Organizational Adaptation in Volatile Environments

Chapter 11

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Organizational Adaptation in Volatile Environments

Theories of organizational adaptation address the value of exploration, flexibility, and change. However, exploration, flexibility and change are not without cost. Thus, theories of adaptation also address the need to balance these forces for change against the costs of change and the benefits of exploiting current expertise. Arguments for change assume that organizational adaptation is the result of balance at a single level (strategic or operational) or of a single type of learning (individual or group). In contrast, what I suggest is that this balance is not at a single level but is the result of maneuvering within an ecology of learning in which change is occurring at many levels — individual, organizational, and environmental. Thus, adaptation is not so much a matter of balance as it is of finding the right evolutionary path and of trading change in one dimension for stability in another.

This way of thinking about organizational adaptation as resulting from strategic maneuvering in a learning ecology will be illustrated using a computational model, ORGAHEAD (Carley and Svoboda, 1996; Carley, 1998) Computational theorizing is an important tool for developing our understanding of the complex systems we refer to as organizations; it enables the researcher to think through (in a computer assisted fashion) the interactions of dynamic non-linear processes. Using ORGAHEAD the types of maneuvers that result in adaptation and maladaptation for organizations faced with environments that range from stable to highly volatile will be explored. This computational model can be thought of as the embodiment of a theory about how organizations change. Analysis of the results generates a series of theoretical predictions about organizational adaptation.

ORGAHEAD can be thought of as an operationalized grounded theory. Its basis is the body of research, both empirical and theoretical, on organizational learning and organizational design. The model has built into it several theories of different aspects of organizational behavior. From the information processing tradition comes a view of organizations as information processors composed of collections of intelligent individuals each of whom is boundedly rational and

constrained in actions, access to information by the current organizational design (rules, procedures, authority structure, communication infrastructure, etc.) and by his or her own cognitive capabilities. Organizations are seen as capable of changing their design (DiMaggio & Powell, 1983; Romanelli, 1991; Stinchcombe, 1965a), and as needing to change, if they are to adapt to changes in the environment or the available technology (Finne, 1991). Different organizational designs are seen as better suited to some environments or tasks than are others (Hannan & Freeman, 1977; Lawrence & Lorsch, 1967). Aspects of the model have been tuned to reflect the findings of various empirical studies related to these theories. The set of theories that is unified into a single computational theory of organizational behavior interact in complex fashions to determine the overall level of organizational performance. The aspect of organizational performance of concern here is accuracy; i.e., whether or not the organization, given some set of tasks, makes the correct decision for each task. A number of theories speak to the impact of learning on organizational performance or accuracy. Herein, the concern is with two such theories — one focused on experiential learning and the other on strategic learning.

The Experiential Learning Perspective: According to this perspective organizations learn as the individuals within them perform tasks and accumulate experience. Individuals gain experience as they face a series of similar or identical tasks over time and receive feedback on how well they are doing. For individuals, experiential learning results in large initial gains in performance, but with decreasing gains over time as the individuals gains familiarity with the task (the S shaped experience curve). Experiential learning on the part of personnel can be beneficial to the organization. Organizations with more highly trained, more experienced personnel, are usually expected to perform better. Individual experience, however, does not always translate directly into organizational experience (Darr, Argote, & Epple, 1995). Rather, the organization's design serves as a procedure for combining or aggregating the experience of individuals (Carley, 1992; Cohen, March, & Olsen 1972; Hastie, 1986). Thus, if we could clone personnel, two organizations with different designs but the same personnel would exhibit different performance. [1]

The Strategic Learning Perspective: According to this perspective organizations learn by exploring new ways of doing business; but, organizations also become more staid and do less exploration as they age. In this case, organizational learning results from a process in which strategic planning by the CEO or some central unit about how to position the firm to achieve high future performance leads to changes in procedures, re-assignments of personnel, and re-engineering of the workforce.[2] Over time, institutional norms, sunk costs, traditions, emergence of stable social networks, and so forth gradually increase the cost and decrease the value of, and likelihood of, exploration. Such strategic learning, which can be observed as changes in the organization's design, can be beneficial to the organization. That is, organizations which adopt designs that are forecasted to improve their performance are expected to perform better; unless, the forecasts are wrong. To be sure it is an individual, such as a CEO, or a group of individuals, such as an executive committee, that is engaged in the strategic planning exercise. However, the CEO or executive committees actions are realized as embedded changes in the organization's design (just as the interactions among friends becomes embedded in underlying social network). The organization's design and the myths about changing it (such as stories about what worked previously) become in effect, a long term social memory, external to any one individual but that can be more or less relied on when contemplating future decisions. In this social memory or distributed cognition sense, change to the organization's design is an act of organizational learning.[3]

The interaction between experiential and strategic learning is complex and non-linear. Strategic changes in the organization's design may mitigate or enhance the value of experience. Thus, it is difficult to predict the joint impact of both types of learning on organizational performance. In ORGAHEAD, both experiential and strategic learning are simultaneously active. We can use this computational model to theorize about how the interactions between these two types of learning influence overall organizational performance (measured as accuracy). ORGAHEAD is a procedural theory of organizational performance. As such, the relationship between performance and learning is determined by a series of processes such as how decisions are made, how the organization's

structure is changed, and how individuals learn. These processes will be described later. For each organization, at any point in time its performance is uniquely related to the task, the organization's design, the experience of all personnel, the impact of previous designs on the experience garnered by personnel, and the processes by which personnel learn and the design changes. Since we can characterize various aspects of the organization's design and various aspects of individuals as a set of factors we can at any point in time explore the relationship between these factors and the organization's performance. In fact we can think of the organization as simultaneously operating in two spaces — design and experience. An important point to keep in mind is that there is no small set of factors that uniquely captures all aspects of design or experience (this is true both for the model and the real world). Thus a high number of dimensions may be needed to capture all salient aspects of the design space and the experience space. Another important point to keep in mind is that, in a process model, these factors are not simple inputs, rather they shift their values dynamically over time and all factors are inter-related, in complex ways.

We can think of the relation of performance to these various factors as the performance surface. Figure 1 illustrates graphically where the expected performance of an organization given two elements of design, size and workload, is shown. The surface can be thought of as a landscape. All organizations are, over time, trying to search to find the optimal form. In the experience space, search is carried out, in part, by personnel doing tasks and gaining experience. In the design space, search is carried out, in part, by the CEO (or some executive committee) sequentially altering the organization's design. For real organizations and for ORGAHEAD, design and experience are functions of more than two variables and the performance surface is even "messier" than that illustrated.

There are several important points that must be made about the performance surface. First, the processes which result in organizations exhibiting a certain level of performance at a certain point in time also result in a systematic relationship between performance and a large number of design and individual factors such as size, density, span of control, workload, average experience, and retention. These relationships, though systematic, are rarely linear on any dimension. For

example, in Figure 1 an organization that tries to climb this surface by either just increasing size or just increasing workload will often suffer drops rather than increases in performance, even though to be a top performer the organization will need to be high in both size and workload. Second, the large number of factors means that it is not possible to graphically display the performance surface relative to all factors (for either or both of design and experience). Third, the performance surface is the space of possibilities; i.e., it shows the expected relationship between performance and design (or experience) for all possible designs (or experiences). In a world where there are only a few organizations (real or simulated) there may not be an organization at each point in the space. Over time, organizations may come to cluster in certain regions of this landscape. Fourth, the over time trajectory of any one organization is unlikely to be linear. One implication of this is that, although maladaptive organizations may be lower/higher on some dimension than adaptive organizations, if the maladaptive organizations change in the direction of the adaptive organizations they may not see a performance gain.

Place About Here — Figure 1. Illustrative Performance Landscape

For both real organizations and simulated ones the performance surface is not necessarily stable. The environments faced by organizations can change for a number of reasons; e.g., technology, legislation, change in cultural norms, and change in availability of resources. Changes in the environment are often changes in either the task, the way in which organization's can redesign themselves, or changes in the way personnel learn and make decisions. Consequently, environmental shifts can fundamentally alter the performance surface, particularly as perceived by the organization. Consequently, the relation between performance and design may change. Figure 2 illustrates graphically the change over time in the performance surface as a function of two possible dimensions of organizational design.

Place About Here — Figure 2. Illustration of Changing Performance Landscapes

When is change good? To answer this, it is important to distinguish change from adaptation. Change is defined as any difference between an organization at one time and the next. Change may or may not represent learning. Adaptation is defined as those changes that enable the organization to maintain or improve its performance. Since different designs are better in different circumstances, adaptation can be thought of as the successful result of a process of searching for the optimal, or at least a better, design for the environment confronting the organization, given that the organization itself is altering its behavior as the individuals within the organization garner experience. Adaptive organizations then are those that end up situated on the higher peaks.

Change, or exploration, by the organization enables but does not guarantee adaptation. Change in design enables the organization to walk around a performance surface and move toward a peak. There are at least two potential drawbacks to change. If the performance surface is volatile then the organization runs the risk in moving to a new point in design space that while a "peak" at Time 1, is actually a "valley" at Time 2. Further, for most organizations, performance improvements are often garnered by staying at the same point in the design space but exploiting current talents, knowledge, and skills of the personnel. Indeed, March (1996) discusses continuity as being critical for true adaptation. Levinthal and March (1993) suggest that organizational learning, because it involves balancing exploration and exploitation, can result in various types of learning myopias. For example, experiential learning can result in a tendency to exploit knowledge (keep doing what one does well) and so overlook or discount the future, discount what others are doing, and discount contradictory information or failures. They conclude that, despite these myopias, learning is still advantageous to the firm.

Why are myopias advantageous? In this paper a partial answer is provided: since organizational learning occurs at many levels, myopia at one level may be countered by, and possibly even encourage, a broader view at another level. Moreover, without learning, the chance of finding a better design is very low. The chance of finding a better design is non-zero for several

reasons. Essentially, the organization can benefit from fortuitous accidents. At the strategic level, selective retention or random actions on the part of the CEO or the executive committee can result in the organization moving to a better design. At the operational level, selective retention or random actions on the part of personnel can result in the organization with a particular design appearing to be better or worse that it is when all personnel are acting perfectly. This would engender a misperception of the relationship between that design and the organization's performance which may then discourage or encourage the CEO's or executive committee's search for a new design.

Learning is advantageous to the firm precisely because the organization is engaged simultaneously in multiple types of learning. As previously noted, the concern in this paper is with two types of learning — experiential and strategic. Experiential learning, which resides largely in the individual, is seen as resulting from the process of trial and error and learning from feedback. Strategic learning, which resides largely in the linkages or connections among people, is seen as resulting from organizations going through processes of planning, re-organization, and re-engineering. Such change is strategic as such re-organization is generally done because it is expected (for example by the CEO) to improve performance (Butler, 1993; Kilman & Covin, 1988). The value of these two types of learning may depend on the environment. For example, in a stable environment experiential learning should be quite effective as the lessons of experience should remain valid. In a volatile environment hard won experience may be less valuable as the jobs of tomorrow may not be the jobs of today. In a stable environment there may be little to strategize about and the organization may quickly lock onto the right structure; whereas, in a volatile environment being able to anticipate the future may be critical. But is this the case?

We can begin to address questions such as these, questions about the dynamics of organizational life, structure and learning using computational theorizing.

ORGANIZATIONAL ADAPTATION MODEL

ORGAHEAD is a computational theory of strategic organizational behavior as search through the problem space of potential organizational designs. ORGAHEAD was designed to reflect basic realities of organizational life. As in any organization there is a task or set of tasks being done, a set of personnel with each member occupying a particular role in the organization, reporting to others, doing tasks and gaining experience, and a strategic or management function that tries to anticipate the future, assigns personnel to tasks and determines who reports to whom. These fundamental features of organizations are captured in Figure 3 which serves as a top-level view of the ORGAHEAD model. From a learning perspective, within ORGAHEAD organizations are characterized at two levels — operational and strategic. At the operational level, the organization is characterized as a collection of intelligent adaptive ACTS agents (Carley & Prietula, 1994); i.e., each agent is cognitively capable, socially situated and engaged in working on a specific task. At the strategic level, the organization is characterized as a purposive actor; i.e., there is a CEO or executive committee which tries to forecast the future and decides how to change the organization to meet that need. Each of the three primary components within ORGAHEAD will be described in turn — the task model, the operational model, and the strategic model.

Place About Here — Figure 3. Top Level View of ORGAHEAD

Task and Task Environment

In ORGAHEAD, the organization is faced with a sequence of tasks. Each task has associated with it a "correct decision". This correct decision is not known, a priori, by any one within the organization. For each task, the CEO must make the organization's decision. This decision may or may not match the correct decision. Organizational performance is a function of how often this decision matches the correct decision; i.e., of the organization's accuracy.

There are many tasks in which organizations can engage. A common one is the classification task. Classification tasks have the following properties: There is an item that needs to be classified as being of a certain type. The item can be characterized as having a set of attributes, on which it is

classified. Examples of classification tasks include: diagnosis, situation assessment, and multiple choice tests. A simple version of the classification task is the binary choice task. In the binary choice task the objective is to determine for a given binary string whether that string is of Type A or B (a string cannot be both A and B). For each string there is a correct decision. Of course, the decision maker may not correctly classify the string; i.e., the decision maker may misclassify an A string as a B string or vice-versa. The specific task used in the ensuing analysis is a nine bit binary classification task. Classification tasks in general, and the binary choice task in particular, have been extensively studied by researchers interested in team and organizational performance (see for example, Carley, 1992, 1998; Hollenbeck, et al., 1995; Hollenbeck, Ilgen, Tuttle, & Sego, 1995; Lin & Carley, 1997; Pete, Pattipati, & Kleinman, 1995; Tang, Pattipati, & Kleinman, 1992).

Environments can be thought of as task environments; i.e., the set of tasks faced by an organization. For example, when the task is the binary choice task, then the environment might be the set of binary strings of length N that must be classified by the organization. Environments have various characteristics such as bias and stability/volatility. Environments may be biased (another interpretation of this is that they may be a niche environment). One way of thinking of bias is as a greater than chance likelihood of one particular outcome. For example, in the binary choice task, the environment is unbiased if all outcomes (whether the string is of type A or B) are equally likely given a set of strings. The more likely one outcome is than the other, given a set of strings, the higher the bias of that environment. For the binary choice task, it is unbiased if a string is of type A if there are more 1's than 0's in the set of task features and B otherwise, all strings of length N are possible, and the probability that any task features is a 1 is .5. Under these conditions, neither outcome (A or B) is more likely to occur.

Environments can also vary in their stability. Hannan and Freeman (1977, p. 952) characterize environmental instability as an oscillating sequence of "patches". Seasonal markets — such as lawn care — have this oscillatory nature. Environmental instability is a function of both the frequency of shift and the degree of the shift. We can operationalize this as oscillations between one class of tasks and another; e.g., between an unbiased and a biased task.[4] The degree of shift is

operationalized as the difference in the bias between the two classes of tasks; the greater the difference in bias, the greater the degree of the shift. Frequency of shift is the number of tasks of a specific class the organization faces before it shifts to a different class of tasks. In a stable environment, all tasks are chosen from the same distribution. In an unstable environment, the tasks are chosen from different distributions, both unbiased and biased, in an oscillatory fashion.

The specific task can affect the optimal organizational design and may constrain the level of performance (Carley, 1992). The task largely determines the specific optimal structure. Thus, unless one is interested in finding the organizational design for a specific task, the issue is not what design is found, but what factors affect differences in what designs are found or the rate at which the optimal design is found. In the ensuing analysis, the focus is not on what structures are found, but in what causes different structures to be found and whether different structures are found in stable and volatile environments.

Operational Level

In ORGAHEAD each individual in the organization works on at most part of the task (no individual sees the whole string). The operational part of ORGAHEAD is built out of the CORP model (Carley, 1992; Carley & Lin, 1995, 1997). CORP is an information processing model of organizational performance in which organizational performance results from aggregating the performance of individuals. All individuals are boundedly rational in terms of organizational access to information and cognitive ability to process information (Carley & Newell, 1994; Simon, 1955, 1956). Individuals are limited cognitively; they cannot do the task by themselves and can only handle a maximum of seven pieces of information. They forget, have primacy and recency biases (they remember only the first 500 tasks and the most recent 500 tasks they have seen), remember general trends rather than particular tasks, and are effectively over confident in their decisions. Individuals are also limited structurally. They cannot access all information. What information they can access depends on their role in the organization, and they often must act not on the basis of actual task information but on the interpretation of that information as forwarded by others in the organization. Their roles are a function of the authority structure (who reports to

whom), S, and the resource access structure (who has access to what resources or information), R. Individuals have the capability of learning from their experience over time. In each time period in which they receive information, they report whether they think (on the basis of that information) the overall task is of type A or B, and then they find out whether or not the task really was of type A or B. They learn by keeping track of the likelihood that, when they see pattern x, the task will be of type A/B. Each individual, regardless of his or her position in the organization, acts as an experiential learner, acquires information, classifies the pattern of information that he or she sees, recommends the choice that was most often correct in the past for that pattern to his or her superior, receives feedback as what whether the task was really of type A or B, and increments his or her memory. If the individual has no previous experience, he or she simply guesses. The pattern of information seen by an individual can be either, or both, raw information on this specific task or the recommendations of other individuals for this task.

The process of pattern classification, recommendation, and reporting up through the authority structure is the organizational process by which individual level decisions are aggregated into a single organizational decision — the decision made by the CEO. See Figure 3. At the apex of the organization is a single superior or CEO. Below the CEO there is a network that connects the individuals into a single organizational structure. We can think of this as a directed graph, S, showing who reports to whom. Overlaying this authority structure is a second network that connects individuals to raw task information. We can think of this as a directed graph, R, showing which information on the task is observed or monitored or handled by which individual. This second graph is the resource access structure. Each piece of information is a resource for the organization. The resource access structure determines which part of the task is observed by which individual. Each time period there is a single task for which the organization collectively makes a classification which is the decision made by the CEO. Each time period, the flow of information (and opinions) is from the task to the CEO as filtered by these two networks — the authority structure, S, and the resource access structure, R. The organization's design can be formally characterized by the joint structure — design (S,R).

Organizational performance is measured as accuracy, the percentage of problems in a window of opportunity that the organization correctly classifies. The organization is faced with a sequence of tasks drawn with replacement at random from the population of tasks. Each time period, the organization, as represented by the CEO, must make a decision for the current task. Of the $N(t)$ individuals who are collectively processing $I(t)$ pieces of information, some individuals are processing raw information on the task and reporting their opinions to other individuals; whereas, other individuals are processing these opinions, and still others may be processing both raw task information and opinions. Who is doing what, and who reports to whom, depends on the organizational design. An organization may be composed of anywhere between 2 and 45 individuals organized in one to three tiers below the CEO with a maximum of 15 individuals per tier. There is an additional or first tier composed of a single CEO. As noted, the organizational decision is the CEO's decision. By convention the CEO is referred to as Level 1 and the tier furthest removed from the CEO as Level 4.

Strategic Level

At the strategic level, organizational performance is affected by the ability of the CEO or central unit to anticipate the future and take the appropriate strategic actions to alter the organization's design in response to environmental cues. Change at this level is determined by the organization's change strategy. The change strategy[5] has three parts: what changes to the current design are allowable, conditions under which changes are made, and the likelihood of the various changes.

Recall that the organization's design is characterized in terms of the authority structure and the resource access structure. Change in design involves changing these structures. There are four types of changes possible regardless of the change strategy: *downsizing* — drop n individuals (such that $1 \leq n \leq N_O(t)$), *upsizing* — add n individuals (such that $1 \leq n \leq N_{max} - N_O(t)$), *redesigning* — delete the tie between individual i and j (i reports to j) and reassign individual i to report to individual k., and *re-engineering* — delete the tie between individual i and piece of information s and add a tie between individual j and piece of information s, Exactly how many changes of a particular types occur at a time is given by a Poisson distribution.[6] Changing

connections through re-design and re-engineering moves connections and will not lead to an absolute increase or decrease in personnel. Changes in personnel, through upsizing and downsizing, cause changes in all of the ties associated with those personnel.

The organization begins with a particular design ($S(0)$,$R(0)$) and proceeds to process 500 tasks. After this, regardless of the change strategy, the organization continuously cycles through the following actions: make decisions for a sequence of tasks, evaluate performance, propose a change to the structure, change the structure. The four strategies vary in when they move from the decision phase to the structural change phase and in the way in which they decide on a possible new design. The four strategies are stable (no change), random, procedural, and strategic.

Organizations with a stable change strategy do not alter their design over time. This is the baseline case against which to evaluate the extent to which change is adaptive. Organizations with a random change strategy, randomly alter their design every time the organization's performance changes by 5% or more. The level at which change occurs in the organizational structure and the type of change is random. After a change occurs, the organization remains "dormant" long enough for new people (and old) to get used to the new organizational design. Change was equally likely at all levels (25%) and there was a 25% probability that no change would occur. Organizations with a procedural change strategy hired personnel when things were going well (5% or more improvement in performance) and fired personnel when things were going poorly (5 % or more drop in performance). under this strategy, change was more likely at lower levels in the organization. Specifically, the probability of change at level 4 is 50%, 30% at level 3, and 5% at level 2. Again, there was a 25% probability that no hiring or firing would occur when the efficiency warrants it. Under the "strategic" strategy, the organization used strategic planning to determine whether or not to make a change and whether a change was made depended on expectations. Over time, the organization learned what types of changes were effective and became increasingly adverse to making changes that were not expected to improve performance. This was implemented via simulated annealing.

Simulated annealing is a heuristic approach to optimization (Kirkpatrick, Gelatt, & Vecchi, 1983; or for an overview see Rutenbar, 1989). In an annealer, the system tries to optimize some function by moving through states sequentially, and the path through those states is constrained by the set of ways of altering the current state. A move is chosen from the set of possibilities, and its potential impact is evaluated before it is accepted (or not) by the Metropolis criteria. According to the Metropolis criteria non-risky moves are always accepted and risky moves are sometimes accepted but with a decreasing likelihood over time. This rate of decrease is controlled in part by the temperature of the system. The temperature of the system determines its excitation; thus, as the temperature drops, the system becomes more rigid and less capable of change. The result is a heuristic based optimization process that tends to locate better states but is not guaranteed to locate the best state. Similarly, the organization moves through a series of organizational designs, one at a time. Over time, the organization attempts to optimize its design given some cost function (such as minimizing salary, maximizing the number of widgets produced, or maximizing decision accuracy). The CEO or central unit has a set of possible strategies (move set) that dictates which designs are possible given the current design. The CEO does not compare all strategies, but simply evaluates a strategy by trying to anticipate the future (Allison, 1971; Axelrod, 1976; Cohen & March, 1974). Strategic adaptation requires the CEO to have knowledge about which individuals in the organization have what information and which capabilities. Consequently, the organization's optimization process is imperfect. Strategic change moves the organization closer to the goal but may not achieve it (March & Simon, 1958; Simon, 1944). Organization's gamble on redesigns that might possibly "increase costs", and they are much more prone to this kind of risky behavior when they are new (Stinchcombe, 1965b). With maturation the organization becomes staid and trapped by its own competency (Levitt & March, 1988).

The goal of the strategic change process as implemented herein is to find the organizational design that maximizes performance. In other words, the goal is to alter the organization's design sequentially so as to locate the tallest peak shown in Figure 1. For the strategic approach, first the organization's performance for 100 tasks is calculated. Then the CEO chooses one change from

the set of possible changes, thereby suggesting a new organizational design. This design is evaluated (using a limited lookahead of 100 tasks). Then the forecasted performance of the proposed design is compared with the previous performance of the current organization, and a strategic decision is made as to whether or not to accept the change. Finally, if the change is accepted, the organization's design is altered and the process begins again. If the change is not accepted, the process begins again with the unchanged organization. Performance at time, *t*, for the current organization is the percentage of the most recent 500 tasks that the organization correctly classified prior to time *t*.

The probability of accepting the new design is determined via the Metropolis criteria. Specifically, the change is always accepted if the forecasted performance for the hypothetical organization is better than the known performance of the current organization. Further, when the forecast is poorer the change may still be accepted. In fact, we can think of the probability of accepting the "bad" design as resulting from the impact of the organization's risk aversiveness on its decision. This probability is calculated, using the Boltzman equation, as $P = P_O \ e^{(-\Delta \ cost(t)/T)}$ such that $cost(t) = 0 - performance(t)$ and P_O is the initial probability of accepting a "bad" design. This probability decreases as the "temperature" decreases. We can think of temperature as the organizations current level of risk aversion. Herein, temperature drops every 100 tasks (time periods) as $T(t+1) = \alpha * T(t)$ where α can be thought of as the rate at which the organization becomes risk averse.

Summary

ORGAHEAD predicts organizational performance (measured as accuracy in doing a task) from the task, operations needed to perform the tasks (individual actions and experience), and strategic changes to alter the organization to do the task better (refer back to Figure 3). All aspects of ORGAHEAD are dynamic. That is, each time period the specific task faced by individuals (and the organization) is different. Over time, the environment of tasks may be changing. At the operational level, individuals learn through experience as they do the task, but what they do and

what they learn is a function of their position in the organization's design. At the strategic level, attempts at anticipating the future often result in changes in this design.

Virtual Experiment

Using ORGAHEAD a series of virtual experiments were run to examine the impact of change strategies on performance and adaptability in a changing environment. In each experiment two or more initial conditions were considered and then, for each condition, using Monte Carlo techniques, the over time behavior of a large number of organizations were simulated.

As with human experiments it is not possible to explore all possible variations possible given the proposed model. Thus, hypotheses in the literature are used to give guidance as to what factors are important to look at and when we are most likely to observe differences in organizational performance.

In the first experiment two environments were examined: a stable environment under an unbiased task condition and a volatile environment oscillating between an unbiased and a highly biased task every 1000 tasks. For the highly biased task, the outcome was an A if there were 3 or more 1's in the string and a B otherwise. In the second virtual experiment, three environments were examined: stable (no shifts), low volatility (shifts every 5000 tasks), and high volatility (shifts every 1000 tasks) for organizations that changed strategically. It is reasonable to expect that the strategy the CEO follows in deciding which change to make to the organization's design should impact the organization's ability to adapt to the different environments. Thus, in both experiments, four change strategies are examined: stable (no change), random, procedural, and strategic.

In both experiments, for each initial condition, 1000 organizations were generated randomly in a Monte Carlo fashion. The initial size of the organization (2 to 45 individuals), the number of levels below the CEO (1 to 3), the initial reporting structure ($S(0)$), and the initial resource access structure ($R(0)$, were all chosen randomly with replacement from the set of possibilities. Each organization was simulated for 2000 time periods (after the initial 500).

The goal of the analysis is to gain insight into strategic adaptation to a dynamic environment. One way of examining this is to see what characterizes the organizations that are adaptive (end up on the peaks in the long run) or maladaptive (end up in the valleys in the long run) in the various environments. As previously noted, the performance surface is multi-dimensional even in the design space. To contain the analysis, only three aspects of design will be examined: size, density, and workload. Size, the number of individuals in the organization, density the fraction of possible connections in the reporting structure that actually exist, and workload is the average number of items of information that each employee needs to handle to make a decision. The higher the workload the greater the information processing requirements on the individuals and the slower they are likely to learn. Since the concern is with adaptation, only the long run performance of the organizations is considered. Since organizations begin with individuals who have no experience initial organizational performance is approximately 50%. The adaptiveness of the organization can thus be seen by measuring its performance at a later time period, such as the last 500 tasks. Since strategic learning is relatively slow compared to experiential learning, looking at organizational performance during later (rather than earlier) time periods provides a more complete understanding of the impacts of strategic change on the organization. Finally, due to speed and space considerations, full data is only available for the 50 most adaptive and 50 least adaptive organizations in all of the conditions. Consequently, it is generally not possible to display the performance surface even relative to just size and workload for all cells in these experiments. For a few cells, the full surface was generated and these will be displayed as needed for illustration.

DETERMINANTS OF ADAPTIVITY

A series of questions about adaptability were raised. For example: Under what conditions is change beneficial? Why is learning advantageous? Does strategic learning provide greater advantage in a volatile environment and experiential in a stable environment? The ensuing analysis examines these and other questions about organizational adaptation. To make clear the determinants of adaptation, the focus will be on a comparison of the relatively adaptive and maladaptive organizations. Adaptive organizations are defined as those 50 organizations (out of

the 1000 simulated) that exhibit the highest level of performance at the end of the 2000 trials. Maladaptive organizations are defined as those 50 organizations (out of the 1000 simulated) that exhibit the lowest performance at the end of the 2000 trials. By examining differences and similarities in the those organizations which, in comparison to each other, are relatively more adaptive or maladaptive, a series of lessons about organizational adaptation can be garnered.

Lesson 1: Change is Not Adaptive

In general, change was not adaptive. To highlight the findings, the average amount of change for several different types of change for adaptive and maladaptive organizations is shown in Table 1. In a stable environment, change is typically maladaptive. Maladaptive organizations end up changing more than adaptive organizations. Downsizing is maladaptive if it gets rid of the organizational knowledge residing in the minds of the personnel — both knowledge about the task and knowledge about people. Further, in an oscillatory or volatile environment, the need for that type of knowledge returns periodically. Consequently, adaptive firms downsize less regardless of the environment. In contrast, upsizing is more valuable in a volatile than in a stable environment. Finally, in a stable environment organizations employing the strategic approach to change tend to change more than their non-strategic counterparts; however, their final performance is comparable to those which change either randomly or procedurally.

Place Table 1 About Here

In general, in high volatility environments, more change is needed than in stable environments to achieve a reasonable level of performance. Interestingly, on average, the adaptive organizations in a volatile environment tend to perform as well or better than the adaptive organization in a stable environment. Essentially, in a stable environment, despite being able to change, organizations typically get locked into competency traps not in what they do, but in how they do it (i.e., in structure). Locking into competency traps leads the organization to cease strategic learning and to exploit experiential learning.

One question is whether the observed differences in top (adaptive) and bottom (maladaptive) performers hold more generally. As was previously noted, full data is not available for each cell and so all correlations cannot be provided. Thus, to address this issue, the available full data for the 1000 organizations with a random change strategy was examined (see Table 2). All correlations are in the expected direction in Table 1. The most significant correlations being those between performance and downsizing. Although the correlations are as expected the relationship between amount of change and performance is not linear. There is evidence of both decreasing returns to change and cases where moderate performers change more/less than either the adaptive or maladaptive organizations.

Place Table 2 About Here

The lesson, from both the current study and this earlier study, is that change is not necessarily adaptive. Whether or not change aids the organization in maintaining or improving its performance depends on the strategy used for selecting changes, the type of environment, and the type of change. Future work should explore whether it also matters when the changes are made.

Lesson 2: History Matters

As was just seen, each of the change strategies leads to a different level of change but results in structures that are comparable in terms of performance. Do the same organizational structures emerge regardless of which strategy is used? If so, the strategy that causes less change could be considered the more efficient one. The point here is not to find the optimal structure for this task. The optimal structure is idiosyncratic to the task and, as such, is not particularly interesting. The point is to see whether the same structure emerges regardless of which change strategy is employed.

Another way of asking this question is, regardless of change strategy, do organizations tend to converge on the same peaks in the performance surface. In other words, do differences in change strategy cause organizations to, in the same amount of time, migrate to different locations in the

performance surface. There are many ways this questions can be addressed. One way, is to look at the performance surfaces. Another way is to look at the differential position of the adaptive and maladaptive organizations given each of the change strategies.

To begin with, what do the performance surfaces look like? If we compare the organizational structure of high performers, those organizations which have a final performance level greater than 85%, with the other organizations for a 1000 organizations that change either randomly or strategically we find that high performers differ in their structure, often quite dramatically. In terms of a performance surface, we would say that not only is this not a single peak surface, but that all peaks in performance are not clustered in the same region. Second, some high performers are trapped on peaks that are far from the area of maximal peak density organization. These organizations have very distinct structures, e.g., there is a group that who size is small (size 10) and workload is low. Third, moderate performers are in regions that border high performers. Sometimes, they are even surrounded by high performers. Thus, for some of these moderate performing organizations moving up in size will improve performance and for others moving down in size will improve performance. Fourth, there is a general trend, low performers (the maladaptive organizations) tend to be lower in size and workload than do the high performers (the adaptive organizations). Finally, although it is not shown here, this surface changes with the change strategy employed by the organization employed (random, up-size when things are going well, other) and with the type of environment.

In Figure 4, the final size, density, and workload for the organizations by change strategy and environment is shown. As can be seen in Figure 4, the design of the adaptive organizations is different by environment and by change strategy. We cannot simply say that one strategy is more efficient than another as all change strategies lead to different final organizational designs. For example, adaptive organizations are smaller and less dense in stable than in volatile environments. Strategy and environment interact. Adaptive organizations that change randomly tend to be smaller, more dense, with lower workload that their strategic counterparts in the stable environment, and smaller, more dense, but have a higher workload than their strategic counterparts

in a volatile environment. In contrast, organizations that change strategically exhibit similar final designs in both the stable and volatile environments.

Place About Here — Figure 4. Impact of change strategy and environment on design of adaptive organizations.

In the foregoing analysis we examined only the adaptive organizations and saw that the change strategy affected the shape of the adaptive organizations. But does it also affect the shape of the maladaptive organizations? In Figure 5 we see that the change strategy leads to different organizations emerging in both the maladaptive and the adaptive arena. In particular, when the change strategy is random or procedural the organizations that emerge as maladaptive tend to be larger, less dense, and possess lower workloads than those emerging as adaptive. Whereas, under a strategy of strategic change maladaptive organizations are smaller, more dense and with lower workloads than their adaptive counterparts.

Place About Here — Figure 5. Impact of change strategy on relative design of maladaptive and adaptive organizations in a volatile environment.

Regardless of the change strategy, two organizations with the same design given the same set of tasks will exhibit the same performance if the employees within the organization have the same knowledge. The results displayed in Figures 4 and 5 however, suggest that two organizations with the same design and different change strategies are actually making different decisions and thereby achieving different levels of performance. How can this be?

There are two reasons. First, the structures that emerge under the different change strategies even when they have the same size, density and workload are somewhat different in configuration. Size, density and workload do not capture all of the nuances of the design. In other words, design matters — the exact configuration of the organization affects its performance. Second, as was

noted, two organizations with identical configurations will perform the same only if the employees are also identical. But, the change strategy affects what the employees know. The change strategy determines what employees learn what when and the context of that learning. Thus two employees who "grow up" in organizations with different change strategies, even when those organizations are faced with the same set of tasks, will learn different things. History matters — the path by which an organization reaches a particular design determines the effectiveness of that design. Consequently, adaptive and maladaptive organizations with the same final design, exhibit different performance because they got there by different routes.

Lesson 3: Avoid Locking in to a Change Strategy: Overshooting, Undershooting, and the Downward Spiral

Consider those organizations that in the end are either adaptive or maladaptive. Organizational change results in increased variation in organizational design (see Figure 6). To be sure, on average there is some difference initially. However, and importantly, this difference grows over time. Maladaptive organizations using a procedural or random strategy tend to overshoot in size, and undershoot in density and workload. Whereas, maladaptive organizations acting strategically tend to undershoot in size and workload and not to decrease far enough in density. The same change strategy can move the adaptive organizations in one direction and the maladaptive organizations in another.

Place About Here — Figure 6. Over time change in design

A detailed analysis was done of the over time behavior of a few organizations that ended up as adaptive or maladaptive suggested that organizations get locked into certain ways of changing. These few cases suggest that organization's develop a meta-learning that constrains future behavior. For example, one highly adaptive strategic organization began by initial high levels of hiring and then over time, when it changed, only changed connections (who was doing what and who reported to whom). As another example, a very maladaptive strategic organization began

small, downsized even more, then got locked into a cyclical pattern of hiring and firing. Thus, it appears that organizations can get locked into a spirals of behavior where over time they come be locked not just into poor/good performance, but into organizational designs and approaches to changing that design that further serve to degrade/improve performance more. Over time this pattern of behavior causes initial difference between the organizations to grow. In this sense, being adaptive is locking into the right pattern of change given the chosen change strategy. Maladaptive organizations appear to be ones that lock into a way of changing that causes them to overshoot or undershoot their objectives, or to re-enforce their current negative tendencies. Future work on the over time trajectories and patterns of change is needed.

THE VALUE OF LEARNING

A conception of organizations as information processors and search engines was presented. From this theoretical conception of organizations it follows that ultimate performance is a function of where you start and the path you follow, that learning although necessary for adaptation is not sufficient, that change is not adaptation, and that the path to success depends on factors both internal to and external to the organization, thus are many paths to success. Organizations were also characterized as being capable of learning at many levels. Learning at one level can interfere with or support learning at another level. Thus organizations with identical designs but different histories will perform differently as the structural learning affects what is learned experientially and the experiential learning affects what changes are made in the organization's structure.

This work is a step in looking at organizational adaptation in different environments. But, it is only a step. The environments examined herein are only volatile in a simple sense— the same class of task is not always being done. But what of environments where the organization is periodically faced with a truly novel task, where over time the organization sees many different tasks, rather than just cycling between two known tasks? Would such novelty affect the answers gleaned herein? In such situations, we might expect that the negative effects of downsizing would be less pronounced, and in fact that downsizing might even be advantageous. In a related vein, in this analysis change was seen as costless apart from information processing costs. If additional

costs were added for change then again the value of change might be less. Clearly other potentially relevant factors have also not been considered in this analysis. Such factors, if included would alter the specific results; e.g., that large low density organizations are most adaptive in stable environments for organizations that change strategically. However, they are not likely to change the critical results — that what designs are adaptive depends on the environment and the change strategy, that change is not necessarily adaptive but becomes more so in a volatile environment, that history matters, and so on. Finally, one of the values of formal theorizing is that it allows the theorist to incrementally add on additional factors and work through the implications of these factors in a rigorous and consistent manner. In this way, insights about design, performance and change build up incrementally.

Hannan and Freeman's (1984) proposed a structural theory of organizational inertia suggesting that though uncommon, change was related to organizational survival. However, in an empirical study Kelly and Amburgey (1991) found that organizational change was not necessarily related to either environmental change or to survival. Their argument was that inertia was not lack of change but change in the old ways. The theoretical conception portrayed in this paper can be viewed as a refinement of both arguments. In keeping with structural inertia theory this work suggests that while change is necessary for survival it is not sufficient. In keeping with Kelly and Amburgey it is argued that for organizations, continuing to change as they have in the past, extrapolation, even in the face of environmental shifts may be dysfunctional. However, unlike Kelly and Amburgey, I would suggest that extrapolation can be beneficial. The point is, whether or not extrapolation is beneficial depends on whether the organization is moving along the correct path. The key to survival/failure is neither change nor extrapolation but determining whether or not you are on the right path. In a sense, this is a much harder search problem. Future research should be directed at determining how to determine which path is the correct one and how to jump between paths.

A possible mechanism for jumping between paths is changing how you change; i.e., strategic change. Consider how the organizations are changing in the foregoing analysis. Over time, the organizations that pursued a random or procedural change strategy did not change how they

changed. Only organizations that changed strategically changed how they changed. A closer examination of the strategically changing organizations suggests that for these organizations adaptation was a matter of fine tuning. The organizations appeared to begin by getting the right number and set of people (initial judicious upsizing and downsizing). However, over time the amount of personnel changeover dropped precipitously and the amount of re-assignment and re-tasking increased. This suggests that the organizations were first growing the right set of people and then tuning themselves by moving individuals about so that they might alter whom they were working with or what they were working on.

Eccles and Crane (1988) argue that over time organizations do indeed act as annealers. This study suggests that annealing may be a valuable learning mechanism for organizations. If learning indeed occurs within the organization at many levels then multiple types of learning need to be considered. If learning at one level can interfere with or support learning at another level, then understanding the conditions under which different types of learning interact with each other and the ways in which the different types of learning are manifested becomes critical for understanding and predicting organizational adaptivity. The possibility of multi-level learning switches the focus of attention from do organizations learn to the conditions under which different types of learning prevail and adaptation occurs. In particular, the interplay between strategic and experiential learning appears to be quite important. At the strategic level, learning is manifested in the linkages among personnel and tasks; but, such learning can interfere with individual experiential learning. Consequently, being able to dynamically change how change is made in these linkages may be critical if organizations are to adapt. The analysis presented in this paper suggests that organizations that anneal and tune their designs over time have this capability.

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[2] Clearly change to the organization's design is not always strategic. Sometimes forces beyond managerial control result in alternative designs. However, the focus herein is on strategic change as such changes are, for many organizations, more sweeping. It is important to recognize that such non-strategic design change, like the strategic changes, are likely to interact with experiential learning, individual performance, and possibly organizational performance (Krackhardt, 1992). Thus, the observations herein about change at individual level and at the structural level are likely to have some relevance even to cases of non-strategic design change.

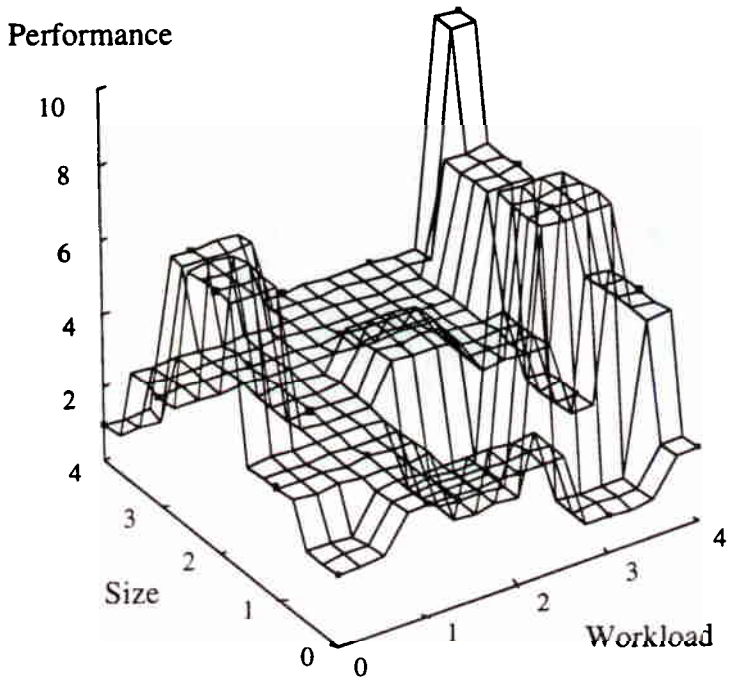
[3] Underlying both experiential and strategic learning is the idea that all types of learning result in changes in the connections among different pieces or sets of information. For the individual, these connections occur within the brain as new ideas become interconnected to old. Artificial systems, such as organizations, also have the same capacity to learn by creating connections among information. For organizations, the pieces of information exist as knowedge bases held in a veriety of ways such as within the minds of individuals, in file systems, in job descriptions, in data bases, or in artificial agents such as webbots.

[4] For an alternate operationalization using formal logic see Bruggeman (forthcoming).

[5] A strategy is a set of moves and the statistical distribution for each move that determines the probability with which that move will be chosen. Different strategies can be defined either by altering what moves are possible, or by altering the underlying distributions. Conceptually, however, some reserachers might be more comfortable thinking of changes in the underlying distribution, particularly small changes, as perturbations of a single strategy. For example, imagine the two following strategies. In strategy 1, the only moves possible are hires and fires and the probability of each is determined with a Poisson distribution with a mean of 0.2. In strategy 2, the only moves possible are hires and fires and the probability of each is determined with a Poisson distribution with a mean of 0.3. For some researchers, this second strategy will represent a new strategy, for others it will represent only a perturbation on an existing strategy.

[6] ORGAHEAD is a discreet event simulator. Thus, the number of personnel or connections that can be added or dropped each period is a positive integer. Poisson is a standard distribution used when x (in this case the number of changes) can take on only positive integer values.

Figures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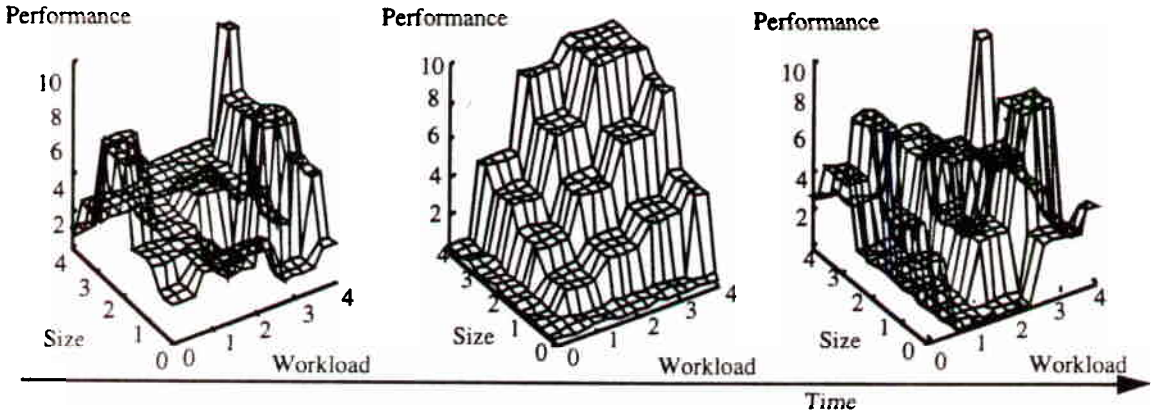
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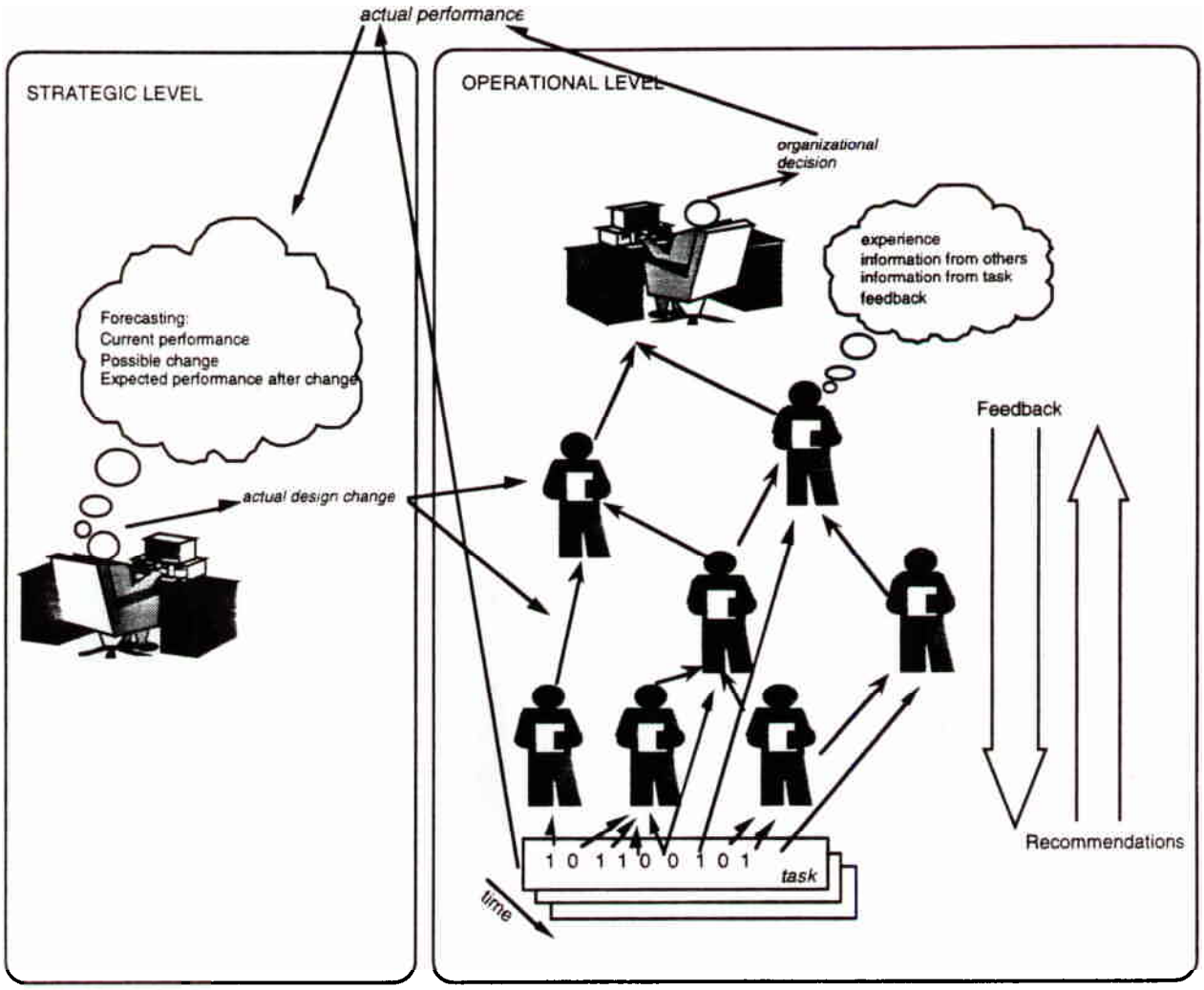
actual performance
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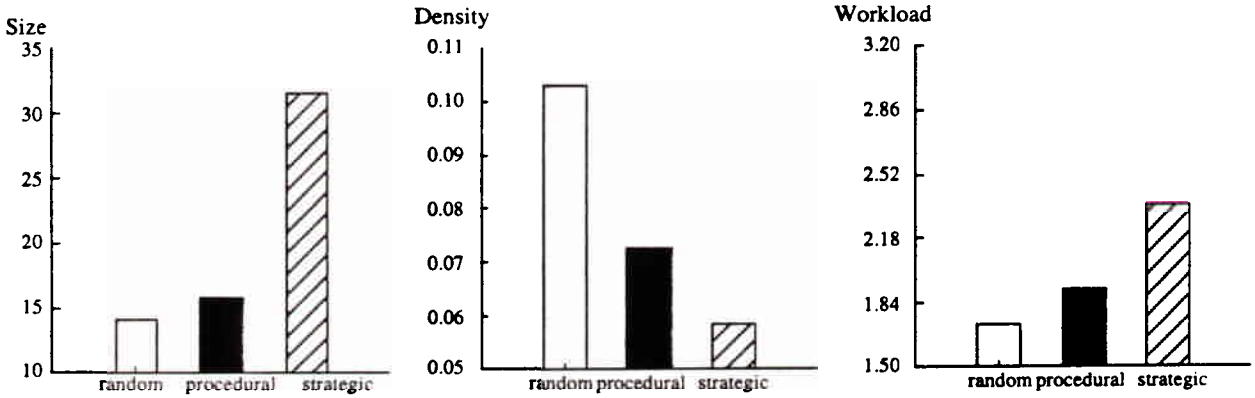
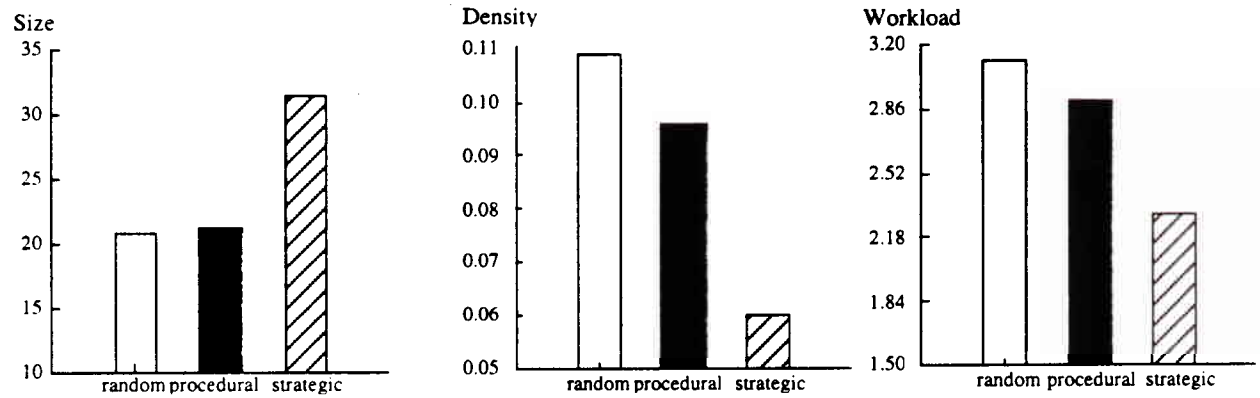
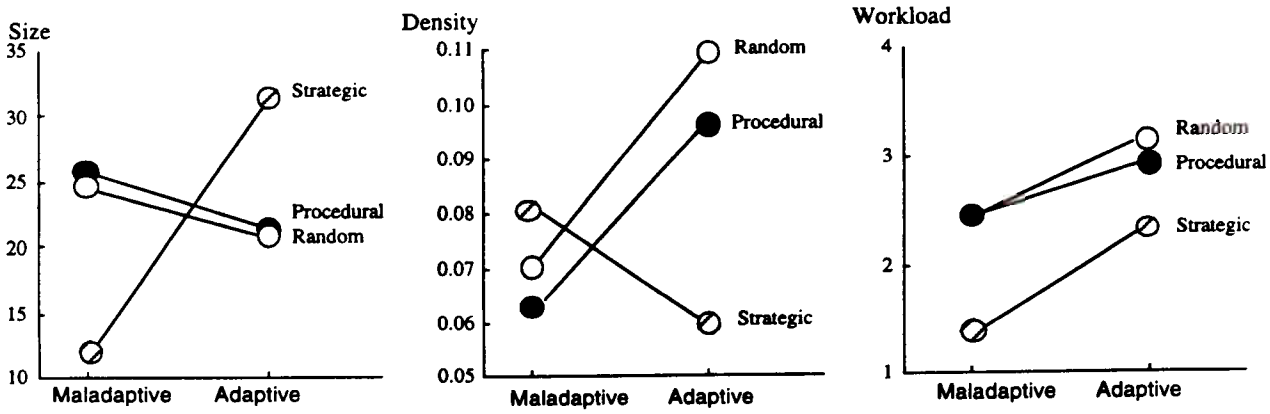
Stable Environment



Volatile Environment

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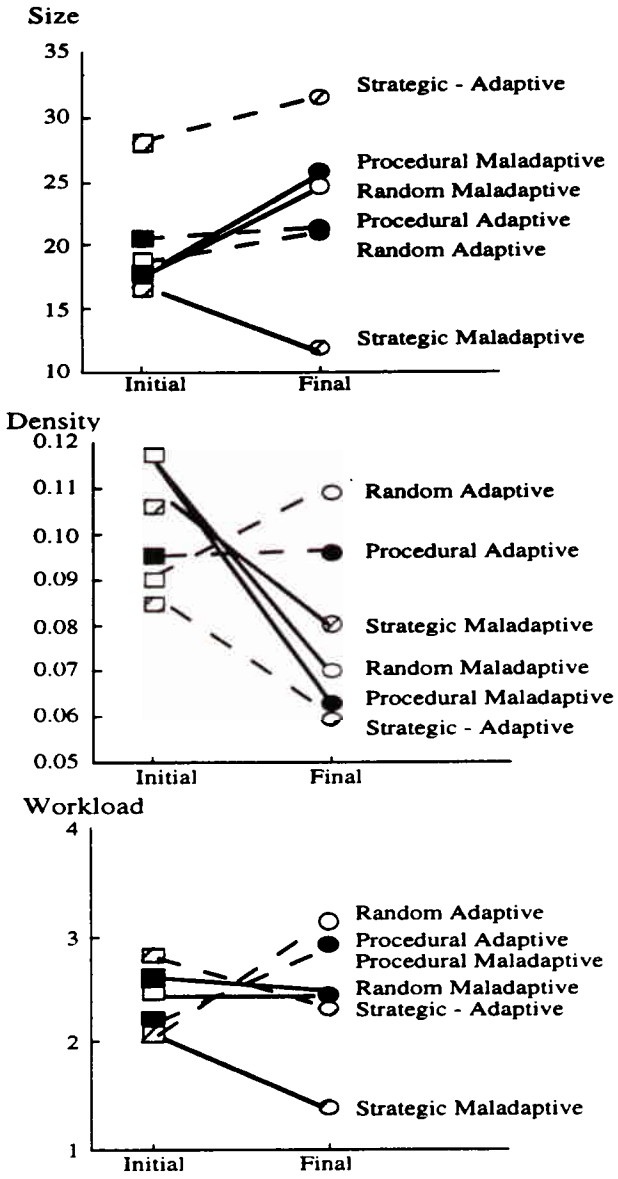
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Table 1

Average number of changes made by adaptive and maladaptive organizations

	Adaptive				Maladaptive			
Environment	Redesign	Re-engineer	Upsize	Downsize	Redesign	Re-engineer	Upsize	Downsize
Stable Environment								
Random	2.38	0.94	1.22	0.52	5.98	2.72	1.62	1.48
Procedural	1.70	1.00	1.02	0.40	6.02	3.24	1.38	1.68
Strategic	54.98	29.92	25.28	14.32	63.30	31.80	15.98	23.44
Volatile Environment								
Random	31.38	12.70	12.48	6.48	30.32	15.40	10.58	7.44
Procedural	30.04	16.24	12.70	6.84	24.94	18.96	10.66	7.18
Strategic	56.78	31.90	11.12	7.60	64.38	33.20	10.10	14.38

Table 2

Correlation between amount of change and performance for stable

Environment	Redesign	Re-engineer	Upsize	Downsize
Stable Environment				
Random	-0.21	-0.19	-0.15	-0.27
Volatile Environment				
Random	0.01	-0.06	0.16	-0.13