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TECHNOLOGY–INFORMATION PROCESSING FIT AND THE PERFORMANCE OF R&D PROJECT GROUPS: A TEST OF CONTINGENCY THEORY

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A study of 98 R&D project groups using a longitudinal design found support for the contingency theory hypothesis that the fit between a task technology's nonroutineness and information-processing needs will predict project performance. The hypothesis was supported for concurrent and one-year-later management ratings of project quality, using absolute difference scores as a measure of fit. The fit between a technology's unanalyzability and information processing, however, was not a predictor of project performance. Implications for contingency design theory and the management of R&D project groups are discussed.

A paramount question of contingency theory models is how task technology influences the information-processing requirements of an organizational unit. Several theorists have made information processing the integrating or central concept in models that attempt to describe how organizations can match different technologies to the design and structure of units in order to achieve high unit performance (Cohen & Levinthal, 1990; Daft & Lengel, 1984, 1986; Galbraith, 1977; Nadler & Tushman, 1988; Tushman & Nadler, 1978). The basic notion of these models is that a proper fit between the complexity of a task technology (henceforth, technology) and the information-processing activity of an organizational unit will result in high unit performance. Generally, in these models nonroutine and unanalyzable technologies are posited to require a high amount of organizational information processing for effective performance, and routine and analyzable technologies to need only a low amount of information-processing activity (Perrow, 1967; Thompson, 1967; Withey, Daft, & Copper, 1983). The present study tested important contingency design theory hypotheses between fit and project group performance with a longitudinal research design, with fit conceptualized as a match between technology and information processing.

In this research, routineness was defined as technologies with repetitive

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and predictable tasks; this definition is similar to that used by Miller, Glick, Wang, and Huber (1991) and reflects the items in the Withey and colleagues' (1983) exceptions scale from their measure of work unit technology. Perrow (1967) used the term "exceptions" (unexpected events) and referred to technologies with a combination of few exceptions and analyzable problems as routine. The present use of the term routineness for the ideas captured by the exceptions scale alone, however, more closely describes the concept and its measurement. Perrow defined analyzability as the existence of analytic procedures to solve a problem. Information processing was primarily the amount of communications among the scientists and engineers working in project groups, both within and outside their groups. Prior research has found these communications to be critical for project group success (Allen, 1977; Katz, 1982; Tornatzky & Fleischer, 1990).

Daft and Lengel (1984, 1986) have been especially influential in their emphasis on information processing as a way by which organizations reduce the ambiguity and uncertainty that they face. Generally, the problem organizations face is a lack of clarity (equivocality) rather than a lack of data. Those authors argued that the amount and richness of information processing and the communication media used should be appropriate to the level of task uncertainty. For example, the best way to process information that is high in richness, defined as the ability to change understanding, is through a face-to-face medium. To Daft and Weick (1984), organizations acted as interpretation systems by scanning and collecting data from their environments, interpreting or giving meaning to the data, and then learning by acting upon the interpretation. Daft and Lengel's (1986) notions are central to contingency design theory, according to which a proper match between task technology and amount of information processing results in high unit performance. Daft and Lengel posited a positive relationship between the nonroutineness (uncertainty) faced by a work unit and the need for increased information processing for task performance, a proposition specifically relevant to the present study and reflected in Hypothesis 1. Further, they saw the unanalyzability (equivocality) of technology as a second force that increases the amount of information processing needed to perform tasks (see Hypothesis 2).

Prior research on the fit between technology and information processing, however, has been limited. Hrebiniak (1974) found technology to be related to coordination within work units. Tushman (1979) found that research projects with decentralized communication patterns and technical service projects with hierarchical communication patterns were better performers. Hence, it appears that communication structure and task requirements must be coordinated for high performance. Ancona (1990) studied five consulting teams and found that external activities were better predictors of team performance than internal group processes when a team faced external dependence. Two other studies have found that technology was related to activity spanning intra- or interorganizational boundaries (Leifer & Huber, 1977; Tushman, 1977). More recently, Ito and Peterson (1986) found that the task difficulty dimension of technology (Perrow, 1967) predicted boundary-spanning activity by work unit members. Unfortunately, this study, as well as several others in the literature, did not measure performance. Therefore, it is really not known whether a fit between technology and information processing results in higher unit performance—a critical question in contingency theory.

A research and development (R&D) project group is a particularly useful unit of analysis in which to test hypotheses from contingency theory that match technologies and information processing requirements. Project groups can be expected to vary on the degree of uncertainty in their technologies; information processing in project groups, particularly communications among scientists and engineers, has been found to be a critical variable for project success in prior research (Katz, 1982; Katz & Allen, 1985; Tornatzky & Fleischer, 1990); and these groups tend to be self-contained to a substantial extent, with project-level performance a meaningful and measurable variable. Information processing in a project group context includes communications within and outside a group. Both domains are important because the primary activities of project groups are to import scientific and technological information, communicate and process the information into technological innovations, and then export the innovations to another part of the organization or outside the organization.

Venkatraman (1989) argued that how fit is conceptualized in a research effort has important implications for the formation of hypotheses and the analytical technique used to test for relationships. In the present study, fit was conceptualized as a theoretically defined match between information processing and technology, following Daft and Lengel's (1986) argument that the amount of information processing should be matched with the forces of the nonroutineness (uncertainty) and unanalyzability (equivocally) of a work unit's technology. Specific hypotheses about the fit between information processing and each dimension of technology were then formulated, following Schoonhoven's (1981) suggestion to avoid ambiguous hypotheses.

> *Hypothesis 1: Project groups with a level of nonroutineness closely matched with their amount of information processing will be higher performers than those lacking such a match.*

> *Hypothesis 2: Project groups with a level of unanalyzability closely matched with their amount of information processing will be higher performers than those lacking such a match.*

METHODS

Respondents

Professional employees from four industrial R&D organizations participated in the research. R&D organizations were selected because their matrix designs—superimpositions of project groups on existing functional-based units—created project groups that were self-contained to a considerable extent and because performance on the project group level was important to the organizations and was measured. Questionnaires were obtained from a set of 98 project groups comprising 683 professionals, representing a 90 percent response rate. Eighty-seven percent of the respondents were men, and the average age of all respondents was 36 years. All held baccalaureate degrees, and 75 percent held graduate degrees. The average project group contained 8 professionals, and the average tenure in groups was 31 months. During the time of this study, each respondent belonged to only one project group.

Measures and Procedures

The ten-item scale developed and validated by Withey and colleagues (1983) to measure Perrow's (1967) two dimensions of work unit technology was used in the present study. A principal axis factoring analysis (communality estimates on the diagonal of the correlation matrix) was conducted for the present data, with an oblique rotation that resulted in a two-factor solution with loadings similar to those reported by Withey and colleagues. Factors were retained in this and subsequent factor analyses when they had eigenvalues before rotation greater than 1.0 and a natural break occurred in a scree plot. In addition, a factor loading of greater than .40 was required for the assignment of an item to a factor. Ratings were then scored in a certain direction. Coefficient alpha reliabilities are reported in the diagonal of the correlation matrix (Table 1). A five-point response scale ranging from "to a small extent" to "to a great extent" was used. *Nonroutineness* was measured by five items scored in the direction of nonroutineness; an eigenvalue of 7.23 was obtained, and 49 percent of the variance was explained. *Unanalyzability* was measured by five items scored in the direction of unanalyzability; an eigenvalue of 4.40 was obtained, and 27 percent of the variance was explained. A confirmatory factor analysis of this instrument also supported the two-factor solution Withey and colleagues reported (χ^2_{34} = 87.93, $p < .01$, goodness-of-fit index = .922, adjusted goodness-of-fit index = .873, root-mean-square residual = .049).

Information processing by a project group was measured by a five-item scale developed from the prior research on communication and information flows in R&D project groups (Allen, 1977; Katz, 1982; Keller & Holland, 1983). Four items asked about the amounts of information communicated (1) within a project group, (2) outside the project group but within the R&D organization, (3) outside the R&D organization but within the company, and (4) outside the company. The fifth item asked about the amount of written information used in the project group, including reports, journals, and so forth. A five-point response scale was used ranging from "very low" to "very high." A principal axis factoring of these five items and an oblique rotation revealed only one clear factor with an eigenvalue greater than 1.0 before rotation (4.27, 69 percent of variance explained). As a concurrent validity check on the information-processing scale, one R&D organization in the present study had items in a separate section of the questionnaire that asked the individual respondents how many times others had asked them for information on a work-related matter and how many times they had asked others for work-related information. This scale was aggregated to the project group level and obtained a correlation of .45 ($N = 32$ project groups, $p < .01$) with the information-processing scale.

Technology–information processing fit was measured by the simple and direct technique used by Alexander and Randolph (1985) and David, Pearce, and Randolph, 1989. Venkatraman (1989) saw this technique as appropriate for testing relationships when fit is theoretically defined as a match between two variables that are independent of a performance measure, which was the conceptualization of fit in the present study. This technique reduces several problems encountered in prior research on contingency theory: the measurement error and interpretation problems associated with residuals from regression equations (Dewar & Werbel, 1979), the multicollinearity and interpretation problems that arise with the use of interaction terms (Dewar & Werbel, 1979; Schoonhoven, 1981), and the problems of restriction of range, reduced sample size, and interpretation of the magnitude of fit that occur with the split-sample approach (Alexander & Randolph, 1985; Argote, 1982; David et al., 1989). The absolute difference technique called for conceptualizing the two technology variables, nonroutineness and unanalyzability, and the information-processing variable as five-point scales. Fit was then defined as the absolute difference between the values for nonroutineness and information processing and the absolute difference between the values for unanalyzability and information processing. Thus, for each value of nonroutineness or unanalyzability, there is a best value of information processing that results in high project group performance. The closer the fit of the two variables, the higher the expected performance. The two fit measures were reverse-scored so that higher values reflected higher fit. A fit score of 4 would be a perfect match and would predict high performance, and a fit score of 0 would be a perfect mismatch and predict low performance. Hence, with this measure the concept of contingency theory fit is directly interpretable, and the hypotheses can be unambiguously tested. It is important to note, however, that this technique for measuring fit can be susceptible to bias in the wording or scaling of questionnaire items since difference scores are used. To minimize these scaling differences, the scores were standardized, using Z scores, before difference scores were computed. The resulting variables, *nonroutineness–information processing fit* and *unanalyzability–information processing fit*, had difference score reliabilities, based on the formula in Cohen and Cohen (1983), of .71 and .67, respectively.

Project group performance was measured by management ratings of five criteria developed through discussions with management in each organization aimed at identifying the important dimensions of effectiveness (Sundstrom, De Meuse, & Futrell, 1990). These criteria, which were similar to those the R&D organizations studied used internally, were technical quality, budget and cost performance, meeting an assigned schedule, value to the company, and overall group performance. Respondents used a five-point response format (1 = very low, 5 = very high) for these items. A panel of managers in each of the four R&D organizations rated the five criteria, once at the time of the administration of the questionnaire (time 1) and again one year later (time 2). Three to seven managers in each organization who were familiar with the project groups they rated each rated from 9 to 19 projects. At the time of the one-year-later ratings, 91 of the original 98 project groups remained and were rated by the manager panels. On the basis of a factor analysis of project group members' responses (not reported), technical quality, value to the company, and overall group performance were combined to form the variable *project quality*, and the remaining two criteria were combined to form *budget-schedule performance*. Interrater reliabilities, computed as intraclass correlation coefficients (ICCs [1,k]; Shrout & Fleiss, 1979) for project quality were .77 for both rating times, and for budget-schedule performance they were .76 for the initial rating and .74 one year later.

Data collection procedures were the same in all four organizations. Respondents completed the questionnaire during normal business hours on site at each organization in groups ranging from 30 to 70 members each. Only the researcher was present, and confidentiality of all information was guaranteed by the researcher and the management of each organization.

RESULTS

Table 1 gives means, standard deviations, and a correlation matrix for the variables. Correlations among the independent variables had a median value of .44 and a maximum value of .57, with a maximum variance inflation factor of 3; hence, multicollinearity was not a severe problem that would preclude interpretation of the regression analyses (Neter, Wasserman, & Kutner, 1983). Table 2 presents the results of the regression analyses for the independent variables and the project group performance ratings by management at times 1 and 2. The table reports full-equation standardized regression coefficients for the independent variables entered simultaneously. In addition, a series of hierarchical multiple regression analyses was conducted to determine the unique variance, measured as the increment in R^2 and the F-value, each independent variable contributed to the performance variables.

The fit between nonroutineness and information processing was clearly the best predictor of project quality at both times. Nonroutineness–information processing fit, did not, however, predict budget-schedule performance. Neither of the two technology variables predicted either performance variable by itself or as a combination. Further, unanalyzability–information processing fit was not a predictor of either performance variable. Information processing by itself, however, did predict project quality at both times. Also, information processing by itself did predict budget-schedule performance at time 1. For the prediction of project quality, how-

TABLE 1
Means, Standard Deviations, and Correlations[a]

Variables	Mean	s.d.	1	2	3	4	5	6	7	8	9	10
1. Nonroutineness	18.10	3.09	(80)									
2. Unanalyzability	15.91	3.71	.43**	(82)								
3. Information processing	16.24	3.91	.25*	.19	(78)							
4. Nonroutineness–information processing fit[b]	1.77	0.84	.52**	.07	.57**							
5. Unanalyzability–information processing fit[b]	1.13	0.51	.13	.44**	.52**	.47**						
6. Project quality, time 1	12.40	2.45	.15	.04	.20*	.26**	.08					
7. Budget-schedule performance, time 1	7.66	1.72	−.04	−.16	.08	.09	.10	.31**				
8. Project quality, time 2	12.53	2.39	.16	.10	.22*	.40**	.15	.64**	.43**			
9. Budget-schedule performance, time 2	7.55	1.50	.05	.01	.11	.08	.10	.32**	.60**	.46**		
10. Tenure	31.17	14.49	.08	−.06	.10	.11	.03	.08	.09	.07	.09	
11. Tenure variation	0.46	0.21	.06	−.08	.05	.01	−.03	.12	.01	.04	.07	.84**

[a] N was 98 project groups for time 1 variables and 91 for correlations between time 1 variables and time 2 project quality and budget-schedule ratings. Numbers in the parentheses on the diagonal are coefficient alpha reliabilities.
[b] Fit was measured as the absolute difference between each pair of variables.
* $p < .05$
** $p < .01$

TABLE 2
Results of Regression Analyses[a]

Variables	Project Quality, Time 1			Budget-Schedule Performance, Time 1			Project Quality, Time 2			Budget-Schedule Performance, Time 2		
	β	R^2 Increment	F	β	R^2 Increment	F	β	R^2 Increment	F	β	R^2 Increment	F
Nonroutineness	.09	.00	0.93	−.15	.01	1.66	.13	.01	3.00	.00	.00	0.47
Unanalyzability	−.08	.01	2.74	−.09	.00	0.85	.08	.01	2.91	.11	.01	2.19
Information processing	.32*	.06	5.22*	.22*	.04	4.12*	.24*	.04	4.31*	.16	.02	3.22
Nonroutineness–information processing fit	.39**	.11	8.89**	.07	.01	2.91	.47**	.14	11.53**	.03	.00	1.01
Unanalyzability–information processing fit	.12	.02	3.60	.14	.01	3.26	.11	.02	3.77	.15	.01	2.90
Adjusted multiple R^2	.34			.16			.34			.10		
Overall F	9.48**			3.50*			8.76**			1.89		

[a] β is the standardized regression coefficient. The R^2 increments and F-values are derived from hierarchical regression analyses. N was 98 project groups at time 1 and 91 project groups at time 2.

* $p < .05$

** $p < .01$

ever, nonroutineness–information processing fit predicted more unique variance when compared to information processing by itself, although the standardized regression coefficients were not significantly different for the two computations. It is also worth noting that nonroutineness–information processing fit predicted more unique variance in project quality at time 2 (one year later) than at time 1, although the standardized regression coefficients were not significantly different.

Hypothesis 1 predicts that nonroutineness matched with amount of information processing will predict higher project group performance. The significant betas for nonroutineness–information processing fit and project quality, for both time 1 and time 2, indicate support for Hypothesis 1. The second hypothesis similarly states that unanalyzability matched with amount of information processing will predict higher project group performance. Since the fit between unanalyzability and information processing was not a predictor of project group performance, however, Hypothesis 2 was not supported. Prior research has indicated that mean tenure in a project group (Katz, 1982) and tenure diversity (Ancona & Caldwell, 1992) may be important control variables for explaining project group performance. Mean project group tenure and the coefficient of variation (the standard deviation divided by the mean) for project group tenure were separately entered into the regression analyses as control variables. (Table 1 includes these control variables in the correlation matrix.) Neither control variable was significantly related to project quality or budget-schedule performance, and neither affected the significance levels of the results for any of the relationships reported in Table 2.

DISCUSSION

The value provided by the present research is a direct and important test of hypotheses generated from contingency design theory concerning fit conceptualized as a match between technology and amount of information processing in R&D project groups. The results support the hypothesis that a match between the nonroutiness of a group's task technology and the amount of information processing it engages in predicts performance, with nonroutine technology requiring high information processing to achieve project quality. The present study, moreover, is one of the few to have tested the fit between technology and information processing with a group-level measure of performance and a longitudinal research design. The present findings add support to Daft and Lengel's (1984, 1986) argument that the amount of information processing and the communication media used should be appropriate to the uncertainty and ambiguity of a task. As their concepts suggest, the fit between nonroutineness and information processing did predict project quality in the largely face-to-face medium of a project group.

Findings from the present study complement those of two important prior studies. Ancona (1990) found that consulting teams that matched the proper external strategy ("informing," "parading," or "probing") with external dependency were high performers. The present research extended that match to task technology and information processing, since the notion that R&D project groups are often externally dependent for scientific and technological information was implicit here. Further, the Ancona research was an exploratory study of five teams, but the present study used a hypothesis-testing longitudinal design for 98 project groups. Hence, the present study provides an important extension of the Ancona research. Tushman (1979) found the degree of decentralization in communication structure should be matched with the nature of a project's work, defined as research or technical service. The present findings extend this match to nonroutineness in task technology and information processing by R&D project groups.

The fit between unanalyzability and information processing, however, did not predict project group performance. The nature of R&D work may account for this result. R&D project groups basically import scientific and technological information, communicate and process the information into technological innovations, and then export those innovations outside themselves. Thus, information processing is central to R&D work, as it is to most professional organizations. Scientists and engineers often constitute the professional employees of R&D groups, and procedures for analyzability tend to be part of their education and experience. An attraction of these professionals to R&D work, moreover, may be the opportunity it provides to develop analyzable procedures for their work. Hence, unanalyzability may not be a salient variable to which R&D project groups must adjust. The degree of nonroutineness, however, directly affects the amount and kind of scientific and technological information that a project group must obtain and process and to which the group must adjust to be successful.

Neither of the fit variables in the present study enabled prediction of budget-schedule performance. This result may have occurred because the information processing needed to improve performance on the budget-schedule dimension was administrative, and the scientific and technological information being processed by professionals in the project groups addressed the variable of project quality. These results highlight two important points about performance in organizational research: The first is that researchers need to conceptualize and measure performance in terms that are germane to the organization being studied. The second is that performance is more often than not a multidimensional construct, with dimensions that are quite often different from one another. The use of a global performance variable, moreover, may actually hide relationships between independent variables and separate performance dimensions.

Nonroutineness–information processing fit predicted more unique variance in project quality at time 2, one year later, than it did at time 1, although the standardized regression coefficients were not significantly different. These results suggest that a proper match between nonroutineness and the amount of information being processed may take some time to manifest its full effects on performance. Professional work like R&D may be especially likely to have a time lag between a proper fit and the resulting improvement in project quality since it takes time to transform scientific and technological information into innovations. Future researchers testing contingency theory should consider using longitudinal designs to capture any lagged effects of contingency fit on performance variables. So far, only a small portion of prior contingency theory research has used longitudinal research designs.

Findings from the present research suggest some normative implications for the effective design of R&D project groups. When a project faces a nonroutine technology, such as work on a radical technological innovation, the project group should be designed to enhance information processing. Project group designs that increase information-processing capabilities include such characteristics as cross-functional membership, permeable group boundaries, physical proximity of members, and the opportunity for informal, face-to-face interactions among members (Allen, 1977; Katz, 1982; Tornatzky & Fleischer, 1990). When a project deals with a technology that is relatively routine compared to that of the other R&D projects, such as the modification of an existing product or process, the project group may be designed for greater efficiency and less information processing. In a project that engages in considerably more information processing than is needed, members may be distracted from the project's proper focus, or frustration or confusion may develop among them, with a possible impairment in project quality resulting. The routineness of a project's technology can also change over time; for example, a project may make a transition from applied research to product development. This kind of change in routineness would also be expected to affect the amount of information processing required.

In view of the results of the present study and other recent research, future contingency theory research efforts should attempt to capture the longitudinal effects of contingency relationships on unit performance. In addition, a more refined measure of information processing than the one used here would be needed to test propositions contrasting amount and richness of information, since the present information-processing instrument did not separate those elements. Because R&D project groups typically have unstructured and sporadic communications, a more structured field setting or perhaps a laboratory setting may be needed to test amount-versus-richness propositions. The present study used individual R&D professionals as the source of several independent variables that were aggregated to the project group level. Future researchers should consider the addition of independent variables that exist at the work unit level, such as geographic or network location.

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