

SUPERVISORY PRACTICES AND INNOVATION IN SCIENTIFIC TEAMS¹

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In these days of large scale research and development, most investigations are conducted by teams of scientists or engineers. It seems a reasonable assumption that the supervisors of these groups might affect their subordinates' performance.

For example, a supervisor might make a technical contribution through skillful selection of important but solvable problems, through his own ability to solve a problem, or through guiding subordinates toward a solution. In addition, a supervisor might affect performance by altering the climate within his group. He might inspire subordinates to high achievement, protect them from debilitating outside pressures, or structure the group so subordinates stimulate one another.

Despite the reasonableness and potential usefulness of these hypotheses, they have not been well tested with respect to scientists.

This paper reports results of two analyses exploring the relationship between supervisory practices and scientific performance. First does the team or supervisory group a scientist is in matter at all? I.e., what qualities of scientific performance, if any vary with team membership? Second, if performance does vary from team to team, is this related to practices employed by the supervisor?

Source of the data

The study was conducted in a NASA research center and focussed on 94 non-supervisory scientists who comprised 21 small teams. These men

were engaged in exploring the effects of extreme physical conditions on various materials. The number of scientists in each team, not counting the supervisor, ranged from 1 to 11 (median=5). Each team had its own supervisor and was a reasonably stable entity (two-thirds of the non-supervisors had worked under their present chief for at least two years).

Performance and the supervisory group

Measures of performance

Data were obtained about each non-supervisor's performance. The non-supervisors themselves provided information about their output of (a) technical reports (over the past five years). Also, four qualities of each man's performance were judged by other professionals within his lab. The qualities were:

- b. Innovation -- the extent the man's work had "increased knowledge in his field through lines of research or development which were useful and new."
- c. Productiveness -- the extent the man's work had "increased knowledge in his field along established lines of research or development or as extensions or refinements of previous lines."
- d. Contribution -- the extent the man's work had "contributed to general technical or scientific knowledge in his field."
- e. Usefulness -- the extent the man's work had been "useful or valuable in helping his R & D organization carry out its responsibilities."

These qualities were independently assessed by an average of 4.4 judges, each of whom claimed to be familiar with the man's work. Two-thirds of the judges were supervisors (the man's own chief might be among them), one-third were senior-level non-supervisors. Since the judges showed reasonably good agreement (median gamma for 21 pairs of judges = .8 on the quality of innovation²), their evaluations were

combined into a single percentile score (on each quality) for each respondent.

As is usually found for scientists and engineers, these performance measures varied according to the respondent's length of experience, seniority, and formal training (Pelz and Andrews, 1967). Since these effects could mask relationships between supervisory practices and performance, all performance measures were adjusted by adding or subtracting appropriate constants to remove such background effects.³ Thus the final performance measures for individuals expressed how well or poorly each person performed relative to others with similar experience, seniority, and training.

The interrelationships among these various criteria of performance were about as expected. All evaluations were substantially related to one another (correlations ranged .7 to .8), with innovation being least similar to the others. The objective measure, output of reports, was positively related to each of the evaluations (correlations were all about .4), with the relationship to evaluated productiveness being slightly stronger than to the other criteria.

Was performance related to team membership?

To find out whether performance was related to team membership, the scientists were classified according to supervisory groups, and a one-way analysis of variance was carried out for each performance measure.

There was clear evidence that there were differences in subordinates' innovation that were related to team membership. Differences in innovation between scientists in different supervisory groups were markedly greater than differences between scientists within the same group ($F = 1.89$). Surprisingly, there was no evidence that differences

in the other performance measures were related to team membership!
(The differences between groups were no greater than the differences within them -- all F's \leq 1.00.)

The first finding, if replicated in subsequent studies, may be of considerable importance. It says that a scientist's innovation varied according to the particular supervisory group of which he was a member.

The second finding -- that several measures of performance seemed not to be affected by team-related phenomena -- is not subject^{7a} to clear interpretation. Possibly there simply were no effects. However, a more likely alternative is that complex interactions cancelled out any general effects. For example, a supervisor who tended to act in a certain way may have enhanced the performance of some subordinates, but lowered the performance of others. More data than were available in the present study would be needed to adequately explore these possibilities.

Innovation and supervisory practices

The finding that innovation varied systematically between supervisory groups called for additional analysis. Could the supervisors have accounted, at least in part, for differences in subordinates' innovation? If so, what distinguished the supervisors of more innovative groups from supervisors of less innovative groups?

To answer these questions ten different measures of supervisory behavior were related to group-wide innovation. As will be evident, various combinations of supervisory behavior were examined in addition to the ten simple "zero order" relationships.

Measurement of group innovation

An innovation score for each group was computed by averaging the (adjusted) innovation scores of its members. (Recall that each member's score was itself based on several independent assessments of his innovation.)

Measures of supervisory behavior

Each non-supervisor had answered a lengthy questionnaire which included 36 items inquiring about the respondent's immediate chief. These items asked about a wide variety of supervisory practices suggested by previous research or theory. Most items consisted of a simple descriptive statement (e.g., my supervisor "tends to leave me pretty much on my own"), and the respondent indicated how closely it described his supervisor.

An examination of the interrelationships among these 36 items showed they could be reduced to a smaller number of measures. The 10 measures shown in Exhibit 1 seemed the most efficient way of tapping the various aspects of the original items.

Exhibit 1 here

The 10 measures were derived with the help of a Guttman-Lingoes Smallest Space Analysis (Guttman, 1967; Lingoes, 1965). For readers not familiar with this technique, it can be considered as a means of obtaining oblique factors from a non-metric factor analysis. The resulting measures, of course, were themselves somewhat interrelated (as discussed below), but were thought to be superior to what would have resulted from a conventional orthogonal factor analysis, since they more closely mirrored the actual nature of the data.

Measures A, B, and C all concerned task functions of the supervisor -- his technical competence, effectiveness at critical evaluation, and influence in choosing goals and objectives.

Measures D, E, and F concerned relations between the supervisor and his subordinates, including several practices emphasized by writers such as Likert (1961), McGregor (1960) and Bennis (1964). Measure D was constructed from five highly related items, all of which dealt with the effectiveness of the supervisor at motivating others and getting them to work well together. Measures E and F concerned the supervisor's effectiveness at communicating with people, and his sensitivity to differences between them, respectively.

Measures G and H were both concerned with administrative functions of the supervisor -- his effectiveness at planning and scheduling, and at handling inter-group relations. Administrative skill was one of the key factors in Mann's conceptualization of supervisory "skill mix" (Mann, 1965). (Other factors stressed by Mann were technical skills and human relations skills, and are separately included in the data -- see above.)

And last, two measures of supervisory "style" emerged in the data. Measure I concerned the extent the supervisor consulted others before making important decision. Subordinate participation in decision-making is an important feature of Likert's theorizing (op. cit.).⁴

A second "style" measure, J, considered the extent of freedom allowed subordinates by their supervisor. The topic of freedom in science has received considerable debate and some empirical investigation (see Pelz, 1964; Pelz and Andrews, 1966). Conceptually freedom is related to the often-discussed dimension of close-vs-general supervision.

As has been pointed out, these 10 measures of supervisory behavior were similar to dimensions discussed by various previous investigators. Of course, their work suggested many of the 36 items included in the present study, but there was no requirement that the items would cluster together in the meaningful categories which were actually obtained. The fact that they did so is itself an interesting finding and suggest that a replicable set of concepts for describing supervisors is becoming available.

The 10 measures of supervisory behavior indicated how each non-supervisor perceived his particular chief. For these scores to be useful, they should meet two conditions. First, there should be some evidence of reliability -- i.e., perceptions of non-supervisors who described the same chief should be more similar than those describing different chiefs. Second, there should be evidence that the chiefs themselves behaved differently. A one-way analysis of variance performed on each of the 10 measures showed that these conditions were met. On each measure, descriptions of chiefs differed from team to team, and the differences within teams were less than the differences between them. (All F's > 1.00, median F = 2.02. Of necessity, three teams containing just one non-supervisor were omitted from this particular analysis.)

Group scores. Answers from all non-supervisors under a particular chief were averaged into a single score (on each of the 10 measures).⁵ Thus each supervisor was described in terms of what was common among the perceptions of his subordinates, thereby reducing the effects of idiosyncracies of a particular individual's perception, or special features of the relationship between a particular subordinate and his chief.

The interrelationships among these group scores are shown in Exhibit 2. One can see that most of the measures which seemed conceptually

Exhibit 2 here

related -- task functions, human relations functions, etc. -- did tend to relate positively to each other.

Exhibit 2 contains two other interesting findings. Although Measure B, effectiveness at critical evaluation, seemed to have a task content and did relate to one of the other task items, Measure B related even more strongly to several measures in the human relations and administrative areas. Apparently among these supervisors, the successful exercise of critical evaluation was not solely a task function. Similarly, the supervisor's administrative skill at handling relations between his group and other groups was substantially related to his skills in the human relations area.

While interrelationships among skills in various areas might suggest that classification into three functional areas was not useful, one should reserve judgment on this matter. Data presented in Exhibit 3 will show that skills in the same area related to performance in similar ways, but that skills in different areas related differently. On this criterion, the present classification was indeed useful. Also, it should be noted that Mann (1965) found that relationships between skills in the various areas varied markedly in different kinds of organizations and for workers at different levels in the hierarchy. This suggests that relationships shown in Exhibit 2 should be viewed with caution until further studies can assess their representativeness.

Relationships of supervisory behavior to innovation

Exhibit 3 shows how each of the 10 aspects of supervisory behavior, as perceived by the supervisor's own group of subordinates, related to average innovation in his team. In the light of previous research and theory, some of these relationships were surprising, but discussion is withheld for a later section.

Exhibit 3 here

With respect to task functions, a reasonably consistent positive trend appeared. Supervisors who were perceived as being skilled or influential in the task area tended to have subordinates whose work was judged as more innovative than supervisors who were less effective in this area. The trend for Measure A, technical skills, was sharpest. Those for critical evaluation and influence on goals were in the same direction but weaker.

In the human relations area, only one of the three measures showed any substantial relationship to innovation. There was, however, a consistent, and unexpected, tendency for supervisors scoring highest on human relations to have the least innovative subordinates! Highest innovation tended to occur under supervisors who scored moderate on human relations. This finding is different from what has often been found for non-professional workers (Likert, 1961, provides a summary).

The two measures concerned with the supervisor's administrative functions showed consistent, and again surprising, relationships with subordinates' innovation. The more effective the supervisor was at administration, the lower the judged innovation of his group! For Measure I, skill at handling inter-group relationships, this trend was

substantial. Measure H, effectiveness at planning and scheduling, showed the same trend in weaker form. Although organizational scholars have generally assumed that the exercise of administrative functions would enhance a group's performance, this was clearly not the case for innovation by these scientists.

Finally, the two measures of leadership style, use of consultation and provision of freedom, showed moderate relationships to innovation. For both measures, innovation was higher when supervisors scored either high or low than if they scored in the middle. Further analysis, discussed in the next section, clarified the meaning of these trends.

Thus Exhibit 3 suggests that innovation flourished under supervisors who were effective at task functions. But human relations and administrative functions were not positively related to innovation -- in fact, relationships tended to be curvilinear and/or negative.

Combinations of supervisory practices

In addition to examining the simple relationships between each supervisory function and subordinates' innovation (shown in Exhibit 3), relationships involving all possible pairs of supervisory practices were also examined.

Freedom. Exhibit 3 showed a curvilinear, though generally positive relationship between a supervisor's provision of freedom and subordinates' innovation. The meaning of this relationship became clearer when several other supervisory practices were considered in combination with freedom. Results appear in Exhibit 4.

Exhibit 4 here

Note that provision of freedom showed substantial positive relationships with innovation in teams headed by supervisors who scored low on

task functions (Measures A and B), low on human relations functions (Measures D, E, and F), or low on administrative functions (Measure H). But in teams headed by supervisors who were effective in these areas, provision of freedom mattered less, and sometimes even related negatively.

This finding made good sense, and suggests that provision of freedom was a substitute for skillful leadership! In teams headed by less skillful leaders, innovation was high if subordinates were given freedom to explore on their own. But less skillful leadership combined with lack of freedom was associated with less innovative work.⁶

Consistency in leadership practices. Other particularly interesting sets of relationships suggested that there were certain combinations of leadership practices which should occur together.

For example, critical evaluation went with innovation if the supervisor was technically skilled ($r = +.5$ for supervisors with high technical skills -- no table shown). But innovation was low when supervisors low in technical skills attempted to evaluate subordinates' work ($r = -.5$). Thus the relationship between critical evaluation and innovation depended on the supervisor's technical skill. Exercise of critical evaluation needed to be consistent with possession of adequate technical skill.

A second example of the need for consistency occurred when the practices of providing freedom and of consulting others were examined. Freedom was unrelated to innovation if the supervisor failed to precede his own decision-making by some consultation with others. But the relationship was substantial if freedom for subordinates was combined with a chance to influence decisions being made by the supervisor. (Among supervisors

making use of consultation, $r = +.7$, but for supervisors making little use of consultation $r = -.1$ -- no table shown.) This also seemed intuitively reasonable.

Administrative functions. It has generally been assumed that the skillful exercise of administrative functions would result in high performance. Yet Exhibit 3 provided surprising negative relationships -- exactly opposite to the usual assumption.

Exhibit 5 provides further information and shows that the negative relationships occurred mainly for supervisors who scored high in the human relations area.

Exhibit 5 here

Among supervisors who were skilled at motivating others, effective at letting others know where they stood, and sensitive to differences between people, administrative functioning seemed incompatible with innovation. The highest innovation occurred under supervisors who were seen as relatively poor administrators; low innovation occurred under good administrators! (Note that five out of six correlations were strongly negative.) But among supervisors who scored low on human relations, administration was only weakly related to innovation.

Task and human relations skills. In addition to the combinations of practices already described, a careful examination was made of various skills in the task and human relations areas. Blake and Mouton (1964) have suggested that relationships between skills in one area and productivity should be especially strong when skills in the other area are also present. Oaklander and Fleishman (1964), Kahn (1956), and many others have also suggested the same idea. There was no evidence, however, that such a phenomenon occurred for these scientists. Whether the supervisor

was skilled in the human relations area had little effect on the generally positive relationships between task functioning and innovation. Similarly, skills in the task area did not affect relationships between human relations functions and innovation.

Discussion

This paper set out to explore relationships between supervisory practices and scientific performance. A key preliminary question was whether the supervisor mattered at all. When performance was measured in terms of innovation, the answer was "yes": systematic differences between supervisory groups were clearly evident. Furthermore, these differences were related to supervisory practices.

Thus while firm statements of cause and effect are not appropriate with these data, the findings do suggest that the supervisor may play an important role in enhancing or depressing innovation.⁷ For several other aspects of performance, however, there was no evidence that the supervisor had a group-wide effect. Possible reasons for this have already been presented.

When specific supervisory practices were examined, the data presented two surprises and also some potentially useful findings. The surprises are discussed here; the implications, in the next section.

Surprise #1. One surprise was that none of the several measures of supervisory skill in the human relations area related to innovation. Organizational scholars have suggested that human relations functions serve to enhance employee motivation and to facilitate the flow of information. Why did the present results differ?

One reason may be that scientists are different from the non-professional "rank and file workers" who were subjects in most previous studies. For example, it may be that scientists, compared to non-

professionals, are stimulated more by the work itself and less by the social conditions which accompany it. Our findings on the importance of the supervisor's task functions support this speculation.

Alternatively, the difference between our results and those of many previous studies might be attributed to the nature of the task rather than to the nature of the people performing it. Fiedler (1965) found that directive, task-oriented leaders were more effective either in situations which were very favorable for the leader (where the leader had strong power, good relations with his subordinates, and a highly structured task) or in situations which were very unfavorable for the leader. But in situations falling midway between these extremes Fiedler found human-relations-oriented leaders more effective.⁸ Future research on supervision probably should consider the nature of the task more carefully than has been done here and in most previous studies.

And finally, the difference between our findings and those of previous studies may be attributable to examination of different criteria. The present study used performance -- particularly, innovation -- as the criterion of good supervision. In contrast, the criteria used by previous studies have included satisfaction, grievances, turnover, absenteeism, scrap loss, morale, and stress. Human relations may be more important with respect to these criteria than for innovation.

Surprise #2. A second surprise was the markedly negative relationships between the supervisor's performance of administrative functions and his subordinates' innovation. Once again, the findings were opposite to assumptions usually made (but rarely tested) by organizational scholars. Of particular importance was the discovery that these negative relationships were most likely to occur when the supervisor scored high

on human relations.

A major issue here would seem to be the direction of causality. On the one hand, the effective exercise of administrative functions, such as planning and scheduling, may have produced a rather rigid setting which left subordinates little room for innovation. This interpretation would be in close accord with a previous study which showed that creative ability paid off only in flexible situations (Andrews, 1967).

On the other hand, it is possible that causality operated in the other direction. Perhaps supervisors who headed innovative groups were less effective in the administrative area precisely because innovation made administration more difficult.

Both interpretations seem plausible, and, in fact, both may have been operating. There seems to be a fundamental dilemma here for organizations seeking innovation: How can organizations, which always require a certain degree of coordination and interdependence among people and work groups, remain sufficiently flexible to encourage innovation from within? Unfortunately, few studies have been explicitly concerned with organizational conditions enhancing innovation.

Summary and implications

What does this study imply for the director of a research laboratory, the supervisor of an R & D team, or others attempting to encourage innovation within an organization? Let us speculate, recognizing that further research will be needed to assess the generality of our results and their causal dynamics.

Greatest innovation occurred under supervisors who knew the technical details of their subordinates' work, who could critically evaluate that work, and who could influence work goals. Thus the widespread practice of including technical competence among the criteria for choosing supervisors

seems to be sound. This does not mean that a supervisor should constantly "meddle" in his subordinates' activities. But he should be available, competent in the current "state of the art," actively interested in the project, and informed about it. These, in turn, imply that the supervisor should "keep his hand in," perhaps by actually conducting research himself. He probably should not spend all his time monitoring the work of others. Furthermore, for a supervisor to be technically "close" to the activities of his subordinates, his supervisory responsibilities probably should be limited to only a few projects.

What if this kind of structure is not possible, or if a supervisor's technical competence has become obsolete? Again, the data were clear: provide substantial freedom for subordinates. Freedom acted as a partial substitute for skilled supervision. But even when subordinates have freedom, the supervisor still makes some kinds of decisions. For freedom to be effective, the data showed that the supervisor must consult with his subordinates before making these decisions.

Previous research (Pelz and Andrews, 1966) suggests that under complete freedom subordinates may engage in trivial problems, become lazy, and stagnate. To avoid this, the wise supervisor who cannot exercise task functions should attempt to combine freedom with stimulation from sources other than himself. For example, he might arrange meetings where subordinates could present, discuss, and critically evaluate one another's work. The present study showed a technically weak supervisor should not undertake critical evaluation himself.

What about the human relations and administrative functions? Here our recommendations must differ from those often made to supervisors of non-professional workers. We found that innovation tended to be low when

supervisors were thought to be effective at human relations or administration, and especially low when supervisors were effective at both.

If the supervisor is not particularly skilled as an administrator and is somewhat cool toward his men, this need not cause great concern. In fact, freeing supervisors from responsibilities in the human relations and administrative areas may enhance innovation. But since these areas do need attention, there may need to be some other person with responsibility for them. Some organizations assign this responsibility to an "assistant director" or "executive head."

On the other hand, what should a supervisor do if he happens to be skilled at administration and/or human relations -- consciously act ineffectively? Probably not. Should he simply turn subordinates loose? The data say this would not help. One suggestion is that he might attempt to increase the size of each subordinate's own "professional arena." Each subordinate might be encouraged to take on additional tasks, evolve contacts with outside groups, or try new methodologies. These should result in an increased self-reliance and an increased capacity to move in innovative directions.

Exhibit 1.. Ten measures of supervisory behavior and items from which they were derived.*

Task functions

A. Technical skills (an index based on the sum of:)

"He knows a great deal about doing the jobs in my special area"

"He has a good understanding of the body of knowledge that is relevant to my work"

"He has a good understanding of the techniques and methods I use in my work"

B. Effectiveness at "providing critical evaluation"

C. Influence in choosing goals and objectives for subordinate's work

("Consider the choice of goals or objectives of the various technical activities for which you are responsible...Estimate the relative percent of weight exerted by each of the following." Items included "my immediate supervisor.")

Human relations functions

D. Effectiveness at motivating others (an index based on the sum of:)

"He is effective for providing enthusiasm for the work"

"He is effective for providing appreciation and encouragement"

"He is effective at getting people to work well together"

"He is effective for giving recognition for a job well done"

"He is very concerned that I grow and get ahead professionally"

E. Effectiveness at "letting people know just where they stand"

F. Sensitivity to "differences between people"

Administrative functions

G. Effectiveness at "carrying out needed planning and scheduling"

H. Effectiveness at "handling relations between his group and other groups"

Leadership styles

I. Use of consultation in decision-making (an index based on the sum of:)

"He makes most important decisions affecting group activity himself, after consulting others"

"He makes most important decisions affecting group activity himself, without consulting others" (SCALE REVERSED)

J. Provision of "freedom for people under him to explore, discuss, and challenge ideas on their own"

* For all items except that in measure C, the respondent checked a seven-point scale to indicate how closely the statement described his supervisor. For Measure C, the respondent showed the percent of weight exerted by his supervisor.

Exhibit 2. Correlations among average perceptions of supervisor's behavior. (N = 21 teams.)

<u>Measure</u>	A	B	C	D	E	F	G	H	I
A. Technical skills									
B. Critical evaluation	.3								
C. Influence on goals	.6	.0							
D. Motivating others	.0	.6	.0						
E. Let know where stand	-.1	.4	-.1	.5					
F. Sensitivity	.1	.4	-.3	.6	.5				
G. Plan and schedule	-.1	.4	.1	.3	.2	.3			
H. Inter-group relations	.1	.5	-.2	.6	.4	.8	.5		
I. Use of consultation	-.3	.2	-.3	.4	.3	.3	-.1	.1	
J. Freedom	-.1	-.1	-.3	.0	-.1	.1	.1	.2	.2

Exhibit 3. Relationships between subordinates' innovation and various practices of their immediate supervisors. (Vertical scales show mean innovation. Horizontal scales show three sets of supervisors: those scoring low, medium, and high on the designated measure. Each point is based on data from approximately 7 supervisory groups.)

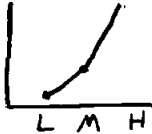
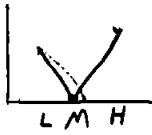
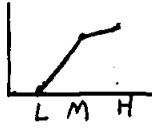

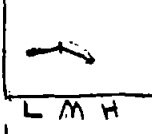
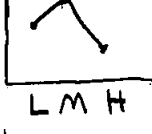
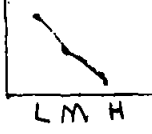
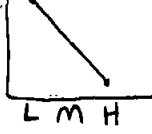

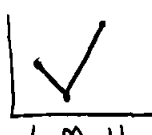
Measure	Trend	Eta	F
Task functions			
A. Technical skills		.52	3.36
B. Critical evaluation		.33	1.13
C. Influence on goals		.28	0.78
<u>Human relations functions</u>			
D. Motivating others		.47	2.48
E. Let know where stand		.04	0.01
F. Sensitivity		.22	0.44
<u>Administrative functions</u>			
G. Plan and schedule		.30	0.89
H. Inter-group relations		.53	3.57
Leadership styles			
I. Use of consultation		.43	2.00
J. Freedom		.33	1.12

Exhibit 4. Correlations between subordinates' innovation and their supervisor's provision of freedom, separately for designated groups of supervisors.

<u>Characteristics of supervisor</u>	<u>Correlation</u>
A. Technical skill	
High (N=10 teams)	.0
Low (N=11 teams)	.6
Effectiveness at	
B. critical evaluation	
High (N=10 teams)	.0
Low (N=11 teams)	.4
D. Skill at motivating others	
High (N=10 teams)	-.3
Low (N=11 teams)	.5
E. Effectiveness at letting others	
know where they stand	
High (N=11 teams)	-.4
Low (N=10 teams)	.6
F. Sensitivity to differences between people	
High (N=11 teams)	.1
Low (N=10 teams)	.4
H. Skill at handling inter-group relations	
High (N=10 teams)	-.2
Low (N=11 teams)	.6

Note: Measures C and G do not appear in this exhibit since the relationship between innovation and freedom was not markedly affected by them.

Exhibit 5. Correlations between subordinates' innovation and two measures of their supervisor's administrative skills, separately for supervisors high and low in human relations skills.

<u>Characteristics of supervisor</u>	<u>Correlations between innovation and:</u>	
	<u>Effectiveness at planning and scheduling</u>	<u>Effectiveness at handling inter- group relations</u>
D. Skill at motivating others		
High (N=10 teams)	-.7	-.5
Low (N 11 teams)	.2	-.3
E. Skill at letting others know where they stand		
High (N=11 teams)	.1	-.6
Low (N 10 teams)	-.2	-.1
F. Sensitivity to differences between people		
High (N=11 teams)	-.5	-.5
Low (N=10 teams)	.5	-.1

References

- Andrews, F. M. Creative ability, the laboratory environment, and scientific performance. IEEE Transactions in Engineering Management, 1967, in press.
- Bennis, W. G. Goals and meta-goals of laboratory training, in Bennis, W. G., Schein, E. H., Berlew, D. E., and Steele, F. I. (Eds.) Interpersonal Dynamics: Essays and Readings on Human Interaction. Dorsey Press, Homewood, Ill., 1964.
- Blake, R. R. and Mouton, Jane S. The Managerial Grid. Gulf Publishing Company, Houston, Texas, 1964.
- Fiedler, F. E. Leadership: a new model. Discovery, April 1965, 12-17.
- Guttman, L. A general non-metric technique for finding the smallest Euclidean space for a configuration of points. Psychometrika, 1967, in press.
- Kahn, R. L. The prediction of productivity. Journal of Social Issues, 12, 1956, 41-49.
- Likert, R. New Patterns of Management. McGraw-Hill, New York, 1961.
- Lingoes, J. C. An IBM-7090 program for Guttman-Lingoes smallest space analysis: I. Behavioral Science, 10, 1965, 183-184.
- Mann, F. C. Toward an understanding of the leadership role in formal organization. In Dubin, R., Homans, G. C., Mann, F. C. and Miller, D. C. Leadership and Productivity. Chandler, San Francisco, 1965.
- McGregor, D. The Human Side of Enterprise. McGraw-Hill, New York, 1960.
- Oaklander, H. and Fleishman, E. A. Patterns of leadership related to organizational stress in hospital settings. Administrative Science Quarterly, 8, 1964, 520-532.
- Pelz, D. C. Freedom in research. International Science and Technology, February 1964, 54-66.
- Pelz, D. C. and Andrews, F. M. Autonomy, coordination, and stimulation in relation to scientific achievement. Behavioral Science, 11, 1966, 89-97.
- Pelz, D. C. and Andrews, F. M. Scientists in Organizations: Productive Climates for Research and Development. Wiley, New York, 1967, in press.

Footnotes

- 1 These data were collected and analyzed under NASA grant NsG-489/23-005-014 as part of a long range investigation of scientists and engineers. Dr. Donald C. Pelz is the general director of this research program.
- 2 Since these data did not represent a probability sample from some defined population, and since the purposes of the study were descriptive rather than inferential, it would have been inappropriate to compute tests of "statistical significance." The criteria for reaching conclusions throughout this article were that a trend be clear and, where appropriate, reasonably consistent. Readers accustomed to looking for tests of statistical significance, however, can be assured that many of the trends would appear as "significant" if tested in conventional ways and that the general conclusions were not altered by the decision not to test "significance."
- 3 The procedures for collecting, combining, and adjusting the performance measures used in this study were highly similar to those more fully described in Pelz and Andrews (1967).
- 4 Likert also considers joint decision-making. In addition to the two items composing Measure I, the questionnaire contained an item asking specifically about the extent the supervisor encouraged his group to make decisions jointly. This item proved to be highly related to both Measures D and I, and therefore has not been scored separately.
- 5 These mean scores were transformed to rectangular distributions. A seven-point scoring was used whenever correlations were computed. Two- and three-point scorings were also used, as will be evident.
- 6 These findings suggest that provision of freedom was affecting innovation rather than the reverse. If high innovation were the cause of a group of subordinates being awarded freedom, one would expect to see positive correlations between freedom and innovation in teams headed by the more skillful supervisors, i.e., the more skillful supervisors would be more likely to match the reward of freedom with innovation. But this was not the case. Rather, Exhibit 4 shows that in groups headed by more skillful supervisors freedom and innovation were only weakly related.
- 7 Although causal directions cannot be firmly identified, it should be noted that the measures of supervisory practices and performance derive from completely different sources. Thus the findings cannot be attributed to a simple "halo effect." (See also footnote 6.)
- 8 Although Fiedler's idea seems useful, his method of typing leaders forced them into either the task or human relations orientations. It did not permit separate examination of leaders high (or low) in both orientations. Furthermore, he hypothesizes that creativity will be "forbidden" under task-oriented leaders, a result clearly not supported by the present data.