Information Processing as an Integrating Concept in Organizational Design[1]

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Concepts of uncertainty and information processing are used to integrate the diverse organization design/structure literatures. This approach more fully explicates the concept of congruence which lies at the heart of contingency ideas. The review suggests a contingency approach to design which develops a feasible set of structural alternatives from which the organization can choose.

A basic goal of organizational research has been to discover what kinds of organizational designs or structures will be most effective in different situations. Ever since Burns and Stalker (4) presented the idea that different approaches to structuring organizations might have differential effectiveness under varying conditions, much work has been done attempting to identify the critical contingencies of design. The generally accepted view of organizational design that has evolved is that the structure of an organization should match or fit characteristics of certain variables both inside and outside the organizational system.

The central research question in design has been to identify variables that will enable researchers to make consistent and valid predictions of what kinds of organizational structures will be most effective in different situations. The attempt to identify critical contingent variables has led to the investigation of issues such as the technologies of an organization (8, 22, 30, 37, 41, 59), the nature of the environment in which the organization must function (12, 13, 15, 32, 36, 44),

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and the nature of interdependencies that exist among the units within an organization (1, 49, 56).

While research on contingent approaches to design has been fruitful, there remain both contradictory results (37, 40), as well as a lack of clarity regarding the concept of congruence or fit. This article uses information processing ideas to synthesize the design/structure literature and to clarify the concept of congruence.

This article builds on the view of organizations as information processing systems facing uncertainty and extends this concept to develop a conceptual model for organizational design and structure. Information processing refers to the gathering, interpreting, and synthesis of information in the context of organizational decision making. This article distinguishes between information and data. Information refers to data which are relevant, accurate, timely and concise. As information must effect a change in knowledge, data may or may not be information, and data processing may or may not be information processing (34). Such a model should serve to integrate much existing research, while stimulating future research aimed at testing the validity and applicability of the model. The approach to developing the model is the presentation of a number of propositions about organizations, uncertainty, and information processing. In each case, some relevant research is noted. From these propositions, a conceptual model of organizational structure is developed. Based on this model, implications for research and practice are identified.

Working Assumptions

There are many different ways of thinking about organizations; each approach is built on different assumptions about how organizations are structured and how they function. It is important to clarify working assumptions which underlie the analysis and to make clear the particular perspective from which organizations will be viewed.

A basic assumption is that organizations are open social systems which must deal with work-related uncertainty (28, 49, 57). There are several sources of uncertainty to which organizations must respond. Since organizations are dependent on inputs from the larger environment, and since this environment is at least potentially unstable, the organization must be able to track and cope with environmental-based uncertainty (35, 57). Within the organization, subunits must be able to deal with problem solving and coordination problems associated with different tasks and with different amounts of task interdependence (8, 32, 56).

If organizations must deal with these several sources of work-related uncertainty, a critical task of the organization is to facilitate the collection, gathering, and processing of information about how different components of the organization are functioning, about quality of outputs, and about conditions in external technological and market domains. In short, organizations must develop information processing mechanisms capable of dealing with both external and internal sources of uncertainty (60).

A second assumption follows from this logic: organizations can fruitfully be seen as information processing systems. Given the various sources of uncertainty, a basic function of the organization's structure is to create the most appropriate configuration of work units (as well as the linkages between these units) to facilitate the effective collection, processing and distribution of information (13, 17, 18, 35). In this context, information as gathered and processed by the organization's structure will be broadly defined to include: plans, work standards, budgets, feedback on performance, inventory levels, external technical and market conditions, etc.

A third assumption is that organizations can be viewed as composed of sets of groups or departments (referred to here as subunits). As organizations grow, they differentiate; to realize economies of scale and benefits of specialization, subunits are created which have specialized tasks and/or deal with specific aspects of the or-

ganization's task environment (28, 32, 49). At the same time, these subunits are interdependent to varying degrees and must share scarce resources — their activities must be linked together (32, 56). This perspective on organizational structure implies a need to shift attention to the subunit level of analysis (8, 21). Rather than asking what should be the structure of a particular organization, more appropriate questions are: (a) What are the optimal structures for the different subunits within the organization (e.g. R & D, sales, manufacturing); (b) What structural mechanisms will facilitate effective coordination among differentiated yet interdependent subunits?

These three working assumptions represent one way of conceptualizing organizations. We shall look at organizations as open social systems which must cope with environmental and organizationally based uncertainty. Organizational structure must perform the major functions of facilitating the collection of information from external areas as well as permitting effective processing of information within and between subunits which make up the organization. The basic unit of analysis will be the subunit; the basic structural problem is to design subunits and relations between subunits capable of dealing with information processing requirements faced during task execution. Finally, this approach to structure directs attention away from a static approach to structure towards a more dynamic approach to the structuring of organizations over time.

An Information Processing Model

Information processing ideas provide a way of organizing much of the structure/design literature. Given the previous set of assumptions, the basic features of a model will be presented by developing a series of propositions, with relevant research.

P1: *The tasks of organizational subunits vary in their degree of uncertainty.*

Uncertainty is defined as the difference between information possessed and information required to a complete a task (11, 18). If they so vary, the nature of a subunit's work will be a major determinant of the amount of uncertainty with which it must deal. Three sources of work related uncertainty, and therefore of information processing requirements, will be discussed: subunit task characteristics, subunit task environment, and inter-unit task interdependence.

Subunit Task Characteristics

Task characteristics have been an important concern to organizational structure researchers (33). While the results of this research have not always been consistent (regarding methods or unit of analysis) or convergent (2, 25), a review of the task literature indicates that task predictability is a thread which links the various studies together. Galbraith (18) suggests that tasks differ in their amount of predictability and thus in the amount of uncertainty which the unit must deal with during task execution.

Task complexity and intra-unit task interdependence are each sources of uncertainty and of information processing requirements (8, 37, 39). For example, routine tasks or tasks with a minimal amount of intra-unit interdependence can be pre-planned, and their information processing requirements are minimal. Complex tasks, tasks that are not well understood, or tasks which involve reciprocal interdependence, can not be pre-planned and are associated with greater uncertainty (35, 49). There is substantial literature to support this uncertainty-based approach to subunit task characteristics (22, 41, 47, 55, 56). As an example, an intensive care nursing subunit (complex task with substantial intra-unit interdependence) faces much greater information processing requirements than does a rehabilitation-oriented nursing subunit (i.e. more routine task and less interdependence among the nurses).

Subunit Task Environment

The task environment has been a much used, yet ill defined and hotly debated term (51).

The reviews by Downey et al. (10) and Downey and Slocum (11) emphasize a perceptual orientation by suggesting that the task environment be defined as those external actors which are attended to by organizational members. The environment is generally seen as a source of uncertainty, since areas outside the organization (or subunit) are not under the unit's control and are therefore potentially unstable (28, 49, 57).

While the number of dimensions affecting perceived environmental uncertainty is huge (27), Duncan (12) found that a static/dynamic dimension is a particularly important contributor to perceived uncertainty: the more dynamic or changing the environment, the greater the uncertainty faced by the focal unit. For instance, subunits facing a stable environment can develop rules or standard operating procedures (SOP) to deal with their environment. If subunits face a changing environment, then fixed rules and SOPs will not be able to deal effectively with the substantial environmental uncertainty. Much of the literature supports this uncertainty based approach to the task environment (12, 13, 26, 32, 36, 38, 44).

Inter-Unit Task Interdependence

Task characteristics and task environment are sources of uncertainty for organizational subunits which have important implications for the design of subunit structure. A third source of uncertainty with even broader structural implications is the degree to which a subunit is dependent upon other subunits in order to perform its task effectively. The amount of task interdependence that exists between differentiated subunits is associated with the need for effective coordination and joint problem solving. Task interdependence is thus another important source of work-related uncertainty.

A subunit performing a task which is fairly autonomous has little need for information from or collaboration with other areas. If the subunit's task is changed so that it is dependent upon the work of other units, the need for joint coordination and effective problem solving increases, and the subunit must cope with increased amounts of work related uncertainty. Thompson (49) provides a classification of types of interdependence that might characterize relationships among subunits. In order of increasing complexity, the types of interdependence are: pooled, sequential, and reciprocal. As the type of interdependence becomes more complex, coordination and mutual problem solving demands increase (19, 35). While there is relatively little research focusing on inter-unit task interdependence, Van de Ven et al. (56), Lawrence and Lorsch (32), Aiken and Hage (1), and Gerstberger (20) have reported evidence to support the relationship between the type of interdependence and problem solving complexity. In all, theory and research suggest that the more complex the inter-unit task interdependence, the greater the task associated uncertainty which must be dealt with by respective subunits.

In summary, three factors combine to influence the degree of uncertainty which organizational subunits face. As the task becomes less routine or involves more substantial intra-unit task interdependence, as the task environment becomes more unstable, and as inter-unit task interdependence becomes more complex, subunits must cope with increased amounts of work -related uncertainty (see Figure 1).

P2: *As work related uncertainty increases, so does the need for increased amounts of information, and thus the need for increased information processing capacity.*

Where the nature of the subunit's work is highly certain, small amounts of information are sufficient — perhaps in the form of fixed standards, formal operating procedure, or rules. Little new information or information processing are required during task performance. Thus, the need for continual monitoring, feedback, and adjustment is minimal, and the information processing requirements for the subunit are relatively small. Where the nature of the unit's work is highly uncertain, need for the constant flow of information increases among role occupants.

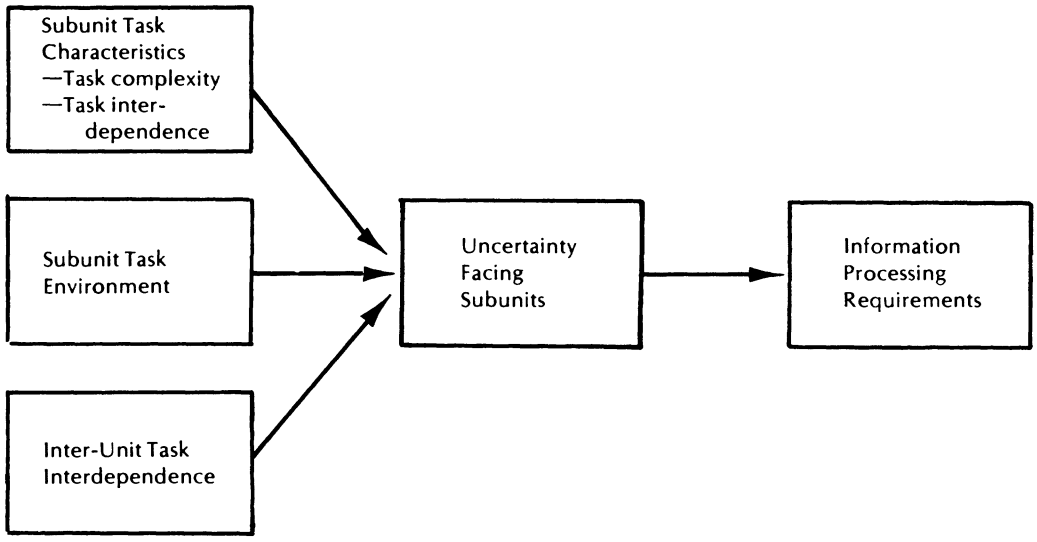

FIGURE 1. Sources of Uncertainty and of Information Processing Requirements.

Under these more uncertain conditions, new information becomes important; there are needs for mutual adjustment; and information exchange among components of the interdependent task is essential (13, 23, 32, 56, 60).

Thus, as the amount of uncertainty which a subunit faces increases, so too does the need for increased information processing capacity. In short, the greater the uncertainty faced by the subunit, the greater are its information processing requirements. Similarly, the greater the uncertainty faced by a set of subunits, the greater are the information processing requirements for the whole organizational structure.

P3: *Different organizational structures have different capacities for effective information processing.*

Structural conditions affect the subunit's ability to attend to and deal with uncertainty. Effective information processing includes the collection of appropriate information, the movement of information in a timely fashion, and its transmission without distortion. Effective information processing also implies the ability to handle needed quantities of information according to these criteria. Two dimensions of subunit structure affects its information processing capacity: The organismic-mechanistic nature of the subunit's structure, and the nature of coordination and control mechanisms which work to tie interdependent units together (e.g. control, planning, or reward systems). To simplify the discussion of subunit structure, the concepts of organismic and mechanistic structure are used. These structural terms will be a shorthand way of referring to a larger set of structural variables which frequently covary including: formalization, centralization, leadership style, degree of participation, lateral and vertical communication, and distribution of power and control (4, 8, 32, 37). These two basic structural dimensions will be discussed in greater detail below.

Organismic and Mechanistic Structures — Research indicates that organismic structures are able to deal with greater amounts of uncertainty than mechanistic structures (5, 13, 47). Why should this be? One way of thinking about the impact of subunit structure on information processing capacity is by focusing on the impact of subunit structure on patterns of communication.

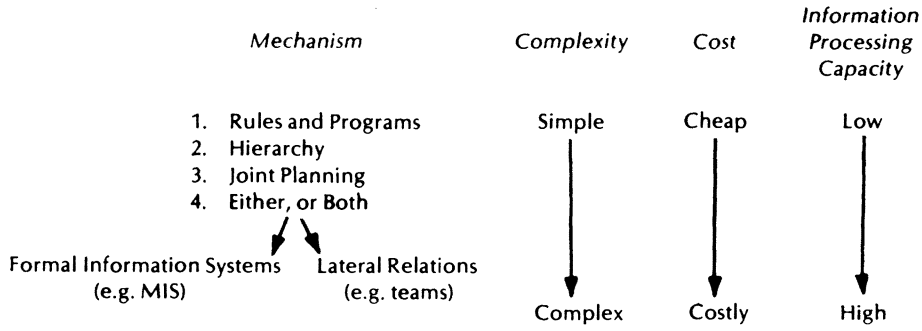

FIGURE 2. Mechanisms for Coordination and Control.

Subunit structure has an important impact on the subunit's ability to process information and deal with uncertainty (20). Highly connected (organismic) communication networks permit efficient use of individuals as problem solvers since they increase the opportunity for feedback and error correction and for the synthesis of different points of view. Because highly connected networks are relatively independent of any one individual, they are less sensitive to information overload or saturation than more limited networks. Finally, highly connected networks tend to be associated with less formality, less attention to rules and regulations, and greater peer involvement in decision making (23, 47). Since each of the above is related to a subunit's ability to deal with uncertainty, organismic communication networks have a greater ability to deal with work related uncertainty than do more hierarchical or mechanistic communication networks. A number of studies have reported results which support this logic (13, 23, 45, 46, 56).

While organic structures are able to deal effectively with greater amounts of uncertainty than more mechanistic structures, there are costs associated with this increased information processing capacity. Organismic structures consume more time, effort, energy, and are less amenable to managerial control. Thus, the benefits of increased information processing capacity must be weighed against the costs of less control and potentially increased response time (17, 18, 45, 50).

Mechanisms for Coordination and Control — The organismic or mechanistic structuring of subunits provides them with different capacities to process information. When considering collections of subunits, the focus must shift to structures that exist to link together or coordinate activities of interdependent subunits.

These structures for linking (to be called coordinating and control mechanisms) include a range of different elements including rules and procedures, planning and control systems, and specific coordinating units such as product teams or task forces. In general, the more complex, elaborate, and comprehensive the coordination and control mechanisms are, the greater the ability to process information and deal with inter-unit uncertainty. As these coordination and control mechanisms become more complex, they also become more costly in the terms of time, energy, resources, and managerial control (3, 14, 18, 32, 56).

Galbraith (18, 19) proposed a range of coordination and control mechanisms. Based on his work, it is possible to construct a continuum of these mechanisms on the basis of cost, complexity, and capacity to process information (see Figure 2). Note that after joint planning there are alternative mechanisms to increase information processing capacity. Formal information or communication systems are most amenable when information is quantifiable or formal in nature (e.g. scheduling, forecasting), while lateral relations are most appropriate for information

which is less quantifiable (e.g. informal communication). Thus, there are two complimentary approaches to achieve substantial inter-unit information processing capacity; one is more mechanistic in nature, the other more organismic.

Designing to Obtain Information Processing Capacity — From the previous discussion, designing a structure to obtain an optimal capacity to deal with work-related uncertainty involves two discrete issues. The first is structuring the subunit along organismic or mechanistic lines to obtain desired intra-unit information processing capacity. The second is creating coordination and control mechanisms which link units to obtain the desired inter-unit information processing capacity.

As units become more organismic, they have higher information processing capacity, but coordination costs within the unit may also increase (e.g. time spent on decision making). As coordination and control mechanisms become more complex, the total system has increased information processing capacity, but again increased costs are incurred in supporting these mechanisms. From these ideas, the basic design problem is to balance the costs of information-processing capacity against the needs of the subunit's work — too much capacity will be redundant and costly; too little capacity will not get the job done.

P4: *Organizations will be more effective when there is a match between information processing requirements facing the organization and information processing capacity of the organization's structure.*

One major criticisms of contingency research is its lack of clarity as to what constitutes a fit or match between task dimensions and organizational structure (40). Proposition 4 introduces information processing ideas as an intermediate step to define more explicitly the concept of fit. Thus, a subunit's information processing capacity (partially determined by its structure) must be capable of dealing with the information processing requirements of its work.

Information Processing Requirements	Information Processing Capacity	
	High	Low
Extensive	Match A	Mismatch B
Minimal	Mismatch C	Match D

FIGURE 3. Relationships Between Information Processing Capacity And Information Processing Requirements.

Proposition 4 can be derived from the basic open systems idea of requisite variety (3, 57). This idea suggests that if work units are to make order out of uncertainty, they must match highly uncertain conditions with complex information processing structures. Conversely, the less uncertainty faced by a subunit, the less its information processing requirements, and therefore its information processing mechanisms need not be complex. It follows that to be effective, subunits must match information processing capacity with information processing requirements (13, 17, 18, 40).

The relationships between information processing capacity and requirements are diagrammed in Figure 3. Hypothetically high performing organizations are those which match capacity to requirements. Mismatch in capacity and requirements should be associated with lower organizational performance.

For example, in cell B, information processing capacity is not sufficient to deal with the uncertainty generated during the task (e.g., the extensive use of formal rules and regulations in R & D laboratories). Decisions will therefore be made with a less than optimal amount of information. It is also possible to have too much information processing capacity for the task's requirements. In this case (Cell C), the extra infor-

mation processing capacity is redundant and costly in terms of time, effort, and control (e.g., the extensive use of horizontal communication where tasks are simple and weakly interdependent).

While relatively little research has been done to directly test this basic hypothesis, substantial literature can be seen as supportive of this matching idea. If information processing capacity must match information processing requirements, then effective subunits with complex tasks or those facing a changing environment should have more organismic structures than those subunits facing routine tasks or stable environmental conditions.

In support of the task-structure hypothesis, Hage and Aiken (22) found that psychiatric agencies (non-routine) were more organismic than were case work agencies (routine). Similarly, Woodward (59) found that successful organizations with relatively complex tasks were less mechanistic than successful organizations with more routine tasks. Other studies with supportive results include Whitley and Frost (58), Perrow (42), Keller (29), Freeman (16), and Hickson et al. (24).

In support of the environment-structure hypothesis, Duncan (13) found that successful subunits in a changing environment had organismic structures while successful subunits facing stable environmental conditions had more mechanistic structures. Other studies with supportive results include Lawrence and Lorsch (32), Burns and Stalker (5), Connolly (9), Miller (36), and Neghandi and Reimann (38).

Not all of the research is supportive of ideas behind Proposition 4. Studies by Pennings (40) and Mohr (37) are frequently cited as providing counter evidence to the matching hypothesis. Pennings (40) found no relationship between environmental conditions and the degree of participation or power sharing in a set of brokerage offices (a relatively complex task). As the model suggests that subunit task characteristics *and* task environment are associated with subunit structure, Penning's results can be used to support the core association between work-related uncertainty, subunit structure, and effectiveness. Penning's (40) research *does* suggest that task characteristics have a more powerful impact on subunit structure than does task environment.

Mohr (37) hypothesized that subunit task characteristics (task complexity and task interdependence) would be associated with supervisory style (a proxy for subunit structure). In support of the information processing model, he found weak support for the task complexity hypothesis, yet substantially stronger support for the impact of task interdependence on subunit structure (e.g. the greater the interdependence, the greater the use of a democratic supervisory style). But the congruence hypothesis (that is, the link between performance and congruence) was supported only for task interdependence. Both studies can be seen as supportive of information processing logic and partially supportive of Proposition 4. They do underscore the need for future research to specify the differential impacts of subunit task characteristics, task environment, and task interdependence on subunit structure and effectiveness.

At the inter-unit level of analysis, the information processing approach suggests that the more complex the interdependence, the greater the information processing requirements. If so, then Proposition 4 would suggest that high performing units facing complex interdependence with other areas should utilize more complex coordination and control mechanisms, while high performing units with small amounts of interdependence should utilize simple coordination and control mechanisms. Compared to the task and environmental areas, relatively little literature speaks to this hypothesis, but Lawrence and Lorsch (32), Aiken and Hage (1), Khandwalla (30), Keller (29), and Van de Ven et al. (56) found that subunits facing substantial interdependence with other areas used complex coordination devices over and above more simple mechanisms. Units facing only limited amounts of interdependence used only simple coordination devices. This pattern of results was accentuated for high performing organizations in both the Law-

rence and Lorsch (32) and Khandwalla (30) studies.

P4A: *Due to the alternative modes of achieving integration, the choice of coordinating and control mechanisms will not be deterministic.*

The theory and research and coordinating and control mechanisms suggest that more simple mechanisms should be utilized to the fullest possible extent; given their greater cost, the more complex integrating mechanisms should be used only for residual interdependence (19, 32). Given several alternative means to achieve greater information processing capacity between subunits (see Figure 2), complete specification of the most appropriate set of coordinating and control mechanisms (formal systems, lateral relations, or both) will be contingent on the nature of the data and other organizational conditions (e.g. managerial values). In short, there will be no one-to-one correspondence between information processing requirements and information processing capacity.

Instead of a structural imperative, Proposition 4A suggests an alternative contingency mode. A consideration of subunit task uncertainty does not lead to a unique structural solution; rather, it leads to a feasible set of structural alternatives from which the organization (or its dominant elite) must choose (6, 19, 49). Consistent with Child's (7) work on strategic choice, organizational structure can be seen as a result of the nature of subunit work related uncertainty *and* the nature of the organization's decision making elite's values (6).

P5: *If organizations (or subunits) face different conditions over time, more effective units will adapt their structures to meet the changed information processing requirements.*

Proposition 4 is, by itself, a static hypothesis. What are the structural implications of changing work demands (e.g. due to environmental conditions or the phase of a program)? The information processing approach suggests that the organization (or subunit) must adapt to varying information processing demands. Research supports this approach to the structuring of organizations over time.

At the organizational level of analysis, Utterback and Abernathy (54) found that structure of production organizations was dependent on the stage of the product's development. They found that in the idea or initial development stage, more organic/flexible structures were most appropriate, but that mechanistic structures were most appropriate in the product's implementation or diffusion stages. Illustrating this process approach to structure from a different angle, Chandler (6) found that one set of more successful organizations was able to cope with changing technological and market conditions by adaptation of structures.

At the project or departmental level of analysis, Duncan (13) found that successful subunits will adapt their structures to cope with different degrees of work related uncertainty. Zaltman et al. (60) and Utterback (52, 53) reviewed the innovation and organization literatures and suggest that as projects or departments move through problem solving phases, different structural forms are appropriate. More specifically, Zaltman et al. (60) suggest that organismic structures are appropriate in early stages of a project, while more mechanistic structures are most appropriate during implementation stages.

In all, Proposition 5 suggests that not only may different subunits have different structures, but that the same subunit may have different structures over time. This process approach to structure directs attention away from a static approach to structure towards a more dynamic approach to structuring organizations over time.

The five propositions form the basis of an information processing approach to organizational structure (see Figure 4). The basic notion is that subunits face different amounts of work-related uncertainty and that to be successful, they must match information processing capacity to information processing requirements. Since differ-

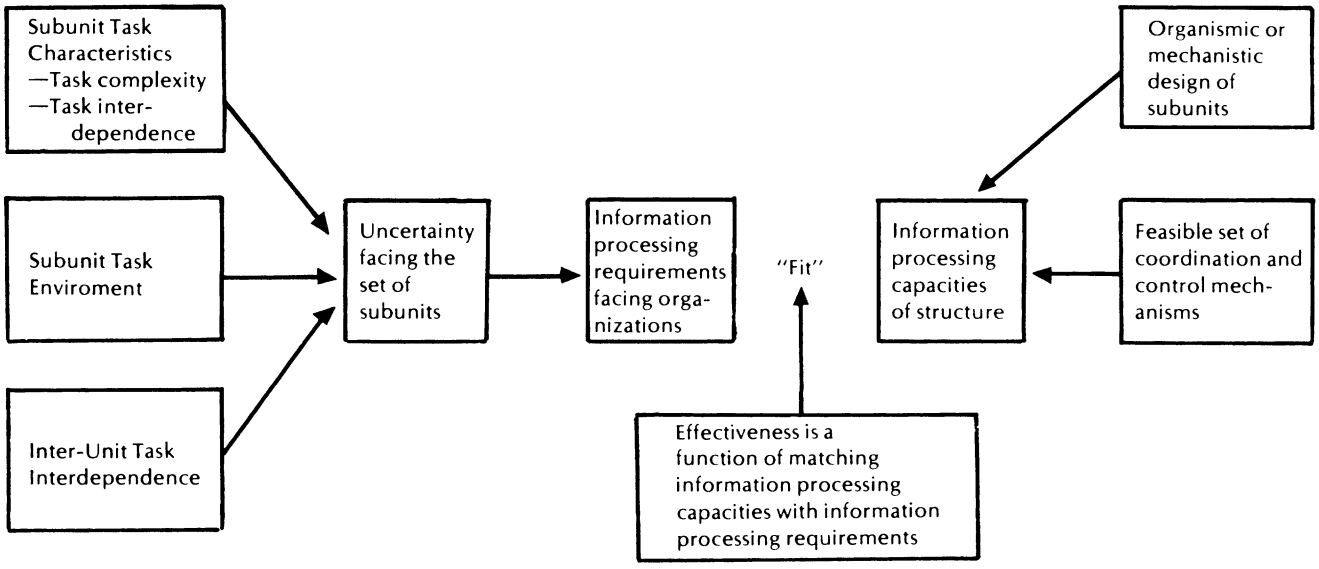

FIGURE 4. The Information Processing Model.

ent structures have different information processing capabilities, subunits can deal with work related uncertainty with appropriate structural arrangements. Thus, the essence of organizational design is: subunits must choose from a feasible set of structural alternatives, a particular set of organizational arrangements, to most effectively deal with their information processing requirements. Finally, since an organization's (or subunit's) information processing requirements are likely to change over time, the task of organizational structuring or design will never be fully accomplished.

Summary

The concept of information processing as well as the model of structural conditions associated with organizational effectiveness have implications for both research and practice. While various components of the information processing model have been derived from previous research, the model's central hypothesis remains to be fully tested. Research needs to be done to test whether organizational effectiveness is indeed associated with the fit or match between the information processing requirements facing an organization (and its subunits) and the information processing capacity of its structure.

Future research could focus on the relative impact of task characteristics, task environment, and task interdependence on subunit structure, the differential effectiveness of alternative mechanisms of coordination and control, and on the impact of managerial decision making on the choice of organization structure. Finally, future research could focus on the evolution of structure over time and the existence of mechanisms other than structure for increasing subunit information processing capacity (e.g., special boundary roles or organizational climate).

More pragmatically, the information processing model holds promise as a tool for the problem of designing organizations. The model implies that design should first consider the composition and structure of organizational subunits and then consider appropriate mechanisms for linking those units together. The mod-

el implies a number of specific steps in designing an organization's structure. The first step is an identification of the most critical information processing needs and the formation of subunits around those needs. Thus, organizational roles with the highest need for information processing would be grouped together in subunits (a methodology for implementing this aspect of design is presented in Kilmann and McKelvey (31)). Second, those subunits would be structured along organismic or mechanistic lines according to the degree of uncertainty that each faces. Third, groups of subunits would be linked together with coordination and control mechanisms. The complexity of these mechanisms would be influenced by the amount of task interdependence among the subunits. Finally, this model suggests that the task of organizational design is never fully accomplished. As information processing requirements change, so too must the organization's structure.

Both research and practice can benefit from a comprehensive integrating model of organizational structure and design. The information processing model is one approach. This approach has promise, but its ultimate effectiveness remains to be determined by further exploration and research.

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