INTERDEPENDENCE, INTERACTION AND PRODUCTIVITY

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This paper concerns the relationship between group interaction and group productivity in accomplishing group tasks. Group tasks, almost by definition, require some minimal level of interaction and interaction can stimulate synergistic solutions to problems. But groups can also engage in excessive discussion which is often fruitless-a situation memorialized by the definition of a camel as a horse designed by a committee. But to say that sometimes group interaction contributes to productivity and sometimes it does not isn't very helpful either to the theoretical understanding of group processes or to the practical task of improving group performance. There have been a large number of studies of group interaction (McGrath, 1984; Hackman and Morris, 1975; Kelley and Thibaut, 1969; Collins and Raven, 1969; indicate the range of studies), but "research that directly relates measured characteristics of group process to performance outcomes is scarce (Hackman and Morris, 1975, p.51)." Researchers have not addressed the question, "Under what conditions does group productivity vary directly with group interaction?" The formulation we will present provides one answer to the question and takes a step toward understanding the circumstances in which group interaction contributes to productivity.

While social psychologists recognize that some features of interaction can interfere with the accomplishment of a group's objectives (Steiner, 1972; Hackman and Morris, 1975) and have developed procedures for improving group performance such as the Delphi technique (Dalkey, 1969; Delbecq, Van de Ven and Gustafson, 1979) little has been said about the general

relationship between the amount of group interaction and the productivity of the group. Researchers have studied factors related to interaction rates of individuals but have not pursued interaction rates of groups. Writers have characterized individual specialization in particular types of interaction, but have not looked at variability across groups in the nature of the interaction that occurs and how different kinds of interaction relate to group productivity. In short, while investigators have studied group process, rarely have they related group process to group performance, although "it is common for researchers to speculate about the functions of group process when they are developing research hypotheses or interpreting empirical findings (Hackman and Morris, 1975, p.47)." In part this may stem from a pessimistic view of the role of group process, "i.e. seeing it as something that for the most part impairs group task effectiveness. (ibid.)" But the lack of both theoretical development and empirical studies also reflects a belief that the relationship depends so heavily on the nature of the group task as to rule out any general propositions. Furthermore, task-contingent propositions are not put forward because they require a different conceptualization of types of tasks than currently exists. (see, for example, McGrath, 1984)

The present authors subscribe to the view that relationships between amount and type of interaction and group productivity are contingent on the nature of the group task. Furthermore, we take neither an optimistic nor a pessimistic view of group process; rather we take the view that process can either promote or interfere with group performance depending on the requirements of the task and the nature of the group structure. Most

importantly, we believe that the contingencies are not so task-specific that they preclude general propositions. Building on the typology of James D. Thompson (1967), we view the nature of interdependence among group members as the factor which conditions the relationship between interaction and productivity. Interdependent relations among group members in part result from the requirements of the group task and the organizational context in which the group operates. In this report we will formulate two general propositions and test them using data from a study of 224 research and development teams representing 30 major corporations. We will also analyze overall interaction into components and explore the relationships between each component and team productivity.

FORMULATION OF THE PROBLEM.

Not all tasks carried out by groups are group tasks. A considerable body of experimental research, for example, has compared group and individual performance on a range of tasks (see review in Kelley and Thibaut, 1969); this research of necessity uses tasks that an individual may complete without the assistance of anyone else. In our view, while such tasks are often assigned to groups, they are not group tasks and, in many cases, groups are less effective than individuals in accomplishing these tasks. Needless to say, a task that an individual could complete wholly on his own does not require interaction and interaction with others may well interfere with task performance. The scope of our concern then is restricted to group tasks which we define as follows:

> A group task is a task that requires resources (information, knowledge, materials and skills) that no single individual possesses so that no single individual can solve the problem or accomplish the task objectives without at least some input from others.

Our definition requires that the task imposes at least some degree of interdependence among members for it to qualify as a group task. This interdependence may range from the minimal case where each person works on his/her own and contributes to a final product that is made up of the sum of the individual products to the maximal situation where each group member requires inputs from every other member in order to make his/her own contribution. We should note that we also want to exclude those cases where a task that could be accomplished by an individual is assigned to a group for "political" reasons, eg., so that every person can have a sense of participation in the decision.

Interdependence is a structural property of a group that may result from requirements of the group task, the organizational context in which the group operates, characteristics of group members or some combination of all of these. It can vary in kind and degree.

Thompson (1967) proposed a typology that provides a useful starting point for our examination of interdependence. He distinguished three levels of interdependence: (1) pooled, (2) sequential and (3) reciprocal. Pooled interdependence occurs when "each part renders a discrete contribution to the whole and each is supported by the whole" (p.54). Thompson illustrates this concept using three branches of an organization that do not interact with one another but must perform adequately in order not to jeopardize the total organization. When the outputs of one unit become the inputs for another, we have a case of sequential interdependence which Thompson notes is not symmetrical. Finally, when the outputs of each unit become inputs for the other units, he refers to reciprocal interdependence, "..illustrated by the airline which contains both operations and maintenance units. The

production of the maintenance unit is an input for operations, in the form of serviceable aircraft; and the product (or by-product) of operations is an input for maintenance, in the form of aircraft needing maintenance." In Thompson's view, the three types are nested: all sequentially interdependent relations involve pooled interdependence and all reciprocally interdependent relations involve both sequential and pooled interdependence. The types themselves represent different degrees of interdependence.

In applying this typology to groups and group members, we modify and expand Thompson's formulation. Thompson's concerns focused on large organizations or sub-organizations, eg., the maintenance unit of an airline; our concerns involve looking at smaller units or individuals. Van de Ven et al. (1976) examined interdependence at the work unit level of analysis and defined it as "the extent to which unit personnel are dependent on one another to perform their individual jobs." These researchers used Thompson's typology and added a fourth type which they termed, "in a team arrangement." In part we follow Van de Ven et al. but we believe that their fourth type can be represented as a high degree of reciprocal interdependence. We characterize groups by classifying each relationship between two members as: 1) either sequential or not and 2) either reciprocal or not. We then aggregate over the group to determine the number of dyads that are: sequentially interdependent, reciprocally interdependent, both or neither. The "neither" category represents "pooled interdependence" since, from the definition of a group task above, it follows that pooled interdependence characterizes group members working on a group task.

Our procedures allow for finer distinctions than Thompson made. We separate type from degree so that we can assess degrees of both sequential and reciprocal interdependence. Groups can vary in the proportion of members involved in reciprocally interdependent relationships and we can coordinate these proportions to degrees of reciprocal interdependence in the group. A higher degree characterizes a group where all members are involved in reciprocally interdependent relations than one in which only half the members are involved in such relations.

Members of reciprocally interdependent dyads depend on one another for resources (information, evaluations, skills, material goods, etc.,) and typically, the exchange of resources entails interaction. While one can conceive of the mutual exchange of material objects, for example, with very little social interaction, we can more readily find examples of asymmetric, sequential relationships that involve minimal interaction-the assembly line is only the most obvious model. Pooled interdependence in the limiting case may require no interaction at all, for example, when each group member completes part of the task and turns the completed part into a central collection point.

We propose that groups with high degrees of reciprocal interdependence represent structures that require high levels of group interaction. But reciprocally interdependent structures do not determine the level of interaction. For both internal and external reasons, groups may not attain the required levels; a dominant group leader may intimidate members and suppress needed interaction; coping with pressures from the environment may so occupy the time of members that little is left for needed interaction. Sometimes groups do not complete their tasks, solve their problems or fulfill their assignments because of internal difficulties and/or external

pressures. Where the level of interaction that occurs in the group is less than the level required, one can expect the group to be less effective or less productive than when the level equals or exceeds what is required.

Of course, in those group structures that do not require high levels of interaction, group effectiveness and group productivity will be independent of level of group interaction. In some of these structures, a high level of interaction may even be counterproductive, since time spent interacting may be time spent away from working on the task. The nature of the task and the context in which the group operates are factors that affect the interdependence structure, that is, the type and degree of interdependence in the group. While we will not consider factors that influence the type of interdependence structure in this report, we should note that tasks involving idea generation seem to be prototypes of those that produce reciprocally interdependent structures, particularly in situations which demand a range of knowledge and expertise. It is widely recognized that such tasks require high levels of unfettered interaction and this recognition has led to the development of procedures such as "brainstorming" (Osborn, 1957) to overcome internal barriers that may impede interaction. While these have had some success, we believe that looking more broadly at structural interdependence in the group may enable us to enhance some of these interventions.

We can bring together the key elements of this discussion in a more formal statement of the principal proposition guiding our study:

> Pi: Given a group task and a high level of reciprocal interdependence in the group, group productivity will be directly related to level of interaction in the group.

In this research, we apply PI both to overall interaction, and to several different components of overall interaction, distinguished according to the purpose for which the interaction took place. These components involve requests for technical assistance, exchange of information, using others as "a sounding board for ideas" and consultation in connection with planning future activities. We are interested in these components for two main reasons. First of all, interaction in work groups is not monolithic so that examining different aspects of interaction should provide a more complete picture of the division of labor in the group. In some cases, we expect that the components and overall interaction will present a uniform picture while in others the components may be differentially related to features of group structure, group task or outcome. On the one hand, we expect that the frequency of overall interaction and the frequency of each component will vary directly with the type and degree of interdependence in the group. On the other hand, we would predict that the nature of the group task would affect whether the group had specialists for each component or had most members engaging in all types of interaction with relatively equal frequency.

The second reason for examining components of interaction is that such examination allows us to evaluate the consistency of our theoretical

principles. While we do not expect all components to have the same frequency of occurrence - e.g., interaction for information exchange will be more frequent than using others as a sounding board - all of these frequencies should be sensitive to the degree of reciprocal interdependence among team members. Reciprocal interdependence is a mutual relationship in which each needs the other to execute some part of his responsibilities.

One member may provide assistance while the other uses it or both may assist each other. The more people with whom a given individual is mutually interdependent, the more likely that individual is to seek technical assistance from someone, or the more likely someone is to seek technical assistance from him. Increasing the number of reciprocally interdependent relationships for a given individual should have the similar effects on information exchange, using others as a sounding board for ideas and consulting others for planning future activities. High levels of reciprocal interdependence affects both the need for, and the likelihood of, each type of interaction. Furthermore, if interaction with respect to a particular component is insufficient to meet the need, group productivity should be adversely affected. Therefore, group productivity should vary directly with the level of each component, given a group task and a high level of reciprocal interdependence in the group.

When the group's task depends heavily on idea generation, our definition above implies that no individual can generate all the ideas necessary to accomplish the task. Increasing reciprocal interdependence means that members depend increasingly on one another for ideas; for the group to be successful, then, members must supply one another with ideas. Hence, as reciprocal interdependence increases, group success requires obtaining inputs from an increasing proportion of the group membership. If relatively few members of the group monopolize particular components of interaction, some members will not receive needed inputs and others will have fewer opportunities to provide useful outputs. If the team leader is the recipient of all information exchange, then other members will not obtain information they require; if only a few members initiate requests for technical assistance, then some members who could benefit from technical

assistance will not secure it. In both cases, restricted patterns of interaction will impair the group's effectiveness. Restricted patterns of initiation or receipt of interaction, however, create problems only when success depends on involving a high proportion of members, that is, for idea generation tasks in groups with a high degree of reciprocal interdependence. We can summarize this discussion in a second general proposition:

> Given groups with a high level of reciprocal interdependence working on tasks requiring idea generation, group productivity is inversely related to the degree of concentration of both initiators and receivers of interaction.

We believe this proposition applies to overall interaction as well as to each of the four components we distinguish. While our study did not directly observe group interaction, we have investigated our general propositions using a questionnaire survey of relatively permanent work groups. The next section will describe the survey and the measures we employed.

THE STUDY AND THE MEASURES OF THE KEY VARIABLES

The research reported here was part of a large scale study of the organization and productivity of research and development teams in private industry. The number of teams involved, their geographical dispersion and their continuing operation precluded direct observation of team interaction. Instead, we distributed an extensive questionnaire to every member of each team in the study. In addition, for each team, two external evaluators from the company who were not members of the team but were knowledgeable about team activities were each asked to evaluate team performance by responding to a brief questionnaire.

The teams that were included in the study were selected by the participating companies according to guidelines we provided. The guidelines defined a team as a group of people working on a common task who recognized that they were members of the group and were recognized as such by the organization. We asked for teams of between 5 and 20 members, that had been in existence for at least six months and would continue for at least an additional six months, and whose activities included a significant research component. In addition, we requested that companies avoid performance criteria in selecting teams for the study, at least to the extent of not including only highly successful or highly unsuccessful teams.

Two hundred twenty four teams from thirty major corporations took part in the study. These companies represented eight different "lines of business." We made no attempt to obtain a random or representative sample--how one would define a universe is not a simple question-but sought instead to maximize the heterogeneity of the sample.

The teams in the study had a total of 2285 members and 2077 returned questionnaires which is a 90.9% rate of return. We have evaluator data from 220 of the teams; for 184 teams, at least two evaluators returned the questionnaire. For some companies, the same two people evaluated all teams; in others there were 2 different evaluators for each team from that company. Although our guidelines indicated our interest in teams with between 5 and 20 people, teams in the sample ranged in size from 3 to 34 9 teams were smaller than 5 and 10 teams were larger than 20. In studying interaction, variability in team size poses a number of analytic problems because most of our interaction measures vary with size and our procedures for controlling size do not fully remove size effects.

The propositions presented above entail measuring three sets of variables: 1) Productivity; 2) Interaction and 3) Interdependence. We discuss each set in turn.

The Productivity Measure

Our questionnaires provide a number of different indices of productivity; some of these involve global judgments while others employ more specific, concrete questions. We also have three perspectives on the team's productivity from three different roles the external evaluators, the team leader or leaders and the team members. We have examined the properties of these indices and their interrelations (Cohen et al.. 1986) and can briefly summarize our findings: 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. For the analyses to be presented here we use as our measure of group productivity the responses of team evaluators to the question: "In your opinion how productive-in the sense of producing information, devices, materials, etc.-is this unit?" Respondents circled a number on a seven point rating scale with one end labeled "Highly productive" and the other labeled, "Not at all productive." (Above "4" on the scale was the label, "About average.") Where there were two or more evaluators (in 184 of the teams), their ratings were averaged. The same question was asked of members and team leaders and in 88% of the teams, the average evaluator rating differed from the median member rating by one scale point or less. (The

same level of agreement between average evaluator rating and leader rating occurred in 87% of the teams.) We choose external evaluator ratings since these are less likely than either leader or member responses to be influenced by internal processes occurring in the team; member evaluations, in particular, could reflect satisfaction with the level of interaction in the group in addition to judgments of task accomplishment.

We have transformed the scale so that it ranges from -3 to +3 with 0 as "about average". The average productivity rating for all the teams in the sample was 1.43; all but 30 of the teams are "above average." This may reflect a bias in the way companies selected teams for the study or it may reflect an inherent feature of the operation of R & D teams. In many cases, our evaluators are the people responsible for allocating personnel and resources to the teams. Since demand for resources usually exceeds what is available, these evaluators are likely to cut off any team they regard as non-productive. Hence any teams that might have received low ratings either had already been, or were about to be, terminated. Interestingly enough, the leader ratings were even more positive than those of the external evaluators, averaging 1.75.

Measures of Interaction

All interaction measures are based on sociometric-like questions. Along with the questionnaire, each respondent received a roster list containing the name and a roster number for every team member. The questionnaire was set up so that a person could describe his/her relation to another team member simply by checking the appropriate box which was labeled with the other person's roster number.

For overall interaction, respondents were asked, "How often do you talk with other members of the unit concerning matters related to the unit's work?" For each other team member, the respondent was asked to indicate how frequently he spoke to that person in one of five categories ranging from "Never" to "Daily". For each team, we generate a matrix from this question where the ij^1 entry is a weight from 1 to 5 representing the category chosen by the i"H respondent for the j*Vi object. By averaging over all cells, we obtain a quantity which we call, "average pairwise interaction" which represents the average frequency reported by team members for their work-related interactions with other team members. In the total sample, there is a high degree of agreement among members of a pair; in more than 86% of the over 15,000 dyads, the discrepancy between the ij',1 cell and the ji-*1 cell is zero or one category.

As expected, this measure correlates negatively with team size, -.55; in a finite work day, there is a limit to the number of people with whom one can interact. In large teams, this limit is exceeded for all members so that a number of pairs never interact; as size increases, the proportion of such pairs increases more rapidly and an average taken over all pairs decreases correspondingly. Since we are concerned with interaction as a team property and since team size varies, almost any measure we could devise would be size-dependent. At a later point in our research, we may be able to distinguish between core and peripheral team members and examine only interaction in core pairs. Since cores should be relatively small in size, it might be possible to construct measures of core interaction that are independent of size.

To measure each component of interaction, we employ some of the techniques of network analysis (Holland and Leinhart, 1976). For each component we asked two questions: The first concerned which team members the respondent frequently approached for the particular kind of interaction, eg., for technical assistance or for information; the second inquired who approached the respondent for the same purpose. Respondents were asked to check the boxes under the roster numbers of the appropriate other members. If member i indicates that he/she approaches member j for technical assistance, we will say that there is a technical assistance "link" from i to j. Using the paired questions, we can identify links that are "acknowledged" by both the initiator and the receiver-where member i says he/she approaches member j for technical assistance in answer to the first question and member j says he/she is approached by member i in answer to the second. (Note that acknowledged links are not the same as reciprocated links; the latter occur when i mentions j and j mentions i in answer to the first question.) Since we are interested in stable interaction relationships in the group as a whole, we construct our measures using only acknowledged links.

For each component of interaction, we generate a matrix for each team where the ij cell is "j" if member i approaches member j and member j acknowledges that approach and "0" otherwise. We compute three measures from each team matrix: Density, Row Concentration and Column Concentration. Density is the observed number of links divided by the maximum possible number of links-if S is team size and there are no missing cases in the team, the maximum equals S(S-1)-and we use this quantity as an indicator of the total amount of interaction in the team with respect to the particular

component. The row sums of this matrix represent the number of links each team member initiates while the column sums indicate the number of links in which each member is the recipient of the interaction. Ordering the row (or column) sums from smallest to largest, we then compute the Gini index (Shryock and Siegel, 1973) to measure row and column concentration:

$$GINI = \sum_{i=1}^{s-1} (X_i) < W - \sum_{i=1}^{s-1} L(X_{i+1}) > (Y_i)$$

where X_s the cumulative proportion of the group up to the entry, Y_i is the cumulative proportion of choices represented by the i^{th} entry and s is the size of the team.

This index is "0" if the row (or column) sums are all equal and "1" if concentration is at a maximum, i.e., if a single team member initiates (or receives) all the links.

Missing cases pose serious problems for our usage of acknowledged links, since a team member who names another who is a missing case cannot possibly have an acknowledged link. We investigated techniques for estimating the proportion of such links that would be acknowledged, but decided that such procedures introduced needless complications to the analysis. Instead, we chose to eliminate teams where missing cases could introduce a serious bias; teams where 25% or more members did not return questionnaires were excluded from the analyses involving components of interaction. There were 26 such teams (11.6% of the sample).

The Measure of Interdependence

We also used two sociometric-like questions to derive our measure of interdependence. We asked respondents to check the roster numbers of all unit members to whom each of the following statements applies:

> My ability to finish my work depends on these people first completing theirs.
>
> These people and I need a MUTUAL EXCHANGE of work products throughout the course of our work.

We assumed the first question tapped relations of sequential interdependence while the second indicated relations of reciprocal interdependence. Although Thompson argued that his nested types formed a Guttman scale (Thompson, 1967, p. 55), our format did not lend itself to that scaling technique. Each of these questions generated a matrix for each team and we computed the density of each matrix. The median density for the indicator of sequential interdependence is .20 while the median is .27 for reciprocal interdependence. This result is not consistent with Thompson's formulation because it signifies that many respondents reported reciprocally interdependent links that were not also sequentially interdependent, i.e., the relations were not nested. (In fact, there were 2504 instances of i saying he was reciprocally interdependent but not sequentially interdependent with j and 2305 of i saying he was both.) While this may be an artifact of our method, we prefer to modify the nesting constraint

because at the dyad level, reciprocal interdependence can be a simultaneous relation as well as a relation sequenced in time. For example, two group members may consult with one another and depend on the consultations without one consultation necessarily preceding the other.

Since the densities of both measures are correlated with team size, we divided the sample into size quartiles and computed the median for each quartile for both sequential and reciprocal interdependence. We then classified each team according to whether it was above or below the median of its own quartile on each variable. This produced two measures that were relativized to team size; we then combined the two measures and generated four categories of interdependent teams: Low Sequential-Low Reciprocal; High Sequential-Low Reciprocal; Low Sequential-High Reciprocal; and High Sequential-High Reciprocal.

RESULTS

All the analyses presented in this section are based on 194 teams; we exclude 26 teams because sociometric data are missing from 25% or more members and four teams because data from external evaluators are missing.

Table 1 examines the relationship between overall interaction and productivity contingent on the type of interdependence. For each category of interdependence, we present means and standard deviations for average pairwise interaction and evaluator ratings of productivity and also the partial correlation between interaction and productivity, partialing out team size. Table 1 shows three main results: 1) Average pairwise

TABLE 1

Overall Interaction, Productivity and their Relationship, Contingent on Interdependence

Type of Inter-dependence	Number of Teams	Average Pairwise Interaction		Evaluator Rating of Productivity		Partial Correlation between Interaction and Productivity (controlling for team size)
		Mean	S.D.	Mean	S.D.	
1. Low Sequential-Low Reciprocal	61	3.09	.674	1.30	.985	.136
2. High Sequential-Low Reciprocal	38	3.37	,688	1.33	.953	-.007
3. Low Sequential-High Reciprocal	38	3.10	,758	1.59	,796	,143
4. High Sequential-High Reciprocal	57	3.52	,715	1.59	.797	.464*'

** p < .01

For Average Pairwise Interaction:

one way ANOVA yields an F of 4.697, p<.01

T-test comparing Low and High Sequential (combining types 1&3 and 2&4) yields a T of 3.569, p<.001

For Evaluator Ratings of Productivity:

T-test comparing Low and High Reciprocal (combining types 1&2 and 3&4) yields a T of 2.220, p=.01

interaction varies systematically with interdependence ranging from a mean of 3.09 for Low-Low to a mean of 3.52 for High-High (3.0 represents approximately one interaction a week and 4.0 represents more than one a week but less than one a day); 2) External evaluators consider teams with high reciprocal interdependence to be more productive than teams with low reciprocal interdependence; 3) The partial correlation between interaction and productivity is significant only for High Sequential-High Reciprocal teams.

We anticipated the first result. We asserted earlier that when team members perceive interdependent relations with one another, they perceive a need for interaction; thus we interpret this result to mean that actual interaction varies with the need for interaction. The second result, however, is somewhat surprising; given the diversity of activities of these R&D teams, we anticipated that productivity would be unrelated to type and degree of interdependence. On reflection, however, we think we may not have given sufficient weight to the importance of idea-generating activities for R&D; it may be that high reciprocal interdependence facilitates idea generation and thus teams with low reciprocal interdependence cannot be maximally effective.

The third result provides strong support for our first proposition; the correlation of .464 for High-High is consistent with the proposition. However, the lack of a significant correlation for the Low Sequential-High Reciprocal category poses a problem. In Thompson's view, the Low-High type should not exist so the 38 teams would represent error types according to this position. It would be expedient to view these as error types because this category yields some puzzling and inconsistent results-it has a low

TABLE 2

Regression of Average Pairwise Interaction on the Components of Interaction

Variable*	Coefficient	Standardized Coefficient	T Value	P (1 tail)
Constant	2.341	.000	32.51	0.000
Technical Assistance	2.424	.340	4.18	0.000
Information Exchange	.840	.160	2.03	0.022
"Sounding Board"	1.162	.159	2.01	0.023
Consultation for Planning Future Activities	1.686	.195	2.96	0.002

(N-195)

F ratio for the regression with 4 degrees of freedom = 59.64 yielding $p<.001$,

Multiple R = .746 R^2 = .588

***Each component is measured by the density of the matrix of acknowledged choices.**

average interaction, a high average productivity rating and no correlation between the two. We will return to this issue after examining our results regarding components of interaction.

We have asserted that our basic propositions apply not only to overall interaction, but also to what we have called, "components" of interaction. We have posited four components which are reflected in dyadic relationships where: 1) one team member seeks or provides "Technical Assistance" to another; 2) the two members "Exchange Information"; 3) one member uses another as a "Sounding Board for Ideas" and 4) the members are in "Consultation for Planning Future Activities." The results in Table 2 are consistent with our formulation and so serve as a validation of the indicators we have used. The table presents the regression of the measure of overall interaction, "Average Pairwise Interaction." on density measures of the four components. The multiple R in the table is .746 and R -.557 and the standardized coefficients for each of the components are all significantly different from zero.

In Table 3, we consider the variation of the densities of each of the components according to type of interdependence. Bartlett's test and one-way analyses of variance indicate that type of interdependence is a significant source of variation in each component. Examination of the table shows that High-High has the highest mean for each component and Low-Low has the lowest mean. The mean density of High Sequential-Low Reciprocal falls in the middle for all four components; once again the Low Sequential-High Reciprocal category behaves inconsistently, sometimes higher than High Sequential-Low Reciprocal, sometimes lower, and lower than Low Sequential-Low Reciprocal with respect to Consultation for Planning Future Activities.

TABLE 3

The Relationship of Components of Interaction
to
Types of Interdependence

Type of Inter-dependence	Components: Technical Assistance	Information Exchange	"Sounding Board for Ideas"	Consultation for Planning Future Activities
	(Mean Densities with Standard Deviations in Parenthesis)			
Low Sequential-Low Reciprocal (N=61)	.126 (.072)	.189 (.105)	.115 (.073)	.103 .064)
High Sequential-Low Reciprocal (N=38)	.137 (.097)	.251 (.146)	.131 (.087)	.117 (.058)
Low Sequential-High Reciprocal (N=38)	.151 (.097)	.221 ,152)	.129 (.089)	.096 (.074)
High Sequential-High Reciprocal (N=57)	.191 (.123)	.288 (.138)	.166 (.128)	.167 .105)

For each component, Variances are Heterogeneous by Bartlett's test: Technical Assistance $p < .001$; Information Exchange $p < .05$; Sounding Board for Ideas $p < .001$; and Consultation for Planning Future Activities $p < .001$,

TABLE 4

The Relationship of Components of Interaction to Productivity, Contingent on Types of Interdependence

Type of Interdependence	Components: Technical Assistance	Information Exchange	"Sounding Board for Ideas"	Consultation for Planning Future Activities
	(Partial Correlations controlling for Team Size)			
Low Sequential-Low Reciprocal (N=61)	120	.007	-.005	.089
High Sequential-Low Reciprocal (N-38)	.043	-.191	-.178	.147
Low Sequential-High Reciprocal (N=38)	.106	,217	.028	.217
High Sequential-High Reciprocal (N=57)	.479**	,388**	.358**	,335**

** p < .01

Except for this category, the data are consistent with our earlier argument that actual interaction varies with what we have termed, "need for interaction."

Table 4 deals with the relationship of components interaction to productivity for each type of interdependence. Each entry is the partial correlation between the density of the component measure and evaluator rating of productivity, controlling for the size of the team. Only for High Sequential-High Reciprocal teams do we find correlations significantly different from zero. While this result supports our first proposition, the findings for Low Sequential-High Reciprocal are not consistent with our expectation. We should note that the results in Table 4 do not represent independent tests of our first proposition, nor are these results independent of the result for overall interaction. Our intention is not to show independent support but rather to demonstrate a consistency across different properties of member interaction.

Our second proposition argued that in reciprocally interdependent teams, if a few members initiated (or received) most of the interaction, it would be detrimental to the productivity of the group. Table 5 provides the relevant data. The table presents the partial correlations between the Gini indices for initiating and receiving for each component and evaluator ratings of productivity. (A high value of the Gini index indicates a high concentration of initiators or receivers.) The significant negative correlations in seven of the eight cells for High Sequential-High Reciprocal support our second proposition. For Low Sequential-High Reciprocal, the correlation is significant only for concentration of receivers of Information Exchange. With High Sequential-Low Reciprocal Teams we find two

TABLE 5

The Relationship of Concentration of Initiators and Receivers to Productivity for each Component of Interaction, Contingent on Types of Interdependence

	Components:							
	Technical Assistance		Information Exchange		"Sounding Board for Ideas"		Consultation for Planning Future Activities	
Type of Inter-dependence	Init.	Recv.	Init.	Recv.	Init.	Recv.	Init.	Recv.
	(Partial Correlations controlling for Team Size)							
Low Sequential-Low Reciprocal (N=61)	-.07	.16	-.03	-.04	.06	.19	-.11	.07
High Sequential-Low Reciprocal (N=38)	-.06	-.02	.04	.06	-.03	.09	*-.28**	.32*
Low Sequential-High Reciprocal (N=38)	-.09	.03	-.02	-.28*	.03	.16	-.20	-.06
High Sequential-High Reciprocal (N=57)	-.38**	-.32**	-.32**	-.34**	-.30**	-.42**	-.41**	-.16

* $p < .05$

** $p < .01$

significant correlations for the component, "Consultation for Planning Future Activities": Productivity is negatively correlated with the index of concentration for initiators and positively correlated with the index of concentration of receivers. This suggests that if many members consult with a few people, perhaps the team leader or leaders, the interaction will contribute to increased productivity.

DISCUSSION

The data presented provide support for the contingent propositions relating properties of interaction to group productivity. Our results suggest that reciprocal interdependence is an appropriate abstract property on which to conditionalize the relationships between productivity and the amount, type and concentration of interaction. In this section, we will first consider the problem posed by the category of Low Sequential-High Reciprocal Interdependence and then turn to some of the theoretical and practical implications of our findings.

The problem of the Low Sequential-High Reciprocal Category

From the perspective of Thompson's conceptualization, reciprocal interdependence implies sequential interdependence so that in the language of Guttman scaling that Thompson uses, this category is an error type. The 38 teams in this category (19.8% of the sample) do not represent an excessive number of "errors"; hence we cannot say that we have so many cases that this type must be substantively significant rather than error.

Furthermore, if we do treat this type as error and use conventional procedures for dealing with error types, we obtain results that are equivalent to those presented. For example, if we combine Low Sequential-High Reciprocal teams with High Sequential-High Reciprocal or if we randomly distribute these teams between High Sequential-High Reciprocal and Low Sequential-Low Reciprocal, we observe the same pattern of significant correlations as appear in Tables 1, 4 and 5. Thus a case can be made for treating this type as an error type.

There are, however, several arguments against considering the Low Sequential-High Reciprocal category as an error type. Thompson developed his schema to deal with relations between larger units-organizations or large divisions of an organization. Using the concepts at the dyad and team levels allows us to incorporate more nuances into the typology. Thus, on theoretical grounds, we can argue, as we did above, that reciprocal relations can be simultaneous as well as ordered in time. In addition, our questions require respondents to aggregate over time and over different aspects of their work relations. It is possible that i gives j work products for subtask x and j gives i work products for subtask y creating a reciprocal interdependence even though the subtasks may be independent and not ordered in time. These possibilities imply that sequential relations need not be nested in reciprocal relations.

We can also make two empirical arguments. As we noted, the high frequency at the individual level for reciprocal interdependence without sequential interdependence is inconsistent with Thompson's formulation. We might question the validity of our techniques as measures of Thompson's concepts; for example, it may be that respondents took the word "completing"

in the sequential question too literally and were too constrained in checking the roster numbers of other members. We prefer, however, to view this result as indicating that the phenomenon is more differentiated than Thompson's formulation suggests. Particularly for groups engaged in activities of which idea generation is a major component, we believe that group members respond in terms of feedback loops that certainly represent one form of reciprocally interdependent relationship but have no time ordering. If this view is correct, it would imply a modification and expansion of Thompson's conceptualization. The need for modification receives additional support when one considers aggregating individual responses to obtain a team level measure. Even if dyadic relationships were nested as Thompson proposed so that every reciprocally interdependent dyad was also sequentially interdependent, a team could still be above the sample median in the density of reciprocally interdependent dyads and below the sample median in the density of sequentially interdependent dyads.* While an alternative aggregation procedure might eliminate the Low Sequential-High Reciprocal category, such a procedure could introduce other substantive problems.

Our second empirical argument is that there is substantively meaningful variation the low level of overall interaction and the variable levels of density for the four components and this deserves further investigation. We did not expect differences between this type and the "High Sequential-High Reciprocal" type and we need to explain the differences we have observed, particularly since we choose not to treat this category as error.

* For example, this could occur if the sequential sample median was larger than the reciprocal sample median and a team had only reciprocally interdependent dyads with a density that fell between the two medians.

We can explain some, but not all, of the differences between the High-High and the Low Sequential-High Reciprocal. If we plot average pairwise interaction against productivity rating for the Low Sequential-High Reciprocal category, we find three teams that are distinct outliers. If we drop these three teams, then the Low Sequential-High Reciprocal looks more similar to the High-High. We present this comparison in Table 6.

The second column of Table 6 shows that, with the outliers removed, overall interaction, and three of the four components of interaction are significantly related to productivity. In addition, four of the eight concentration measures have significant negative correlations with productivity. With the exception of the measures relating to using others as a sounding board for ideas, the results in the second column of Table 6 are very similar to those for the High-High in Tables 1, 4 and 5. As one might expect, since only three teams were dropped, excluding the outliers does not affect the mean overall interaction, the mean productivity rating and the mean densities.

We regard these results as partially removing the troublesome problem of the Low Sequential-High Reciprocal category, that is, we consider them as providing support for our two propositions. The part of the problem that remains centers around measures involving the "sounding board" relationship and the lack of significant relationships remains to be explained.

Examining the three teams that are outliers is also encouraging. The absolute value of the discrepancy between the external evaluators[1] productivity rating and the median of the team members' rating is .75 for these three teams whereas it is .49 for the sample as a whole. (This difference yields a t of 2.30 and a $p < .050$;) We used absolute values because in one team the external evaluators gave the team the highest

TABLE 6

Comparison of Low Sequential-High Reciprocal Category
Including and Excluding Outliers

Parameter	Original Values (N=38)	Values with Out liers Excluded (N=35)
Average Pairwise Interaction	3.10	3.12
Evaluator Rating of Productivity	1.59	1.56
Partial Correlation between Interaction and Productivity (controlling for team size)	.143	.332*
Mean Density of:		
Technical Assistance	.151	.152
Information Exchange	.221	.226
"Sounding Board"	.129	.133
Consultation for Planning Future Activities	.096	.101
Partial Correlations of Each Component with Evaluator Rating of Productivity:		
Technical Assistance	.106	.282*
Information Exchange	.217	.321*
"Sounding Board"	.028	.161
Consultation for Planning Future Activities	.217	.291*
Partial Correlations of Concentration of Initiators and Receivers of each Component and Evaluator Rating of Productivity:		
Technical Assistance Initiators	-.09	-.26*
Technical Assistance Receivers	.03	-.19
Information Exchange Initiators	-.02	-.25*
Information Exchange Receivers	-.28*	-.41**
"Sounding Board" Initiators	.03	-.19
"Sounding Board" Receivers	.16	.06
Consultation for Planning Initiators	-.20	-.36**
Consultation for Planning Receivers	-.06	-.13

* $p < .05$

** $p < .01$

possible rating and the members gave it a low rating while in the other two teams the members rated the team high and the external evaluators rated it low. These discrepancies indicate a lack of consensus that casts doubt on the validity of evaluator productivity rating for these three teams; if this is correct, then much of the difficulty with the Low Sequential-High Reciprocal type may be due to a measurement problem involving three teams.

Theoretical Implications

We have shown contingent positive relationships between team productivity and amount and type of interaction. It is reasonable to infer from our results that there are some circumstances where group process enhances group output. To some extent, these positive effects of interaction may be natural consequences of the organization of the team-especially the leadership-the technical nature of the team tasks and the general climate in which the team operated. To some extent, these effects may have been the result of deliberate efforts to engineer effective groups. (We know that one of the companies in our study distributes a pamphlet designed to make team members and leaders more effective.) Whether the effects are natural or created, however, the possibility that process can improve product should serve as antidote to the pessimistic view in much of the literature that process is only an interference. While we need to be cautious--teams that are considered productive during the course of their work may not be so regarded at the completion of their projects-we nevertheless conclude that our results justify further exploration of the structural and task conditions that may contribute to the positive

relationship between interaction and productivity in groups with a high degree of reciprocal interdependence among members.

We have also shown that some properties of interaction have negative effects on team productivity where there is high reciprocal interdependence. Concentration of receivers of interaction may reflect the power and status organization of the team, that is, where there is concentration, team members direct their interaction toward team leaders and others who are high status members. If so, this result supports the findings of Nobel (1986) that centralization of decision-making in these teams was negatively related to productivity for tasks involving idea generation.

Concentration of initiators may also reflect the operation of status processes in the team. In some hierarchical organizations, asking for assistance or consulting for planning future activities may entail costs to the initiator; a lower status member may be reluctant to initiate such requests to a higher status person out of fear of revealing incompetence to a superior. If such processes operate in teams with high reciprocal interdependence, they are likely to prevent some needed interactions and thus reduce team productivity.

Linking concentration of initiators and receivers of interaction to features of the status and power structure of the team has a sound theoretical basis (Berger, Cohen and Zelditch, 1966, 1972; Berger, Conner and Fisek, 1974). Direct evidence establishing these linkages are possible with the data from this study and we intend to examine the status and power positions of the high initiators and high receivers in teams where there is high concentration.

It might be argued that the observed effects of interaction are due to the special character of the teams in this study. These teams are long term

groups working on very complex tasks that require both the generation of ideas and their implementation. The team members have high levels of expertise and the range of specialities both supports and benefits from a division of labor. But a large variety of work groups fit these abstract characteristics so that limiting our propositions to groups with these properties would not severely reduce their generality. Of course, the limits of applicability of the propositions remain to be determined, but we believe that they are not restricted to R & D teams in large corporations.

Our results further demonstrate the heuristic value of Thompson's conceptualization and also point to the need for additional development of the concepts. Employing these concepts at the team and dyadic levels opens up a range of possibilities for investigating the structure of small units. Considering reciprocal without sequential interdependence as a non-error type probably entails a reformulation of the concepts. Our results indicate that we can reliably distinguish two types of reciprocally interdependent dyads-one in which the members are also sequentially interdependent and one in which they are not. We need to consider whether making the distinction enables us to generate differential consequences for the two types.

We also need to reconsider sequential interdependence. Thompson's emphasis on the asymmetric nature of this relationship led us to consider it "less interactive" than reciprocal interdependence with its "mutual" character. If member B were sequentially interdependent with member A, B is not necessary to A's work so B's interaction aside from pressuring A to finish should not contribute to A's productivity. The image we have had is that of an assembly line, but our findings suggest that the image is inadequate. Implicitly we treated sequential inter<u>dependence</u> as simply

sequential dependence; we need to explore the implications of this difference.

In this report we have focused on teams as our unit of analysis, but teams in our study, especially the larger ones, are heterogeneous in many respects. Members vary, for example, in the proportion of work time devoted to the team from 10 to 100%; some members are essential to the team's activities while others are expendable. Some teams are made up of two or more loosely connected subteams while others have a "core" of key members surrounded by a "periphery" of individuals who provide specific and limited services to the team. Examining interdependence relations among subgroups or within the core or between core and periphery should provide further insights into how interaction relates to productivity. To this end, we are exploring ways to identify team subgroups and team cores.

The interesting future implications should not obscure what has already been accomplished. We have provided a useful way to measure both sequential and reciprocal interdependence at the group level and, in so doing, have provided additional evidence of the utility of Thompson's typology. We have partially solved the problem of the relationship between properties of group interaction and group productivity by testing and supporting two contingent general propositions. Furthermore, we have formulated the contingency in terms of structural properties of the group and measured these using members' perceptions of their relations with one another. It may indeed be the case that what is important is that people perceive interdependence (Scott, 1981, p. 173). We have also introduced the idea of concentration of initiation and receipt of interaction, measured these concentrations with an index not usually employed in group research and presented results

supporting the utility of both the conceptual and operational aspects of the approach. Finally, we should note briefly a few practical implications of the study. Groups typically have tasks to accomplish, a fact that sometimes is overshadowed in the concern with group process. Where interaction is important, concerns with process may serve to remove barriers and facilitate interaction. But this research indicates that interaction may not always be necessary or even conducive to productivity for reasons having to do with the structure of the group. Furthermore, interaction entails costs as well as benefits; time, interpersonal frictions, coordination efforts, etc., mean that interaction is not a "free good." Hence, even if a task requires input from many different group members, group interaction should be encouraged sparingly for only certain types of work arrangements, namely those where group members perceive a high degree of both sequentially and reciprocally interdependent relationships.

The teams in this study were engaged in tasks involving idea generation and evaluation as major components of team and individual activities. It is precisely these kinds of activities where group interaction should have the most benefit by producing synergistic outcomes. We have always believed that barriers to interaction due to status factors, differences in the technical languages of different specialities and organizational rules (eg., going through appropriate channels) reduce the likelihood of synergy in a group (Kruse et al., 1977). Where such barriers exist, they not only lower the overall level of interaction but produce differentiated patterns such that some members initiate and/or receive most of the interaction. Furthermore, who is high or low in the rate of initiation or receipt may have little to do with potential for contributing to the success of the group in completing its task. Our findings suggest that in High

Sequential-High Reciprocal teams, concentration of initiating and receiving may interfere with generating new ideas and new combinations. If we are correct, then our analysis has a clear practical implication for the management of High Sequential-High Reciprocal teams. Those who set up and/or operate teams of this type need to develop mechanisms to avoid concentrating team interaction among a few initiators and/or a few receivers. Training of team leaders to seek inputs from all members and to encourage all team members to interact with one another over relevant matters may reduce the concentration of both sources and targets of interaction. Elsewhere (Cohen et al., 1982 and Cohen et al., 1986) we have examined a specialized role which we call the "Bridge Role"; one of the main functions of this role is "encourage interaction among team members without imposing an authoritative view." In our conception, effective performance of the Bridge Role will reduce the concentration of both initiators and receivers of interaction. Future studies will examine the consequences of the presence of a Bridge Role on such things as total interaction, concentration of interaction and productivity. The present study, however, by indicating the conditions under which concentration of interaction is negatively related to productivity does point to circumstances where someone, either the team leader or another team member, playing a Bridge Role could be particularly appropriate.

SUMMARY

As part of a larger study of the productivity of R & D teams, we have investigated the relationship between properties of team interaction and team productivity. We were guided in this research by two general

propositions that made the relationships between aspects of interaction and team productivity contingent on a high degree of reciprocal interdependence among team members.

We considered several properties of team interaction: 1) total amount of task related interaction; 2) four components of total interaction, each of which represented interaction for a specific purpose and 3) for each component, the degree to which the initiation and receipt of interaction was concentrated among a small number of team members. Sociometric type questions for each of these properties provided the basic data and we utilized quantities computed on the choice matrices for our measures. We utilized similar procedures to obtain measures of reciprocal and sequential interdependence and we generated four types: Low Sequential-Low Reciprocal, High Sequential-Low Reciprocal, Low Sequential-High Reciprocal and High Sequential-High Reciprocal. Our measure of team productivity utilized ratings made by external evaluators who were not members of the team but were knowledgeable about the team's activities.

Contrary to Thompson's formulation, we found evidence that reciprocally interdependent relations occurred without these relationships also being sequentially interdependent and argued that the High Reciprocal-Low Sequential category did not represent error types. Although we expected correlations between interaction measures and productivity for teams where reciprocal interdependence was high, initially we found these relationships only when both reciprocal and sequential interdependence were high. For High Sequential-High Reciprocal Teams, overall interaction and the frequency of each component were positively related to productivity and seven of eight concentration measures were negatively related to productivity. When three

outliers were deleted from the analysis, however, Low Sequential-High Reciprocal teams yielded results that closely resembled those for High-High. We also suggested directions for further analysis of the nature and consequences of interdependence.

In discussing the theoretical implications of this study, we suggested that: 1) we have provided additional evidence for the utility of Thompson's conceptualization of interdependence as well as evidence for the need to modify his concepts in applying them to relationships among team members and 2) we have demonstrated that general propositions concerning interaction and productivity can be empirically supported without considering the specific, concrete features of the group task if the propositions are made contingent on abstract features of the group structure.

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