In-degree Variance	.03	**.12**	.15
Out-degree Variance	.05	.17	.07
Reciprocation	.05	**.20**	**.18**
Density Gain	.08	.13	.17

(Note: All correlations greater than .12 are statistically significant.)

Based on Acknowledged links in 190 teams.

of interaction. The nature of the task and the objectives of the team will determine the importance of technical assistance links or information

exchange links or links based on using others as a "sounding board" for ideas.

Still, the lack of relationship between properties of information exchange networks and Evaluator productivity ratings is something of a puzzle. For example, In-degree variance can be interpreted as a measure of the degree to which there are information exhange specialists on a team. The fact that this property is not related to Evaluator ratings uggests that a specialized role in information exchange may not be as important as previous studies have indicated. Of course, it is too early to say what implications this result has for previous research on the importance of a "gate-keeper" or a "boundary-spanner". For one reason, our analyses focus on internal interaction whereas previous studies examined the interaction between the team and its environment. Nevertheless, our preliminary analyses suggest that examination of other factors in relation to the network properties may shed additional light on issues such as the importance of a "gate-keeper."

6. Team Structure, Type of Work and their Effects.

In a previous study of academic research teams, we developed a general formulation of team structure which distinguished four fundamental types of team social structure. These were:

Type A: "Leader Centered." In this type of structure, planning, decision-making and overseeing of team activities are almost exclusively done by the team leader. Such structures are essentially "one-man" shows. For this structure, a useful metaphor is the research team composed of the Senior Professor and his students.

Type B: "Collegial." Planning, decision-making and supervision are shared in this type of structure. Leaders are "first among equals" with respect to other professionals. While not all members share in the "collegiality", a substantial proportion of the team participates in directing team activities. The rarely-realized academic ideal of collegial interaction is an appropriate image for this type.

Type C: "Autonomous." Members constitute a team in only the most minimal sense in this type of structure. Researchers work independently on quite different tasks which are only integrated at the end of the project. Members in effect work on separate sub-projects under a common "umbrella". While individuals may consult with one another, their tasks do not demand such interaction. The "Holding company" is our metaphor for this type.

Type D: "Mixed." This type is a combination of Types A and B. It is leader-centered in that administrative responsibility is not shared, but it is collegial in intellectual matters. The leader assigns tasks, co-ordinates activities, supervises the work of the team and evaluates the performance of team members. But in all technical matters, the leader actively seeks input from other members and their ideas play an important role in shaping the direction of the team. The popular conception of a surgical team may provide an image for this type. The chief surgeon may consult with his colleagues about diagnosis and plans for the operation, but once the patient is on the table, the chief surgeon is clearly in charge.

To classify teams according to this typology, we asked a lengthy question which provided a paragraph description of each type and asked each respondent to choose the description that best "represents the working arrangement in your unit." See UMQ.16 in the Appendix. Following these descriptions we also asked:

UMQ.16A Any real unit differs from our ideal descriptions. How well does the paragraph you checked describe your unit? 1) It fits very closely; 2) It fits fairly closely; 3) It does not fit closely at all.

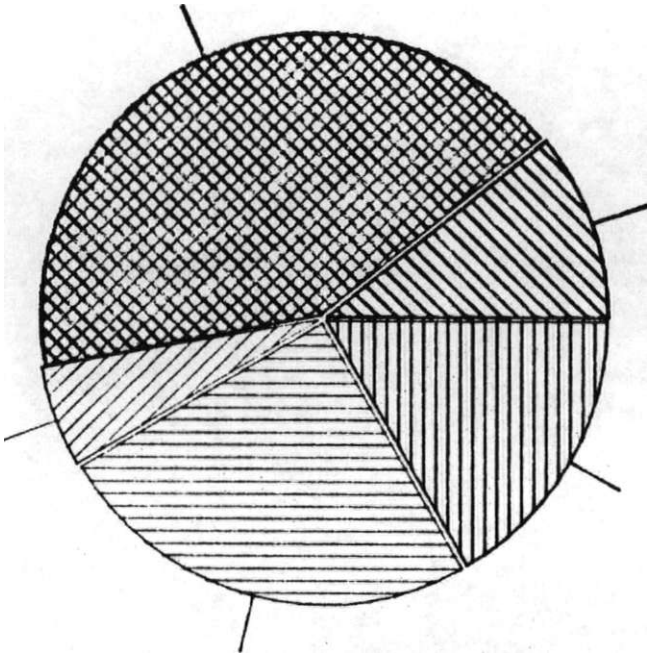
Despite the fact that there was considerable variability within teams in the paragraph selected, only a small percentage of respondents answered that the description did not fit closely at all. For the total sample, the percentages are: Very Closely 20%; Fairly Closely 73%; Not Closely at all 7%. Furthermore, the variability of choice of paragraph within teams is not necessarily error; there may be subgroups within a team and these subgroups may represent different types. Indeed, when we formed subgroups within teams according to which team members reported to a given other team member, we found that these subgroups had greater agreement among themselves than they did with members of other subgroups. For the first set of analyses, however, we decided to treat each team as a single unit ignoring the fact that it could be decomposed into sub-teams. Using the modal response of team members to UMQ.16, we obtained the distribution of team types shown in Figure 12: Type A (Leader Centered): 10.8%; Type B (Collegial): 42.1%; Type C (Autonomous): 5.8%; Type D (Mixed): 24.7% We were not able to classify 29 teams or 16.6% of the sample because there was not a single unique modal response. This was a particular problem for smaller teams where one or more members did not return a questionnaire; 17 of the 29 teams that were not classifiable were composed of eight or fewer members.

Figure 13 presents the relationship between team interaction and productivity for each team type. Level of interaction is measured by taking the average pairwise interaction among team members from Q.12 and dividing the entire sample into 2 groups where LOW = below the sample median and HIGH = above the sample median. Productivity in this chart is the Evaluator's rating and each bar represent the average of this rating for each subgroup. The values for Type C teams are based on too few cases for the difference to be statistically significant (5 in the low subsample and 8 in the high). The difference between the means for Type B Low and Type B High is statistically significant. From this chart, we conclude that only in Collegial teams is level of overall interaction related to Evaluator ratings of productivity. Since one of the key features of Collegial teams is greater requirements of, and opportunities for, member interaction, this result is consistent with our expectations. Moreover, we noted earlier that we were surprised that overall interaction was related to productivity; it appears now that most of that result (Table 5) is accounted for by the Collegial teams.

FIGURE 12: DISTRIBUTION OF TEAM TYPES

c

(94)



(24)

(13)

(37)

(55)

Leader-Centered

Collegial

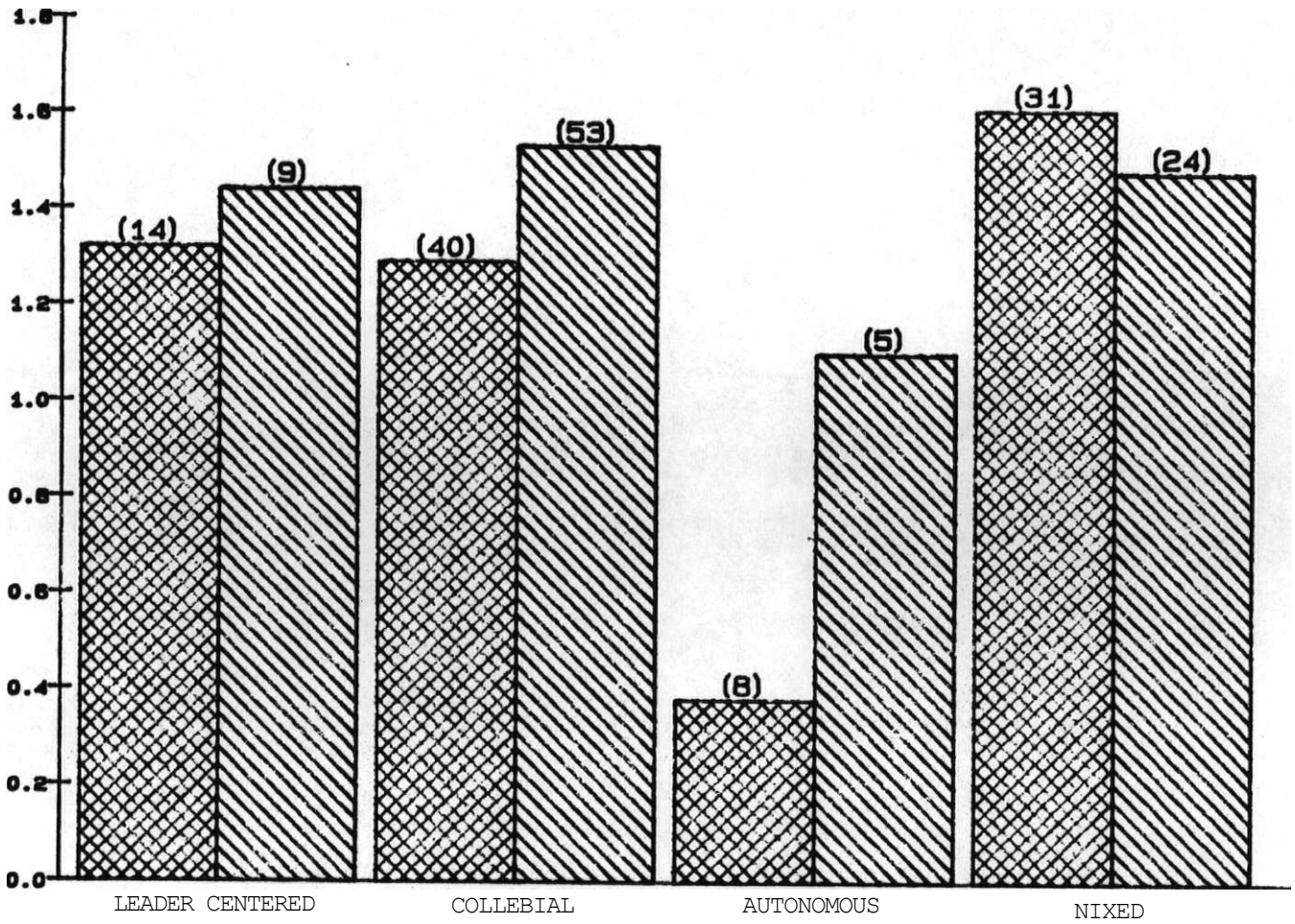
V/A/A **Autonomous**

Mixed

m **Unclassified**

limbers of teams in parentheses.

FIGURE 13: TEAM TYPE. INTERACTION AND EVALUATOR RATING OF PRODUCTIVITY



Team Type

low Interaction

high interaction

limbers of teams in parentheses.

Another feature of the Collegial type of team structure involves the performance of special leadership functions that are less likely to occur in other types of teams. One set of these functions we have termed the "Bridge" role. This role involves matching team members with research problems and team members with each other. It involves translating between the languages of different specialists, reconciling conflicting evaluational standards, compromising antagonistic approaches to problem-solving, formulating the needs of the project into the terms of different technical specialties, and, in general, enhancing the interaction among team members without imposing an authoritative view. While there are some overlaps with ideas like "gate-keeper" and "boundary-spanner," the bridge role emphasizes interpersonal relations much more than these other concepts.

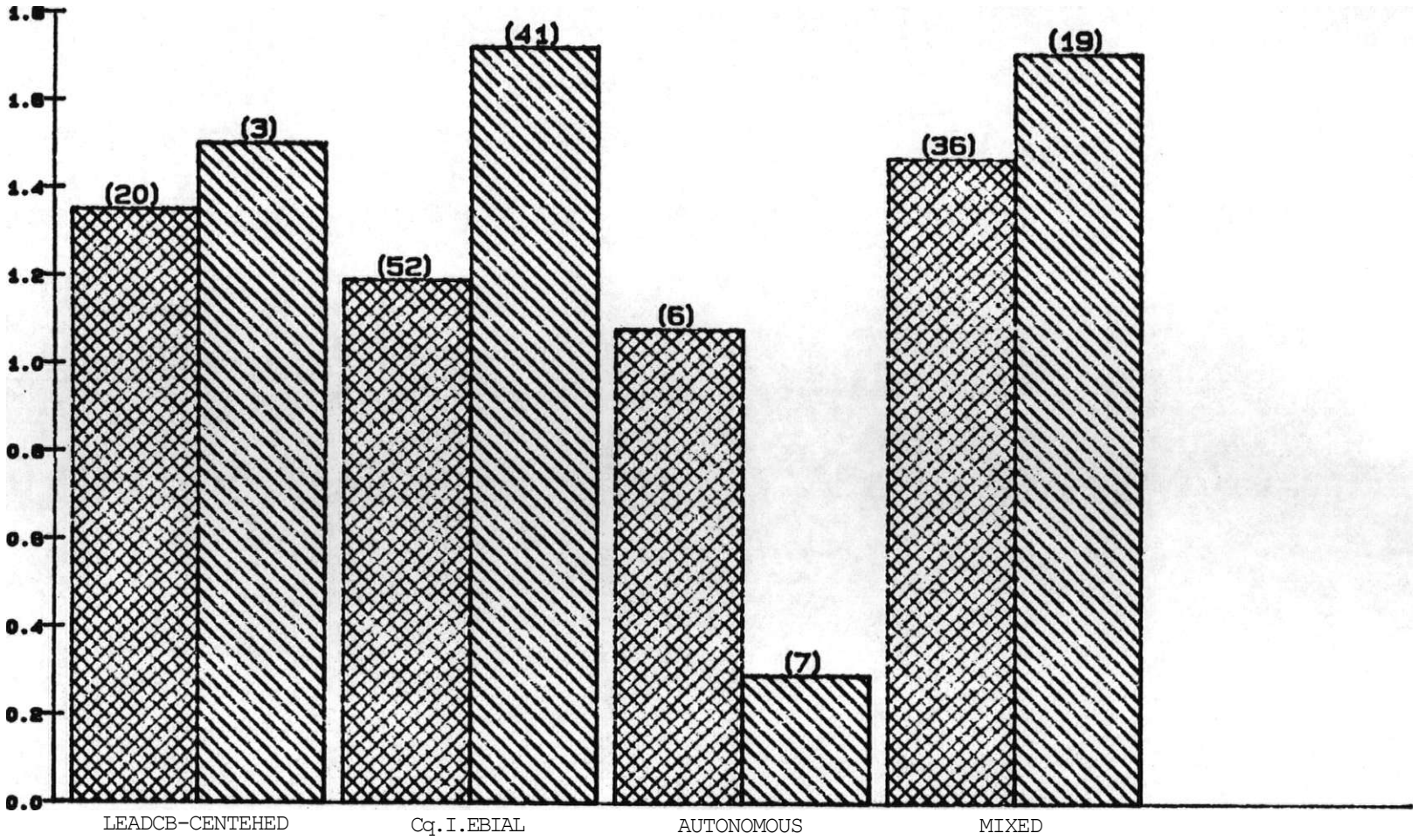
The bridge role does not involve idea generation although the person who plays the role may also be the intellectual leader of the team. Furthermore, administrative and managerial activities are not part of this role although the same scientist can play the bridge and administrative manager roles.

We used parts of UMQ.36 to ascertain whether or not various functions were performed on the team. For 15 functions including "Encourage other unit members to contribute new ideas" and "Recruit new members", each team member was asked to check the roster number of every member (including themselves) who engaged in the activity to a significant extent. Four of these 15 were used to determine the extent to which a bridge role was present on the team: UMQ.36b) Consult people outside the unit for new ideas; d) Encourage unit members to evaluate each other's ideas; e) Translate ideas from the language of one scientific specialty to another; 1) Serve as an interface between the unit and the organization. If there were team consensus that the function was present, then the team was assigned a "1" for that function. Teams where there was consensus that 3 or all 4 of these functions were performed were defined as teams with a clear Bridge Role whereas teams where there was only consensus that 2 or fewer of these functions were present were considered teams without a clear Bridge role.

From our previous work we expected that 1) Collegial teams would be most likely to have one or more persons (not necessarily the team leader) playing this Bridge Role and 2) The presence or absence of this role would make the most difference in Collegial teams—those with a clear Bridge Role would be more productive than those without. Figure 14 presents the relevant data. The vertical axis is the average Evaluator Rating measured from 0="about average productivity". The cross-hatched bars represent teams with, and the diagonally shaded bars represent teams without, a clear Bridge Role. The numbers in parenthesis are the number of teams in each subsample.

As we expected, Type B (Collegial) teams with a clear Bridge Role receive significantly higher Evaluator ratings than Type B teams without a clear Bridge Role. The presence of a Bridge Role does not make a difference for Type A (Leader Centered) or Type D (Mixed) Teams, although there are too few Type A teams with a clear Bridge Role to allow a confident inference. The fact that there are so few Leader Centered teams

FIGURE 14: BRIDGING FUNCTIONS AND PRODUCTIVITY BY TEAM TYPE



Team Type

0-2 bridging functions

3-4 bridging functions

limbers of teams in parentheses.

with a Bridge Role is also consistent with our expectations. Not consistent with our expectations, however, is the observation that about the same proportion of teams with a clear Bridge Role obtains in Type B, Type C and Type D teams. Forty-four percent of Collegial Teams, 54% of Autonomous Teams and 35% of Mixed teams have clear Bridge Roles. These differences are not statistically significant.

What is more surprising is the result that the presence of a Bridge Role has a negative effect in Autonomous (Type C) Teams. Despite the small number of teams in each subsample, the Evaluator Productivity Rating is significantly lower in Type C teams with a Bridge Role. Unfortunately, the small number of Autonomous teams precludes further investigation of other variables that may account for this result.

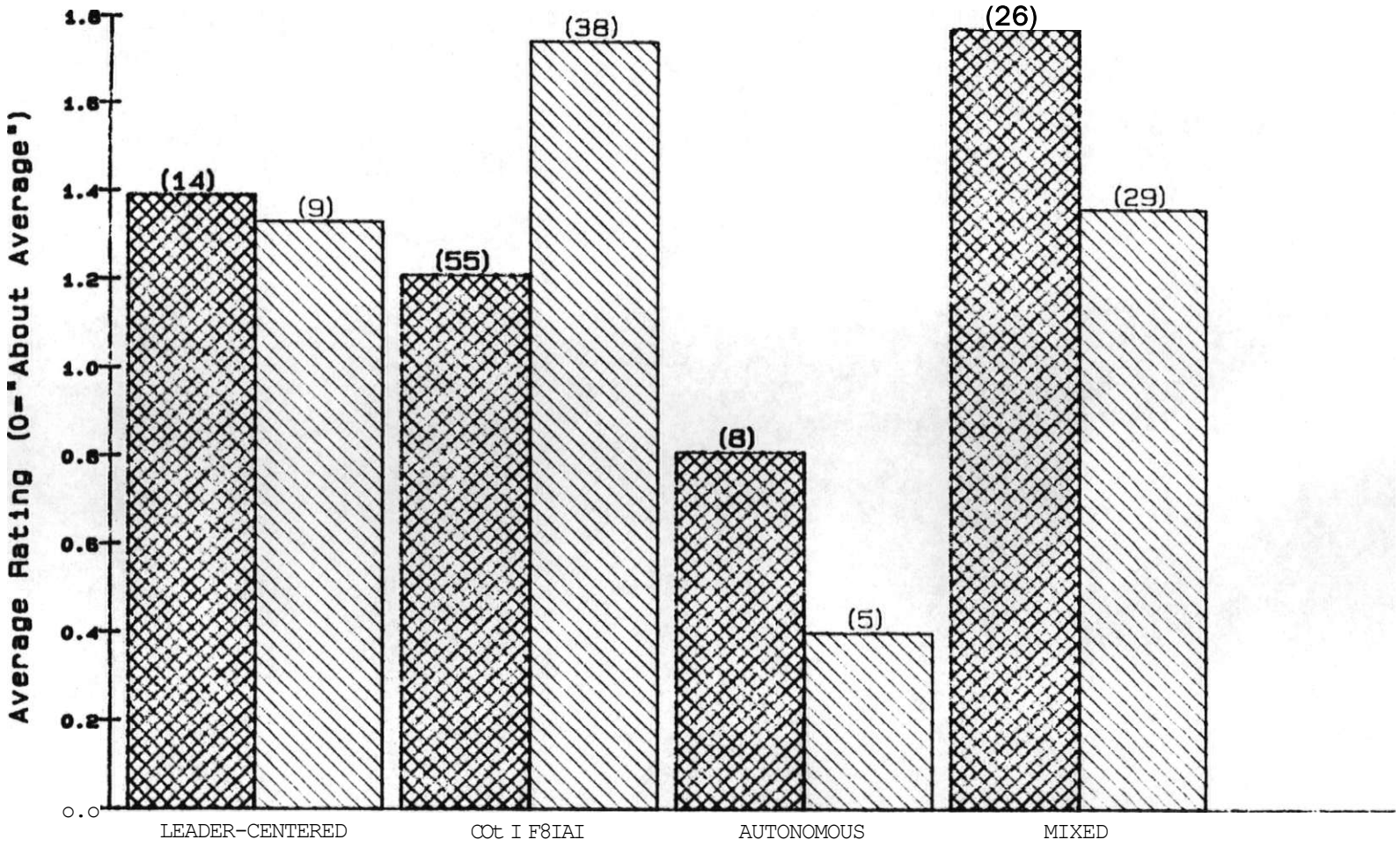
Another set of surprising findings occurs in connection with what we consider as a Manager Role. The functions this role performs include: supervising work and personnel, evaluating work and personnel, setting of work priorities, assigning work and coordinating work. Furthermore, this role requires that the functions be exercised almost exclusively by the team leadership. To classify teams according to the presence of a clear Manager Role, we used the same procedure as we used for the Bridge Role. We determined consensus on the following functions: UM36h: Supervise the work of other unit members; 36i: Evaluate the work of other unit members; 36j: Assign work to other unit members; and 36k: Make decisions about priorities in the utilization of resources. Again we defined consensus that 3 or 4 functions were performed as indicating the presence of a clear Manager Role. The relevant information is shown in Figure 15.

Since one person's exclusive exercise of these functions seems inconsistent with either Collegial or Autonomous structures, we expected that these types would have fewer teams with clear Manager Roles than the Leader Centered or Mixed teams. The results are equivocal: A higher percentage of Mixed teams, 52.7%, have clear Manager roles than the other three types which have almost equal proportions—Leader Centered, 39.1%; Collegial, 40.9%; Autonomous, 38.5%.

What Figure 15 shows that is clearly contrary to our expectations is that Collegial Teams with a clear Manager Role receive significantly higher Evaluator ratings of productivity than Collegial Teams without a clear Manager Role and that Mixed Teams with a clear Manager Role receive significantly lower productivity ratings than Mixed Teams without a clear Manager Role. We believed that one person exclusively performing these functions would put strains on collegiality in Type B teams and therefore would be counterproductive. In Type D teams, where administrative functions are leader-centered, the presence of a clear Manager Role should signify strong leadership and be positively related to team productivity. The data are clearly inconsistent with this formulation.

At this time we can only speculate about the meaning of these results. In Type B teams, the performance of these supervisory functions may be problematical because team organization is looser and more ambiguous. Team tasks, however, may require the performance of these functions. Hence it may be more important to team productivity that these supervisory functions be performed at all than that they be shared among colleagues. A similar argument applies to Type D teams. For these teams which are administratively Leader Centered, but intellectually Collegial,

FIGURE 15: MANAGERIAL FUNCTIONS AND EVALUATOR RATING OF PRODUCTIVITY BY TEAM TYPE



limbers of teams in parentheses.

the Manager Role should not be ambiguous. Too vigorous performance of the supervisory functions, however, may conflict with collegiality in the intellectual realm generating strains in the team which negatively impact team performance. Our interpretation suggests that team member consensus on the performance of these supervisory functions may have different meanings for Type B and Type D teams. Evaluation of these speculations must await further analysis of the data.

Some interesting results emerge when we look at the simultaneous effects of team structure and type of work on team performance. For these analyses, we use an alternative measure of team performance derived from the Evaluator responses to UEQ.12A. The measure is based on ratings of team performance with respect to those objectives which the Evaluator considered either as the "single most important objective" or "an objective of major importance." The Evaluator gave each objective one of seven ratings: Outstanding, Excellent, Very Good, Good, Fair, Marginally Acceptable, Unacceptable. The ratings below "Good" were very rarely used which is similar to the results obtained with the overall ratings of Productivity and Innovativeness. The correlation between this measure of Team Performance and the Evaluator Rating of Productivity is .56. To distinguish this from the other ratings, we shall refer to this measure as the Performance Evaluation.

We classify tasks as Well-Defined or Uncertain and classify teams according to whether the majority of their members are working on one or the other types of tasks. UMQ.22 provides one means of classifying teams since it asks teams members to indicate what proportion of their work fits each of the following categories:

a) Completion of a task requires little more than the straight-forward application of clearly defined procedures and techniques to a clearly defined problem.

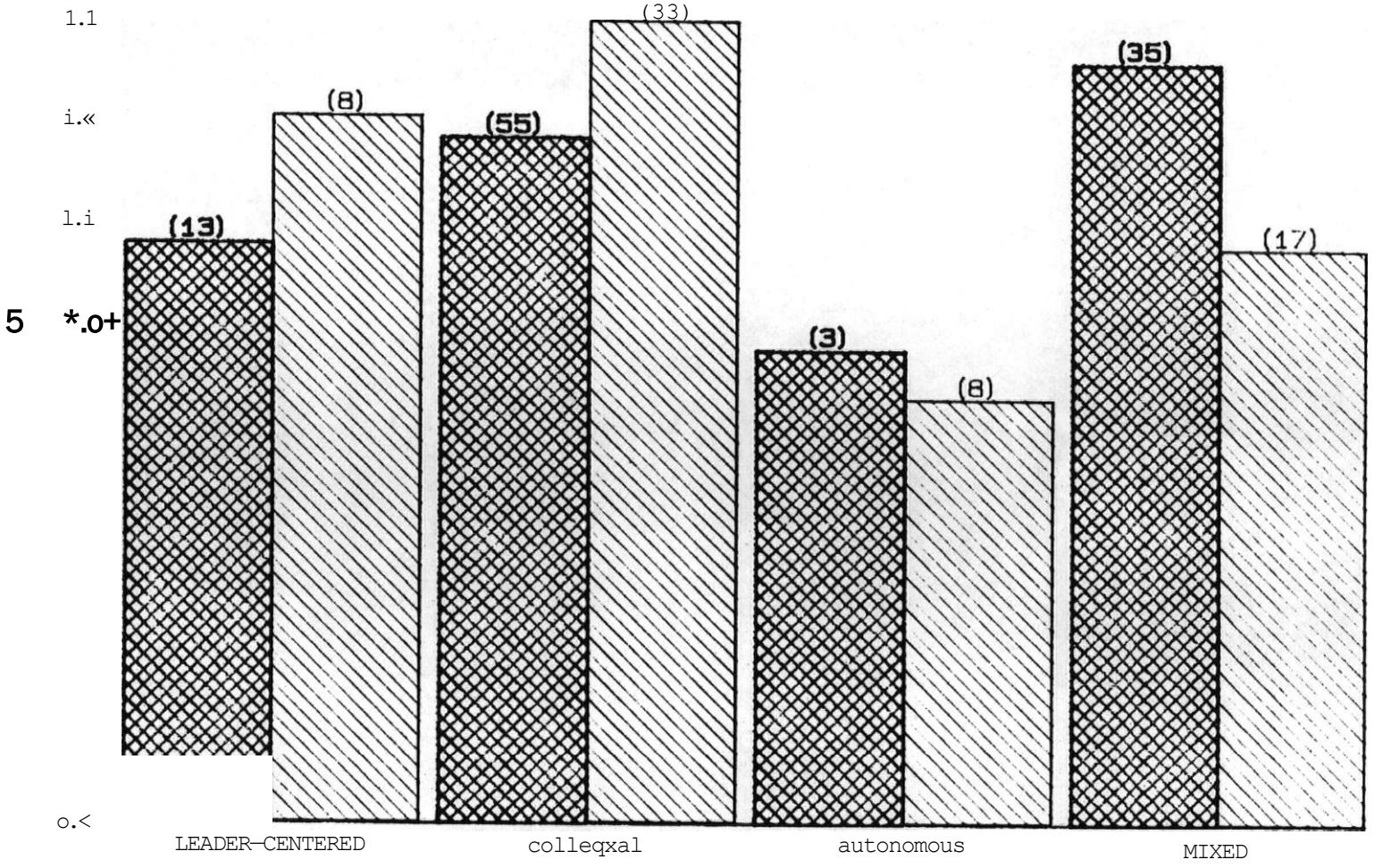
b) Completion of a task requires choice among different methods for pursuing the task.

c) Completion of a task requires development of new procedures to solve a problem; the development of these procedures becomes a task in its own right.

d) Completion of a task requires the solution of a theoretical problem and/or the development of new knowledge.

Figure 16 compares the average Evaluator Performance rating for each Team Type working on Uncertain and Well-defined tasks. In this graph, the zero-point is equivalent to an average rating of "Good". The figure shows: 1) Leader Centered and Collegial Teams receive higher ratings when working on Uncertain tasks than they receive when working on well-defined tasks although neither difference is statistically significant; 2) The reverse is true for both Autonomous and Mixed teams—these teams receive higher ratings when working on well-defined tasks and the difference for Mixed teams is statistically significant.

FIGURE 16: TASK TYPE. TEAM TYPE G EVALUATOR PERFORMANCE RATING



Team Type

well-defined tasks

uncertain tasks

Number of teams in psrentheses.

When we investigate other aspects of team organization, we find results that are consistent with the picture presented using the typology of teams. Consider, for example, the formal organization of the team. By formal organization, we mean the allocation of formal control rights such as: 1) The right to set objectives, 2) the right to schedule work, 3) the right to allocate resources, 4) the right to evaluate work. These decision-making rights can be monopolized by one person or they can be widely shared among team members. Hence teams can vary along a Centralization-Decentralization dimension; teams where control rights over others are distributed over many team members are toward the Decentralization end of the continuum and teams where these rights are exercised by one or two leaders are toward the Centralization end.

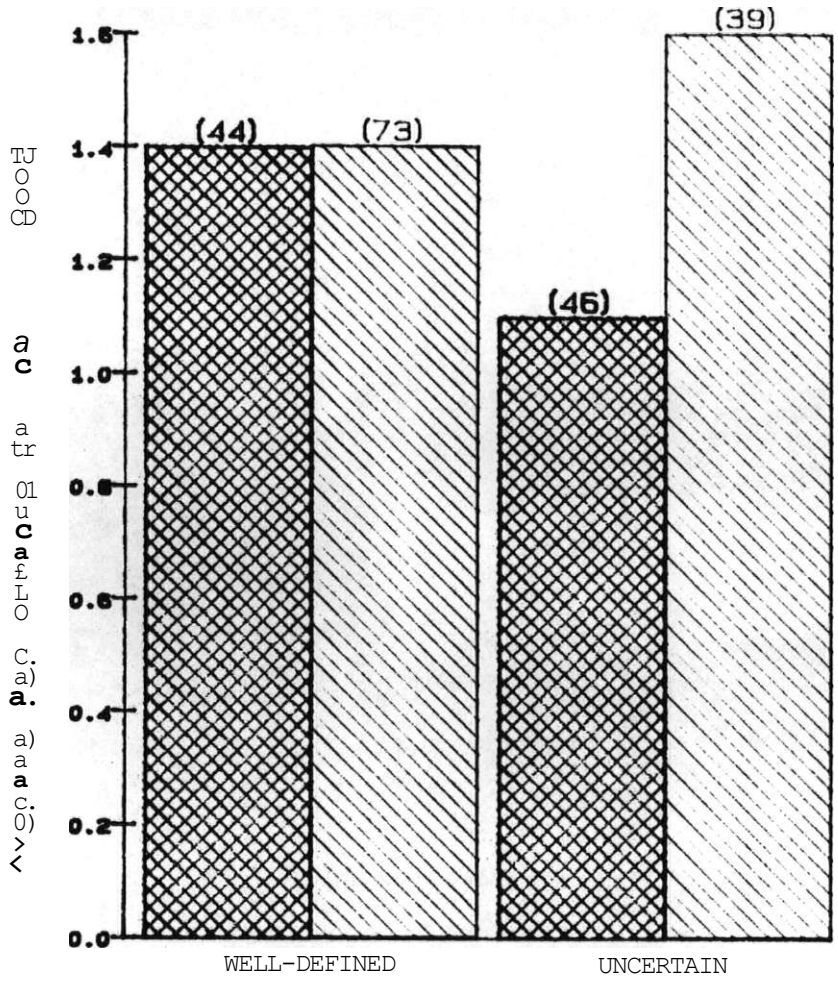
UMQ.23 asked team members about their decision-making with respect to each of the four kinds of rights noted above. Using the proportion of team members who claimed that they could make at least one of these decisions for others or for the team as a whole, we assigned each team a centralization score. In half the teams, 40% or more of team members claimed that they could make at least one of these decisions.

Figure 17 compares the Evaluator Performance ratings of Centralized and Decentralized teams working on Well-defined vs. Uncertain tasks. Centralized teams were those with "scores" of less than 40%. For this analysis, we used UMQ. 9 to classify team tasks; if more members indicated that the "level of the scientific-technical knowledge base" was such that most aspects were understood, the team was considered to be working on Well-defined tasks.

The results in Figure 17 complement those in Figure 16. Here we see that Centralization makes a difference for teams working on Uncertain tasks: Decentralized teams receive a higher Evaluator Performance Rating. On theoretical grounds, we believe that some forms of team organization are more compatible with some type of team tasks than others; Decentralized structures and Uncertain tasks are compatible as are Centralized structures and Well-defined tasks. The data in Figure 17 provide partial confirmation for our views, although we had expected the "Centralized, Well-defined" Teams to have received higher ratings.

There is, however, additional evidence consistent with our formulation of "structure-task compatibility." Consider two problems that often confront teams: Internal conflicts and lack of social or intellectual support. In Figure 18, we examine the consequences of Centralization and Task Type for each of these issues. We use UMQ.35e to determine "internal problems" and UMQ.58b. to measure "lack of encouragement." Compatible structures are: 1) Centralized teams working on Well-defined tasks and 2) Decentralized teams working on Uncertain tasks. Incompatible structures are: 1) Centralized teams working on Uncertain tasks and 2) Decentralized teams working on Well-defined tasks. The first set of four bars presents the data for "internal problems" and the second set deals with "lack of encouragement." In each set, the first two bars represent the Compatible structures. The figure shows that the percentage of teams with Compatible structures that experience each problem is smaller than the percentage of teams with Incompatible structures.

FIGURE 17 CENTRALIZATION. TASK TYPE & EVALUATOR PERFORMANCE RATING



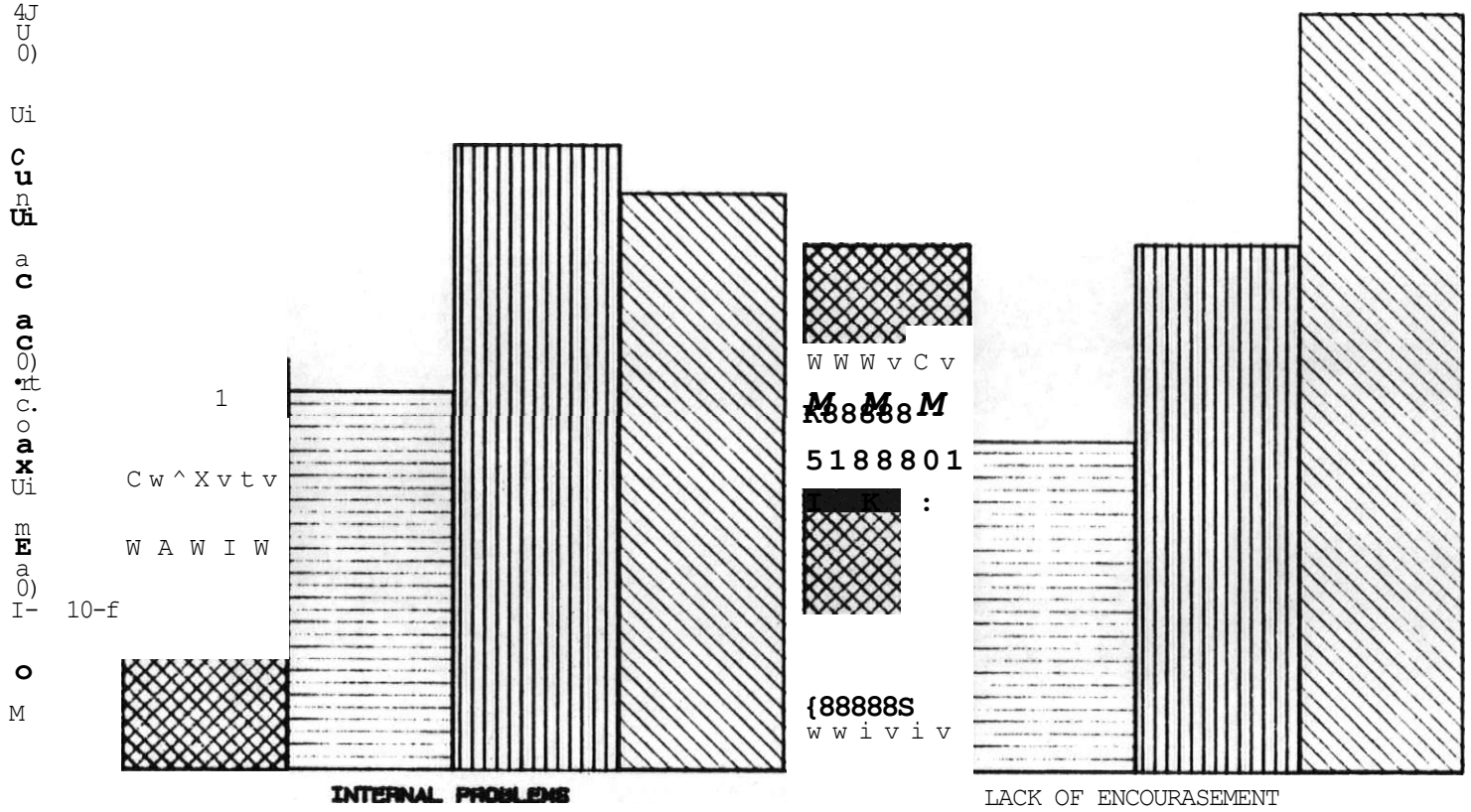
Task Type

centralized

1 decntralized

Number of teems in parentheses.

FIGURE 18: EFFECTS OF TASK TYPE AND CENTRALIZATION



centralized, well-defined tasks

3 decentralized, uncertain tasks

[ ] centralized, uncertain tasks

decentralized, well-defined tasks

Centralized, well-defined and decentralized, uncertain are compatible structures

The results in Figures 16, 17 and 18 support our view that different types of tasks require different social structures. Rather than attempt to find a universally productive form of team social organization, we believe that the appropriate strategy is to attempt to determine what structures are conducive to, or incompatible with, particular sets of task requirements.

7. The Impact of Organizational Characteristics on Team Performance.

This is a potentially very fruitful area which we have just begun to investigate. We classify teams according to members' responses concerning some characteristic of the R & D organization and test whether this classification is associated with external evaluations of the team. We find strong relationships between these organizational characteristics and Evaluator Ratings of Productivity.

In the analysis exhibited in Figure 19, we classify teams on each of several items:

UMQ.46 How characteristic of the R & D organization in which your research unit operates are each of the following? (Very, Somewhat, Not at all characteristic.)

The organization is quick to expand into new R & D areas.
There is too much pressure for quick results.
A significant number of researchers have left the organization recently.

UMQ.47 How characteristic of your present work situation are each of the following? (Very, Somewhat, Not at all characterisitic.)

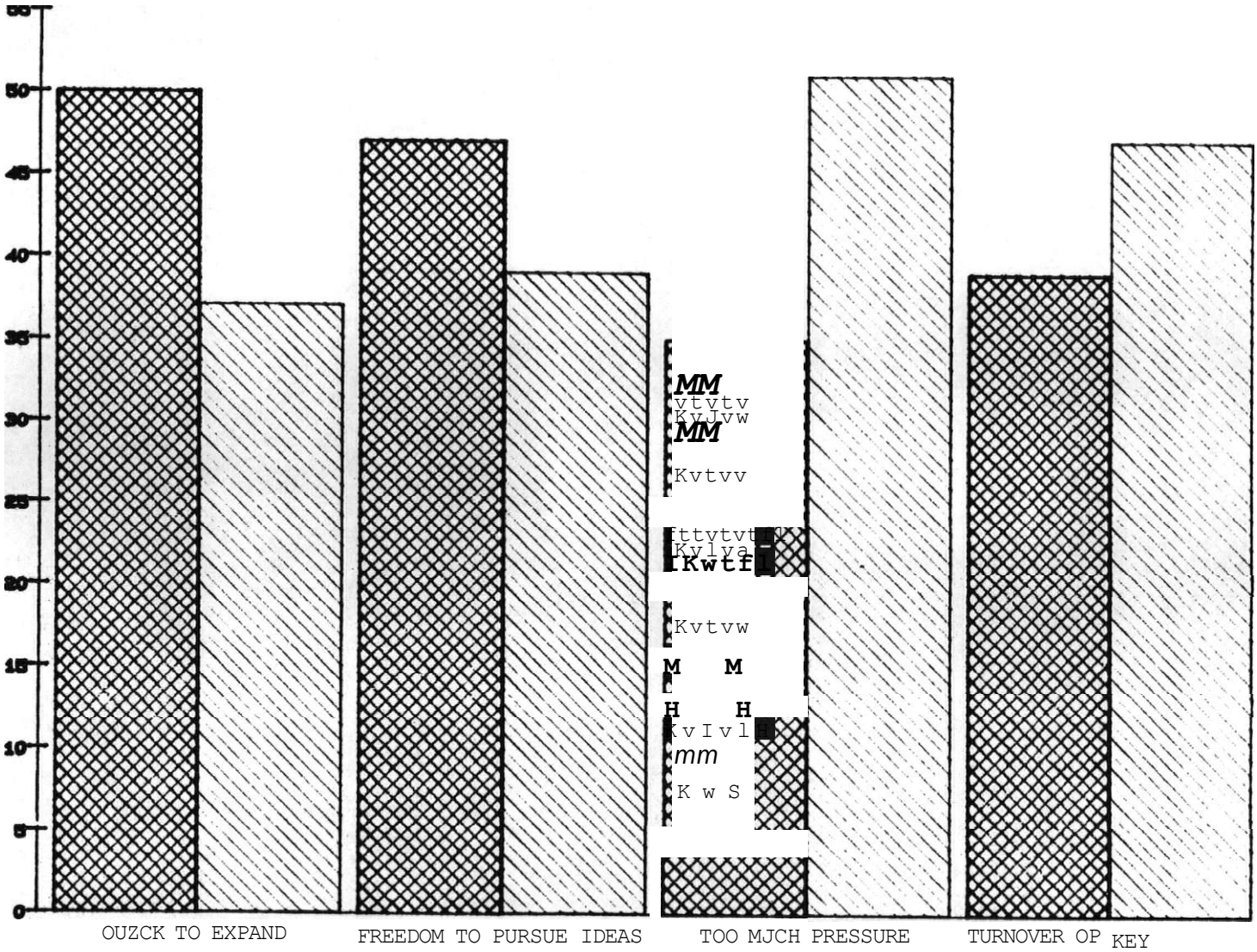
I am able to carry out and pursue my own ideas.

For these four items, "characteristic" means the average team response is closer to the Very characteristic end of the scale whereas "not characteristic" means that the average team response is closer to the "Not at all characteristic" end. The vertical axis in this graph is the percentage of teams above the sample median on the Evaluator Productivity Rating.

The results show that when teams report that expansion and freedom to pursue ideas are characteristic of the R & D organization, teams are more likely to receive high external evaluations of productivity. Furthermore, when teams report that "there is too much pressure..." or that turnover is characteristic, they are more likely to receive low Evaluator Ratings of Productivity, that is, ratings below the sample median.

Of course, team reports, even where there is consensus among team members, may or may not be accurate reflections of what the organization is like—we have no way of checking this. Sometimes, however, beliefs about reality may be more significant than the reality itself. Of course, it is possible that these questions do not reflect specific features of the company, but rather are consequences of generalized positive or negative attitudes. To rule out the latter hypotheses requires us to

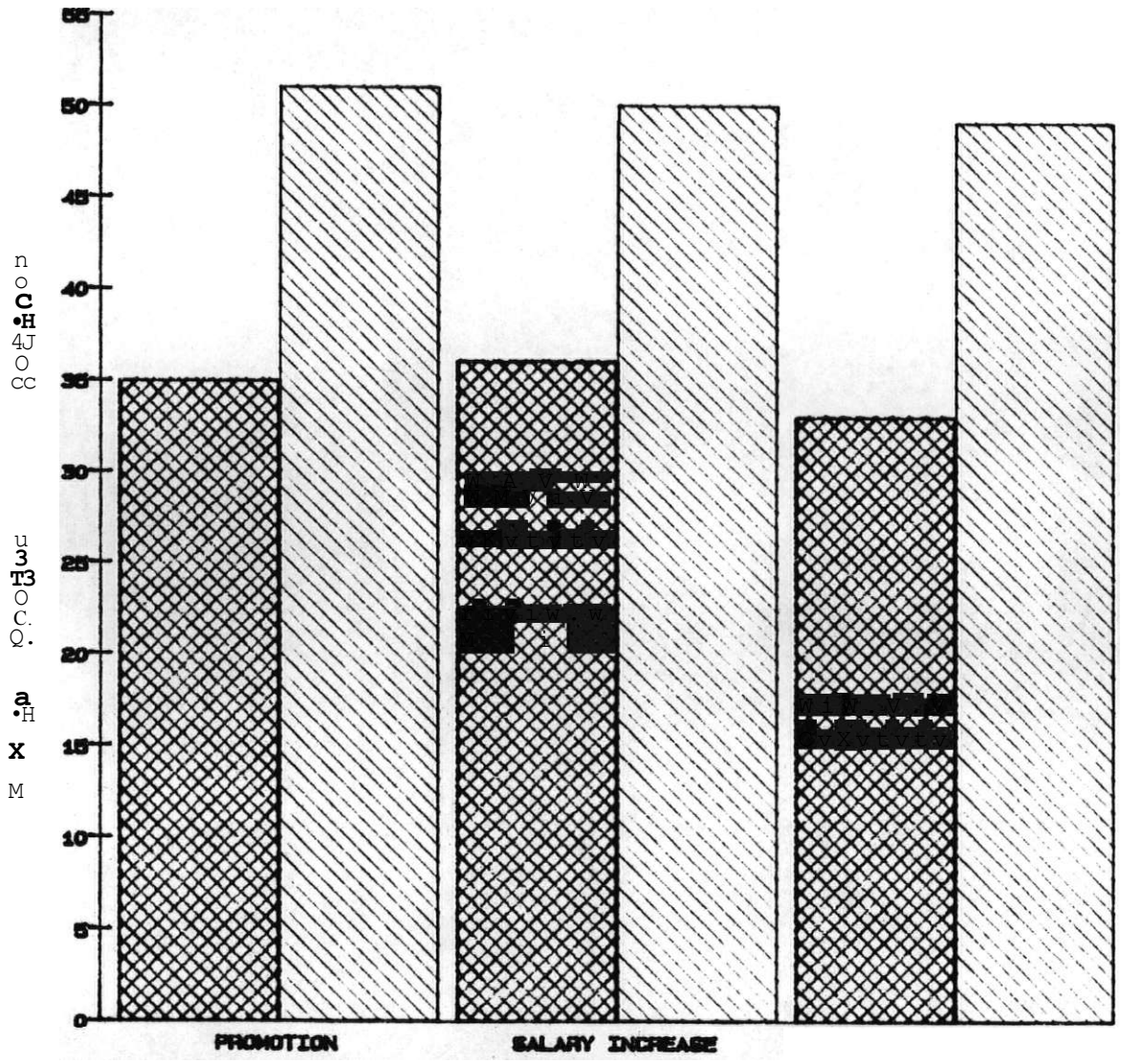
FIGURE 19: ORGANIZATIONAL FEATURES AND EVALUATOR RATIN6 OF PRODUCTIVITY



characteristic of R&D organization

not characteristic

FIGURE 20: "EFFECTS" OF SUCCESS AND EVALUATOR RATING OF PRODUCTIVITY



>v»v»v< few members expect effect

RS^S^ 1 most members expect effect

examine these questions with the individual as the unit of analysis.

Our final analysis concerns the reward system of the organization. It should come as no surprise that teams whose members report that team success will affect their rewards perform better than teams whose members report that success will have little consequence. If the overall result is not news, there is one minor surprise in the findings. The data are from UMQ.45:

> To what extent is each of the following likely to be affected by the relative success of this research unit as a whole? (To a great extent, To some extent, Not at all.)
>
> Your chances of promotion to a higher position in the company.
> Your chances of salary increases.
> Your "visibility" to upper level R & D management.

The findings for each of the parts of UMQ.45 appear in Figure 20. The vertical axis is once again the percentage of teams above the sample median with respect to Evaluator Productivity Ratings. In each case, teams where most members report that team success will affect their chances of reward are more likely to be above the sample median in Evaluator Productivity. The one surprise is that there are so many teams where most members believe that team success will have little effect on their own rewards. (For example, in nearly 25% of the teams, the modal response to "chances of promotion" is no effect at all.) This may be due to the fact that about one-third of our team members devote less than 50% of their time to work for the team or to the fact that 42% of the teams in the sample believe that their chances of failure are close to zero. Here again, further understanding of the results must await investigations using the individual as the unit of analysis.

8. Final Comments.

We believe that this study fills an important gap in research on research. There have been numerous studies of individual scientists and engineers as well as a large number of investigations of R & D using the company or the industry as the unit of analysis. Only a few studies have used the R & D team as the unit of analysis and none of these has examined structural properties of teams. Our findings demonstrate the importance of focusing on the team as the unit of analysis and the fruitfulness of a structural approach.

Although we are only beginning to appreciate their significance, it is clear that our results have both theoretical and practical consequences. We see the following as the main theoretical implications:

1) The data support the utility of our typology of team social structures—Leader centered, Collegial, Autonomous and Mixed.

2) Dimensions of team compostion—particularly homogeniety with respect to status characteristics—offer promise in explaining some within-team effects.

3) This study employs the techniques of network analysis in a significant new way. Analyzing questionnaire responses from all members of a large number of teams opens a number of new avenues in the study of both group structure and group interaction. We have examined overall interaction and also used these techniques to expose different types of communication structures, based on relationships involving: 1) Technical Assistance, 2) Exchange of Information, 3) Use of others as "Sounding Boards" for ideas and 4) Consulting others for Planning one's Activities. While this is an area of considerable promise, it is one that poses a number of methodological problems. For example, we believe that linear techniques understate the relationships between network properties and such things as productivity. Since this is the first study of a large number of networks, it is the first to deal with problems such as the skewness of the distributions of some of these properties and the size-dependence of other network quantities. Our study then raises issues that will probably require exploring the range of available analytic techniques and might necessitate the development of new techniques.

4) The study provides support for the conceptions of "Bridge" and "Manager" roles that were developed in our previous research. The particular importance of both of these roles in Collegial teams raises a number of questions. Our view that performance of managerial functions was not compatible with collegiality obviously needs reconsideration; the direction of reformulation will depend on the degree to which managerial functions are shared among different members in collegial teams. This, in turn, awaits the development of a satisfactory measure of the sharing of functions among team members.

5) Our findings underscore the importance of using the nature of the team task to conditionalize relationships between structural properties of a team and outcomes such as team productivity. The idea that there are incompatibilities between some types of tasks and types of group structure has a range of consequences that need further investigation.

6) The presentation of findings dealing with the effects of organizational characteristics on productivity only touches what promises to be a highly interesting area. We show that shared perceptions of organizational characteristics among team members relate to external evaluations of productivity. A team average represents the shared perception; hence questions concerning variability, degree of concensus and structural position of those who agree or disagree remain.

7) In the original proposal for this research, we argued that the study would generate a high quality dataset that would be unique, interesting and relevant to important theoretical and practical concerns. The results presented here only begin to exploit the richness of the dataset; nearly all of the analyses we have done use the team as the unit of analysis; other levels of analysis—the individual as the unit, the individual in various team contexts, the company—have yet to be explored. We believe that our findings to date and the potential results from these other levels of analysis justify our initial claim.

The practical implications are perhaps more appropriately determined by users of our results. However, we believe that, at the very least, our analysis suggests a new set of diagnostic questions for managers who are concerned about problem teams. The relationships we have presented provide new categories for understanding what is going wrong and what is going right with an R & D team. Categories like "status heterogeneity" allow us to go beyond "catch-all" explanations like personality or morale problems. Furthermore, having diagnosed a status problem, we can make use of available interventions to resolve the difficulty. To conclude, let us list a few key diagnostic questions:

1) Are there problems due to status heterogeniety?
2) Is the level of team interaction adequate to the requirements of the task?
3) Are there sufficient "technical assistance links" to accomplish the objectives of the team?
4) Given the nature of team's task, what organizational form—leader centered, collegial, autonomous or mixed—is most suitable?
5) Given the nature of the team's task, is a centralized or decentralized form more conducive to high performance?
6) Is anyone in the team playing a "Bridge role"? Does the nature of the team's work require such a role?
7) Is the way the managerial role is performed appropriate to the type of organization of the team?
8) If evaluations of team performance from different perspectives are inconsistent, what can be done to clarify the bases of evaluation?

As we continue the research, new questions and, perhaps, new answers will arise.