DYNAMIC ORGANIZATIONS:
ORGANIZATIONAL ADAPTATION
IN A CHANGING ENVIRONMENT

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ABSTRACT

Organizations can and do adapt to their environment. It is often suggested that high performance organizations are those that learn how to learn. This meta learning is often interpreted as acquiring skills, personnel and technology that increase the likelihood that the organization will be able to take advantage of new opportunities when they arise. In contrast, we argue that meta learning involves not just acquiring "the right stuff" but also developing the right change strategies. In order to achieve high performance, organizations need to learn strategies for when and how to change and when to take risks. However, such strategies are not necessarily transferable across organizations.

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INTRODUCTION

A widely held belief is that if organizations do not dynamically respond to a changing environment then their performance will suffer. The basic idea is that without change the organization's design will become increasingly unaligned with the environment. Forward looking organizations try to change on the basis of what they expect the future to be like. Such strategic planning can be a source of competitive advantage. However, despite the best of intentions and the most detailed information, managerial expectations about the future can be wrong. Consequently, not all strategic changes are actually adaptations; that is, not all changes serve to maintain or improve performance. Moreover, some changes might interfere with the ability of personnel to learn and to make use of their previous experience, thus degrading the performance of the entire organization.

In this paper, we examine the dynamic relationship between strategy, structure and performance. Following Porter's (1996) argument we see organizations as having an operational component where performance improves when the organization performs the same activities better than other organizations, and a strategic component where performance improves because advantageous choices were made about how to do things differently than other organizations. Using computational analysis we examine the over time behavior of a set of organizations that have the capability of learning both structurally (by altering the connections) and operationally (by personnel gaining experience). We will look for evidence of meta-learning; that is, evidence that the organizations have learned how to learn and so evolved effective change strategies. An effective change strategy is a pattern of choices that produce a sustainable advantage (consistently preserving or improving the organization's relative performance). The ability of organizations to learn to learn has been heralded as critical for adaptation. Our analysis will lend insight into the extent to which this might be true, and if so, what form of meta-learning is particularly valuable.

ADAPTATION

Literature on strategic and organizational adaptation is rife with examples of organizations that change over time (DiMaggio & Powell, 1983; Romanelli, 1991; Stinchcombe, 1965a; Stuart & Podolny, 1996). This change is due in part to organizations trying to move outward to the productivity frontier (Porter, 1996). Part of this change is simply a reflection of larger societal changes such as demographic, technological, institutional, and environmental changes (Bettis & Hitt, 1995; Garud & Kumaraswamy, 1995; Mascarenhas, 1989). And, part of this change is due to strategic re-organization (Kilman & Covin, 1988) including re-engineering, change in personnel, and new ways of managing (Porter, 1996). Change, however, is not always advantageous (Barnett & Hansen, 1996). For example, some types of
change, such as gains in individual experience, may improve organizational experience (March, 1981). Whereas others, such as downsizing, may have long term deleterious consequences. Many researchers argue that successful change, or adaptation, may involve developing absorptive capacity (Cohen & Levinthal, 1990) or becoming a learning organization (Senge, 1990). A resource-based view of the firm would argue that the key characteristics of learning to learn is the acquisition of the right resources, knowledge, and personnel so that the organization can take advantage of new opportunities Chang, 1996; Majoor & van Witteloostuijn, 1996). Another key element, according to Senge (1990), is system thinking.

System thinking involves thinking through the set of factors that affect performance and the complex relationships, and feedback, between them. An important characteristic of the organization as system is that it is complex. More precisely, in the organization as system there are many interacting non-linear processes. Consequently, thinking through the implications of a change, of a particular organizational action, is non-trivial. Different change processes may interfere with each other. For example, consider the potential for interference between re-engineering and individual learning. When performance drops organizations may enter a downward spiral by choosing to move personnel to work on tasks using resources with which they have little experience, thereby loosing the benefits of the experience these same personnel had in other tasks and with other resources, which in turn may lead to a further reduction in performance, which may lead to further re-engineering. Alternatively, such re-engineering may make it possible to perform more tasks simultaneously thereby increasing the speed of organizational response and possibly increasing overall performance regardless of individual expertise or training.

Most theories of strategic choice and organizational design speak to the relative advantage of different choices or designs in different situations (Argyres, 1996; Hannan and Freeman, 1977; Lawrence & Lorsch, 1967). Such theories provide some guidance for organizational change. However, such theories often take a fairly static view of design, suggesting one-to-one mapping of design and environment or task, without considering the ability of the organization to change to a new design or the impact of past design on current performance. In other words, such theories tend to emphasize either strategic change or operational change, without recognizing the connection between the two. Empirical evidence suggests, however, that the dynamic linkage between strategy and design is an important determinant of competitive advantage (Ingram, 1996). Moreover, there may be certain configurations of strategy that are more attuned to certain organizational designs (Miller, 1996). In other words, a more dynamic approach is called for, one that looks simultaneously at operational and strategic change.

The difficulty is that strategic and operational change may be only loosely coupled. Returning to the example, will the re-engineering be an adaptation? Thinking through this process involves understanding the linkage between strategic changes (such as re-engineering) and operational changes (such as individual
learning). In practice, these changes are only loosely coupled. Strategic changes made by management are a function of both past actions and past performance. However, management rarely has direct information on the impact of previous actions and must often make decisions based on anticipated feedback (Levinthal & Myatt, 1994). The only knowledge that can be acted on is: (1) what actions were taken in the past (strategic knowledge); (2) how the current organizational design is related to performance (operational knowledge); and (3) expectations about the impact of a change in design on performance (forecasts, based on guesses, strategic knowledge, and operational knowledge). An obvious meta-strategy is to continue to do what was done in the past. Such strategic homogeneity is likely to be associated with industry profitability (Dooley, Fowler, & Miller, 1996); however, it can backfire resulting in a competency trap (Barnett & Hansen, 1996). At the strategic level, choice of future actions results from past actions. However, evaluation of those actions is based on operational knowledge about how the organization's current design is related to its performance and guesses about the future. What is the impact of such loose coupling between the strategic and the operational on organizational adaptation?

THE ORGAHEAD MODEL

One way of reasoning about organizational adaptation is to use computational analysis. Computational analysis is particularly suited to the examination of complex non-linear and dynamic systems. This is the approach taken in this paper. For our analysis we use the ORGAHEAD (Carley, 1996a, 1997; Carley & Svoboda, 1996) computational framework. ORGAHEAD is a computational model of organizational performance in which: (1) the organization can change its structure in anticipation of the way in which environmental changes might affect performance, and (2) individual personnel can learn and so change their behavior over time. Within ORGAHEAD the strategic and operational levels are decoupled in the manner previously suggested. This model couples a standard model of individual experiential learning with a model of organizations as strategic adaptive agents. These agents, and the organization as a whole, are operating within a task environment. Change at the environmental level is considered exogenous to the organization. At the operational level, individual learning is carried out using a standard experiential learning model based on work in cognitive psychology. At the strategic level, learning is carried out using a simulated annealing model.

Task Environment

The task environment is the set of tasks that the organization faces. This environment changes exogenously to the organization. Such changes are reflected in changes in the distribution of problems seen by the organization. The type of task
used herein is a classification choice task (Carley, 1992). In a classification choice
task there is a set of information and a set of choices. The information is classified
and on the basis of this classification a choice is made. Such tasks have been
widely studied (Hollenbeck, Ilgen, Sego, Hedlund, Major, & Phillips, 1995; Hollenbeck, Ilgen, Tuttle, & Sego, 1995; Mihavics & Ouksel, 1996; Pete, Pattipati, &
Kleinman, 1993; Tang, Pattipati, & Kleinman, 1992) and appear in many situa-
tions. Typical illustrations of this task include determining which product to pro-
duce, determining whether or not to increase a budget allocation, radar classifica-
tion, and medical diagnosis. The organization's performance is deter-
mined by the actions of the personnel as they work on tasks.

The specific task we use is the nine-bit binary choice task. The goal is for the
organization to correctly determine whether outcome A or B is the right decision
given the incoming pieces of information (the nine bits). For the sake of exposi-
tion, let us imagine that the outcome A corresponds to "demand for A-widgets is
higher than demand for B-widgets" and that outcome B corresponds to "demand
for B-widgets is higher than demand for A-widgets." We will assume that A and
B are substitutable and so the demand cannot be simultaneously high for both.

Each time period the organization sees a string of nine bits. Each bit corresponds
to a feature. Each bit indicates whether a feature is (1) or is not (0) present. Some
features suggest that outcome A is the correct decision, and others that outcome B
is the correct decision. For example, if A-widgets are big cars and B-widgets are
small cars, then one feature might be the price of gas is high. When this feature is
true, that might suggest that small cars are to be preferred. Each of the nine fea-
tures supports either A or B. If the feature is present (1) that supports A, and if the
features is not present (0) then that supports B. The correct answer is dependent
only on the number of features that are present, not on combinations of features. 1
If more features are present than not (there are more 1's than 0's), then A is the cor-
rect decision; otherwise, B is the correct decision. Each time period, the organiza-
tion sees a different problem; that is, a different nine bit string. These problems are
chosen (with replacement) randomly from the set of possible problems.

The organization, after observing the nine piece of information for that period,
must decide whether it thinks outcome A or B is more likely to be correct. Of

course, the organization could be wrong; for example, it might incorrectly classify
the incoming information. The organization's performance is thus measured as the
percentage of tasks during a period that it correctly classifies. Or, in the expository
example, the percentage of times the organization correctly predicts the relative
demand for A and B-widgets. How the organization makes these decisions
depends on the way in which personnel are trained, the extent of their training, and
the way in which they are connected in the organization. This operational behavior
of the organization will be described next.

First, however, a caveat. We described this task in terms of production. This was
purely an expository device. The proposed model is clearly not a detailed model of
production. For one thing, it treats performance purely from a forecasting perspec-
tive; that is, did the organization correctly predict the demand. Many associated costs are not considered such as the costs of re-tooling to change the level of producing A or B-widgets. Second, the organization is only forecasting a binary variable not a continuous variable. Nevertheless, the model we have proposed captures the core element—trying to classify information to make a decision. The limits we have just discussed, and others, are most likely to increase the variance in organizational behavior but not the relative behavior. That is, if we find the organization of form X outperforms organizations of form Y then, when these other factors are considered, we will probably still find that X outperforms Y, but the extent to which X outperforms Y may depend on these other factors. The advantage of the proposed model is that by focusing on the key element, the classification decision, the simplicity of the model should help to lay bare the relationship between types of learning and organizational performance rather than obscure that relationship.

Operational Level

Organizations are characterized as complex, computational entities composed of a set of personnel coordinated, at least in part, through an authority structure (connections among personnel) and assigned to a position in the resource access structure (connections between personnel and raw task information). In this authority structure subordinates pass their opinions about the true state of the task to superiors. These personnel are adaptive agents, each of whom occupies a particular position in the organization and has the capability of learning over time as experience is gained with the task being performed and the resources being used. In a manner similar to that suggested by Bush and Mosteller (1955), each agent is modeled using a stochastic learning model in which the probability of making a particular decision changes incrementally in response to feedback. However, our agents are more realistic than the original stochastic models. This added realism was achieved by detailing the specific limits on the agent’s attention, memory, and information processing capabilities. These specific capabilities place particular bounds on the agent’s rationality in manners consistent with various findings in cognitive psychology and behavioral decision theory; such as primacy and recency effects, overconfidence in decisions, recall of expected behavior rather than particular instances, and so forth.²

The structure is characterized as a series of interlocked networks: authority (who reports to/commands whom) and resource access (who has access to what resources). No distinction is made between the authority structure and the communication structure (who communicates to whom). Indeed, the two structures are equivalent. Each of these networks can be characterized using various social network measures such as at least upper boundedness and span of control. Change in the structures can be monitored by examining changes in these measures or in the overall networks.
The specific organizations we examine range in size from 2 to 45 personnel arranged in 1 to 3 layers with 0 to 15 agents at each level. These layers—A, B, and C—are arranged such that personnel can communicate between layers, but not within a layer. Illustrative structures are shown in Figure 1. Each agent operates on incoming information. This may be raw task information (a particular bit) or it may be the opinions of other agents. Agents are boundedly rational and cannot process more than seven bits of information. Thus, no agent can perfectly do the task when alone; that is, this is a distributed decision making task. The final organizational decision is made by the agent (or agent's) in the top level (A). The organizational decision is the simple majority vote of these agents. Agents in any level may be assigned to examine raw task information. Agents in level C may report directly to agents in level B. Agents may have multiple subordinates and/or multiple superiors. The flexibility of this formalism is such that many common organizational forms can be represented in it; for example, teams, hierarchies, matrix, m-form, and market structures can all be represented.

Strategic Level

Management can alter the structure of the organization in response to expectations about future performance. A managerial change agent, such as a CEO, or a group, such as a board of directors, acts for the organization in this capacity. This corporate actor makes a series of strategic decisions which involves a certain amount of risk taking. The strategic actions that can be taken are to hire or fire personnel, add or drop connections among personnel, and add or drop connections between personnel and resources (bits in the task). These actions can be thought of as the micro-instantiation of more general acquisition processes. Organizational performance is affected by the ability of the CEO or some central unit to anticipate
the future and take the appropriate strategic actions to alter the organizational structure in response to actual or anticipated environmental cues. In this section the term CEO is used to refer to this corporate actor, but keep in mind that it could just as easily be a group or some other individual making these decisions.

In a detailed empirical study of investment banking Eccles and Crane (1988) argued that the process of strategic change in organizational design gone through by human organizations is an annealing process. Based on this empirical argument we have chosen to model the process of strategic adaptation as an annealing process using simulated annealing. Simulated annealing is a heuristic approach to optimization that is computationally analogous to the physical process of annealing a solid (Kirkpatrick, Gelatt, & Vecchi, 1983; Rutenbar 1989). The goal of the annealing process is to find that state which minimizes costs (or in our terms, maximizes performance). The process of annealing involves heating the system to a state that admits many alterations, then, given a schedule of decreasing temperatures, cooling the system slowly so that it reaches thermodynamic equilibrium at each temperature in this schedule, and eventually freezing the system in a good configuration. This process is carried out by having a set of possible moves for altering the existent state to another state, choosing a move, evaluating the proposed state that this move would create, and then moving to that new state if it decreases costs and possibly even if it does not. The frequency with which such cost-increasing moves are accepted decreases with times the temperature cools. Because simulated annealing is a heuristic optimization technique it is not guaranteed to find the optimal solution; nor does it always make the best move. Typically, however, simulated annealing moves the system to a state that is better than where it started.

Now let's place this process in an organizational context. Doing so will both provide the reader with a better understanding of the model and will demonstrate how features of the model derive from or are consistent with known organizational behavior. The following two paragraphs describe the model and identify which aspects of organizational and strategic theory it is consistent with. Additionally technical details on the model appear in Carley and Svoboda (1996).

For a particular task, the organization's performance is a function of its design. The organization's design can be characterized by the organization's value on a large number of dimensions (such as size, span of control, number of predefined routines, degree of autonomy granted the individual work units and so on). In other words, the relation between design and performance can be described by a multi-dimensional surface. For illustrative purposes, imagine that design can be uniquely characterized by two dimensions, such as size and span of control. In this case, the performance landscape faced by the organization might look like that shown in Figure 2. What the annealing organization tries to do is to climb this surface looking for the highest peak. That is, the CEO is trying to optimize the organization's design for the task being performed. Typically, the CEO cannot simply jump the organization to the highest peak (the best design) for several reasons.
First, the CEO cannot see the whole surface; managers are human and therefore at most boundedly rational. Second, the CEO may be constrained (economically, legally, or culturally) such that certain changes in the organization's design are either unthinkable or not allowable. An example here would be federal regulations on mergers and support for joint ventures. Industries will differ in what these performance surfaces will look like. Thus, in some industries it will be easier for CEOs to move their organizations to the highest peak. The "lumpier" this surface the less likely it is that the optimal design will be found.

The annealing process describes the strategic process by which management causes the organization to traverse this performance landscape. Basically, the organization starts with some design, this is largely an accident of the time at which it was founded (or in human organizations, whom the founders were). The CEO alters the structure strategically; that is, a change is made if it appears to move the organization closer to the goal regardless of whether or not it actually does so (March & Simon, 1958; Simon, 1944). Periodically the CEO engages in a
strategic planning process which centers around proposing and evaluating a new
design (such as, "get rid of all middle management"). The CEO thinks ahead about
how that change will affect the organization's performance. Changes are made on
the basis of this anticipated feedback (Levinthal & Myatt, 1994). The CEO cannot
forecast the future, but only tries to think ahead a few steps. This speculation is
informed by knowledge about the organization (including who knows what and
who can do what) and possibly knowledge about how well other organizations
with that design have performed (Stuart & Podolny, 1996). This speculation will
set an expectation; that is, the proposed change will improve/not-improve perfor-
mance. The CEO is not omniscient, does not compare all strategies, but simply
evaluates a strategy through a kind of "what if" analysis, trying to forecast or antici-
patate, albeit imperfectly, the future (Allison 1971; Axelrod 1976; Cohen & March,
1974). If the expectation is that the proposed change will improve performance
then the change is made. Since the forecast is known to be imperfect, the CEO may
at times gamble on redesigns that might possibly "increase costs" if it is felt that
there is some long term advantage. If the expectation is that the proposed change
will not improve performance then the change still might be made. That is, the
CEO might choose to take a risk. This corresponds to the idea that the decision-
makers perception of risk and propensity to take risks is thus a key element in the
strategic process (Pablo, Sitkin, & Jemison, 1996). However, the likelihood that
the CEO will take risks decreases with time as the organization ages and so
becomes more rigid in its behavior (possibly due to cultural constraints). Overtime,
the number of high risk moves decreases (Stinchcombe, 1965b) as the organi-
zation locks into a certain way of doing business and so gets trapped by its
competency (Levitt & March, 1988). Initially the CEO chooses what change to
evaluate more or less randomly. Over time, however, the CEO will learn what
types of changes are most likely to generate positive expectations. As time goes
on, the CEO will increasingly choose to evaluate those changes that were most
often made in the past. In other words, the CEO will over time increasingly exploit
known ways of doing work and solving problems; for example, "in the past we
often hired new personnel so I will consider hiring new personnel." Notice that the
CEO is not comparing all strategies and taking the best. Rather, the CEO is only
examining one strategy and taking it if it is good enough. In this sense, the CEO is
satisficing.

Clearly the life of the CEO, or the organization's change agent, is more complex
than it appears in this model. For example, there may be multiple tasks, personal-
ity factors to consider, more than one strategy for change may be considered at a
time, and so on. However, the process just described does capture many of the core
elements in this type of strategic thinking; for example, imperfect forecasts, deci-
sions made on the basis of expectations, perception of risk, increasing risk averse-
sion, and locking onto strategies that are "tried and true." By focusing in on these
aspects of strategic change, we can examine how strategic and operational action
can combine, or not combine, to generate a learning organization.
Additional Implementation Details

In ORGAHEAD the CEO has a set of possible ways in which the organization's structure can be altered. These "ways" include such procedures as changing who reports to whom, hiring personnel, firing personnel, and changing who has which resources and so can do which task. Different types of "industries" can be simulated by allowing or disallowing certain ways of changing the organization and/or altering the cost function that the organization is trying to optimize. These "ways" are the move set used by the annealer, and represent the constraints on types of changes the CEO can make given legal, economic, cultural and other resources constraints. The CEO proposes a new design (the old design changed by making one of these moves), and then "simulates" the behavior of this possible new design. This is done by giving the hypothetical organization with the proposed structure a series of tasks to do. The performance of this hypothetical organization is then compared with performance of the actual organization. In ORGAHEAD the probability of accepting a new design (a strategy from the move set) is defined by the Metropolis criteria and the Boltzman probability criteria. According to this criteria, the CEO will always implement the proposed change if the hypothetical structure is expected to be a better performer than the current structure. Otherwise, the risky change is accepted with a small probability and that probability reduces over time. This probability is given by the Boltzman equation, $e^{-\frac{\Delta cost(t)}{kT}}$, where $cost(t) = 1/\text{performance}(t)$.

The rate of change is set by the temperature cooling schedule. For the virtual experiments that we ran temperature ($T$) drops each time period as $T(t+1) = \alpha * T(t)$ where $\alpha$ is the rate at which the organization becomes risk averse and $t$ is time. When the organization changes its structure, it is done so on the basis of the expectation that the new structure will be a better performer, rather than on actual feedback from previous exercises. Thus, some of the changes that are taken may actually, particularly in a changing environment, degrade performance.

VIRTUAL EXPERIMENT

Using ORGAHEAD a virtual experiment was run. Two different task environments were considered (see Figure 3): the stable environment and the changed environment. These environments can be thought of as reflecting the likelihood that B-widgets should be produced. In the stable environment the demand for type A and B widgets is, on average, the same. Thus each time period there may be a greater demand for A or B, but over time, this demand averages out. Under this condition, the organizational response changing demand is not critical. In the changed environment, the average demand for A and B-widgets is initially the same; but, at some point a major change occurs and the demand for B-widgets skyrockets. During this latter phase there is still some demand for A-widgets, but in
general B-widgets are preferred. The step change in demand occurs half way through the task set (40,000 tasks), at task 20,000. There is one task per time step.

Additionally, two different cooling schedules (change in risk adversity over time) are considered (see Figure 3). In the first, the organization gradually becomes more stable over time as the CEO takes fewer and fewer risks. The rate of temperature decrease, \( a \), is 0.78 for the normal cooling schedule shown on the left in Figure 3; and \( \alpha \), is 0.605 for the Medeiros cooling schedule shown on the right in Figure 3. For both, \( T = 19 \). The memory window remains constant, 250 cycles. In the second, the organization, due to the shift in the environment, begins to experiment more after the shift occurs. This shift in risky behavior occurs at the same time as the shift in the environment. In the second, the organization becomes more risk adverse until the environmental change and then it jumps up to being
Figure 4. Performance measurement.

much less risk adverse.\textsuperscript{6} We examine the impact of this second cooling schedule only in the changed environment.

For each condition 1000 organizations were simulated. The initial size, number of connections, and location of connections were chosen randomly in a standard Monte-Carlo approach. In all of the experiments, for each organization examined, the command and communication structures are equivalent. Every 500 tasks the CEO can propose, evaluate, and (depending on the decision) implement a change. Thus, since the organization faces 40,000 tasks, there are 80 times when the CEO can propose a change; that is, 80 change cycles. When the CEO thinks about a proposed change, the “hypothetical organization” is “simulated” for 250 tasks and its performance measured on these 250 tasks. This expected performance is then contrasted with the latest actual performance. Actual organization performance is measured every 500 tasks.
Table 1. Illustrative Data Collection
Table for Measuring Decision Performance

<table>
<thead>
<tr>
<th>Expected Performance Outcome</th>
<th>Action</th>
<th>Improvement</th>
<th>No Change</th>
<th>Degradation</th>
<th>Row Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improvement</td>
<td>Change</td>
<td>X11</td>
<td>X12</td>
<td>X13</td>
<td>R1</td>
</tr>
<tr>
<td>No Change</td>
<td>Change</td>
<td>X21</td>
<td>X22</td>
<td>X23</td>
<td>R2</td>
</tr>
<tr>
<td>Degradation</td>
<td>Change</td>
<td>X31</td>
<td>X32</td>
<td>X33</td>
<td>R3</td>
</tr>
<tr>
<td>Degradation</td>
<td>No Change</td>
<td>X41</td>
<td>X42</td>
<td>X43</td>
<td>R4</td>
</tr>
<tr>
<td>Column Sum</td>
<td></td>
<td>C1</td>
<td>C2</td>
<td>C3</td>
<td>Number of Changes</td>
</tr>
</tbody>
</table>

Note: Each cell contains the number of changes by all organizations that fit those criteria.

Each agent in the organization has a maximum memory capacity of 250 tasks; the agent's behavior reflects what it has learned from solving the last 250 tasks. For all organizations, initially, all possible strategic changes are equally likely: hire 1 or more agents, fire 1 or more agents, make one or more changes in who reports to whom, make one or more changes in who is doing what.

MEASUREMENTS

Performance is measured as the percentage of the tasks during a prespecified period for which the organization accurately predicted demand (A or B). During each period we also track the type of strategic changes made by the organization and the order in which these changes were made. Performance and change behavior is measured during four different periods (see Figure 4). These periods were positioned at the beginning, end, immediately before the change, and immediately after the change. These points were selected so that we could capture change in behavior over time and response to environmental change. By contrasting behavior during these four periods we can gain an understanding of the relationship between strategic change and adaptation.

During each period information was collected on what changes were proposed when, what the expectation was for each proposed change, which changes were taken, and whether the change led to the desired outcome. Information was collected on the order in which changes occurred; for example, did hires typically follow hires. Thus we can determine whether or not organizations get trapped in change cycles that propagate poor performance. For each period we can fill in a table, like Table 1, characterizing the organizations decision behavior. For table 1, the length of each period is 2500 tasks or 5 change cycles. Period 1 occurs between change cycles 1 and 5. Period 2 occurs between cycles 35 and 39. Period 3 occurs
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between cycles 40 and 44. Recall, the switch for the changed environment occurs at change cycle 40. Finally, period 4 occurs between cycles 76 and 80.

Based on this table, we can then calculate eight important indicators of performance:

**Number of Changes:** The number of times the organization makes a change.

\[ \text{Number of Changes} = X_{11} + X_{12} + X_{13} + X_{21} + X_{22} + X_{23} + X_{31} + X_{32} + X_{33} \]

**Success:** The percentage of change cycles during which performance improved.

\[ \text{Success} = 100 \times C_1 / \text{Number of Changes} \]

**Neutral:** The percentage of change cycles during which performance stayed the same.

\[ \text{Neutral} = 100 \times C_2 / \text{Number of Changes} \]

**Failure:** The percentage of change cycles during which performance deteriorated.

\[ \text{Failure} = 100 \times C_3 / \text{Number of Changes} \]

**Accuracy:** The percentage of change cycles for which the CEO correctly predicted the impact of the change or lack of change.

\[ \text{Accuracy} = 100 \times (X_{11} + X_{12} + X_{21} + X_{22} + X_{31} + X_{41} + X_{42}) / \text{Number of Changes} \]

**Effectiveness:** Normalized ratio of number of changes in which performance improved or stayed the same to the total number of changes made. This value is scaled between -1 and 1 so that a 1 indicates performance always improved or was maintained, a -1 indicates performance always degraded, and a 0 indicates that both are equally likely. This is an optimistic definition and includes no change as a positive event.

\[ \text{Effectiveness} = 2 \times \{(X_{11} + X_{12} + X_{21} + X_{22} + X_{31} + X_{32}) / (R_1 + R_2 + R_3) - 0.5\} \]

**No Change is Good:** Percentages of change cycles where no change was made in which performance increased.
No Change is Good $= 100 \times (X_{41}/R_4)$

Fortuitous Accident: Percentages of change cycles where a risky change was made in which performance increased.

$\text{Fortune} = 100 \times (X_{31}/R_3)$

Within the set of organizations simulated some end up being high performers and some end up being low performers. We define as high performers, the 50 organizations (5% of all organizations) which during the final period (4) exhibited the highest performance. Similarly, low performers are those 50 organizations that exhibited the lowest performance during the final period. It is not the case that the organization's that end high were the highest 50 all the way along. However, on average they did tend to be better than average performers through out time. Whereas, the organizations that ended up as the lowest ultimate performers typically exhibited lower performance through out time. Additional studies should be done to characterize the specific over time performance of these organizations.

**LEARNING PATTERNS OF CHANGE**

A common expectation is that high performing organizations are often movers and shakers, able to change, adapt, and alter the way they do business frequently (Chang, 1996). But is frequent change, really a hallmark of high performance? March (1991) describes such change as exploration and argues that too much exploration can actually hurt the organization. Rather, he argues, organizations need to learn to balance exploitation of current capabilities and exploration of new ways of doing business. Our results suggest that the difference between high and low performing organizations may not be how much they change, but when they change. Thus sustained advantage is a function not only of making choices (Porter, 1996); but of making the right choices at the right time.

Over time, management is becoming more risk averse and so the number of changes is decreasing. However, this pattern of descent is different for the high and low performing organizations (Figure 5). Path dependencies exist and thus, history matters. Initially, all organizations make a comparable number of changes. Then, in the middle periods, the high performing organizations make more changes and the low performing ones make fewer. Then, in the last period, the low performing organizations make more changes than the high performing organizations. Over time there is little appreciable difference between organizations facing a fixed and a changing environment.

Over time, in all organizations managers are increasingly likely to consider only those actions that they have taken in the past. That is, they move from strategic heterogeneity to strategic homogeneity. Future actions are based not on past perfor-
Number of Changes

![Graph showing changes over time for different performance classes.]

*Figure 5.* Number of changes made per period by class or

Effectiveness

![Graph showing effectiveness changes over time for different performance classes.]

*Figure 6.* Effectiveness by period for class of organization.

mance but on past actions. Since initially managers in all organizations are likely to accept all changes, regardless of their risk, differences during the second period are attributable to history. That is, managers in high performing organizations ini-
Figure 7.  Accuracy by period for class of organization.

Figure 8.  Fortune by period for class of organization.
Figure 9. No change is good by period for class of organization.

Initially lock onto strategies of change that will continue to be useful over time. Thus, in future periods, they are more likely to propose these successful strategies, and they are more likely to have positive expectations about the impact of these strategies, and they are more likely to then take the associated action. In this case, risk aversion is leading to replication of past successful behavior. In contrast, managers in low performing organizations, initially explore strategies of change that are not useful. The managers are more likely to propose the same actions they have taken in the past, but, when these actions are evaluated they are less likely to take them as they expect the change to degrade performance. In this case, risk aversion is leading to inaction. Eventually, however, the managers of low performance organizations locate strategies that they expect to have positive outcomes and then start making more changes, but by then it is too late.

High performance organizations are not continually high performers. Although on average their performance is higher than low performers they are not always successful. They periodically bounce up to having the highest levels of success but do not stay always at the top. However, high performers are generally more effective than low performers; that is, they maintain or improve their performance more often than do low performance organizations. See Figure 6.

Organizations do not achieve high performance simply because they change the most, or choose the right actions, or because they are lucky. They are high performers, because they change, choose the right actions, and are lucky at the right times. High performance organizations are more likely to exhibit higher initial lev-
High Performance
STABLE

CHANGE

Low Performance
STABLE

CHANGE

Time

Figure 10. Over time changes in adaptation strategies for increasingly risk adverse organizations in both stable and changing environments.

eels of change than low performance organizations. The managers of these organizations make these changes not because they have to, but because they have learned expectations about what changes are likely to be effective. Initially (or immediately following a change in the environment), high performers are more accurate than low performers (see Figure 7). Thus, not only do they change more, but the change they make has the desired outcome. This early accuracy helps them to learn which strategies to use. These strategies become some what less useful over time, hence the oscillation in their performance. Another way in which high performers differ from low performers is that the risks they take, particularly those in the middle periods, pay off (see Figure 8). In other words, high performers are accurate initially, change frequently in mid-course, and are fortunate in the long run.

Over time, organizational inertia sets in and fewer risky changes are made. The irony is that this inertia is actually good for low performance organizations (see Figure 9). Low performance organizations are much more likely than high performance organizations to achieve an increase in performance after a change in the environment (period 3) simply by doing nothing.
**Figure 11.** Success by period for risk taking and risk averse organizations in a changing environment.

**Figure 12.** Accuracy by period for risk taking and risk averse organizations in a changing environment.
**Figure 13.** Effectiveness by period for risk taking and risk averse organizations in a changing environment.

**Figure 14.** Fortune by period for risk taking and risk averse organizations in a changing environment.
High and low performing organizations differ in the order in which they take actions to change the organization. In Figure 10, only those transitions that occurred more frequently than would be expected by chance are shown. Each transition has a 1/4 chance of occurring. The thicker lines indicate transitions that occurred more than twice as often as would be expected by chance. The four actions are: H = hire, F = fire, TC = change who is doing what (re-engineer), PC = change who reports to whom (restructure).

High performing organizations initially build up (H) while low performing organizations are initially more likely to reduce in size (F). High performance organizations tend to move between strategies and they tend to repeat hiring. High performing organizations spend more time moving personnel about—re-engineering (TC), restructuring (PC). Whereas, low performance organizations spend more time changing personnel. Low performance organizations are very likely to get locked into patterns of repeated firing. Over time high performers develop fairly complex change strategies that often emphasize the movement of personnel between tasks or between divisions. Low performers typically have less complex strategies. These strategies repeated downsizing, or oscillations between periods of building up then downsizing tend to decrease operational knowledge. This destruction of operational knowledge decreases the ability of the organization to accurately forecast the future and can lock the organization in a downward spiral where, regardless of the change, performance is likely to decrease.

Finally, let us examine the effect of becoming less risk adverse in the face of environmental shifts. Organizations that become more risk taking in response to a changing environment are more likely to achieve higher success in the long run (see Figure 11). Additionally, immediately after the environmental change they will be less accurate but the high performers will be more accurate in the long run (see Figure 12). In the long run, however, although more successful they will be less effective than organizations that continue to become more risk adverse (see Figure 13). Risk taking organizations are more fortunate than the risk averse (see Figure 14), in large part because they simply take more risks. However, the high performance risk takers have basically substituted well informed choices (accuracy) for fortune; whereas, it is the low performers who are randomly striking out and relying on luck.

In a changing environment, becoming risk taking in response to environmental change is not a guaranteed win. In fact, it has the effect of causing organizations to diverge; that is, the rich get richer and the poor get poorer. More precisely, high performance organizations where the managers adopt this strategy improve their overall performance over that of organizations that do not become more risk taking. In low performance organizations, on the other hand, if the management becomes more risk, the organization's performance is likely to plummet. For high performance organizations, this is because changing risk behavior increases accuracy and the advantages of no change. For low performers, changing risk behavior simply decreases their chances of success because they are moving between orga-
High Performance

Low Performance

Time

Figure 15. Over time changes in adaptation strategies for increasingly risk taking organizations in changing environments.

Organizational designs that are equally ineffective. In a changing environment, if the management responds by becoming less risk adverse then the strategy that emerges is likely to be more complex than the strategy that emerges from a more risk adverse managerial style (contrast Figures 10 and 15). Also, the increasingly risk taking management approach is more likely to lead to a strategy that involves repeated patterns of personnel change (repeatedhirings or repeated firings) than is a more risk adverse management approach.

CONCLUSIONS

This research can be thought of as defining a neo-information processing perspective to strategic management. One of the hallmarks of this approach is that all lines of information flow are specified. We do this by specifying the networks connecting not just personnel, but also tasks, and the connections between personnel and tasks. A second hallmark of this perspective is that rather than simply characterizing the actors as boundedly rational, the details by which actors interact, learn, perceive risks, take risks and the details of their social position are specified. A third hallmark of this perspective is the focus on dynamic and non-linear processes. This neo-information processing approach thus combines structural and cognitive elements that affect strategic behavior into a single dynamic system. Each of these features increases our ability to reason about organizational performance.

We characterized the organization's structure as a web of inter-locked networks. The advantage of this representation is that the power of network statistics can be
brought to bear on all aspects of organizational structure. In previous research on organizations network analysis has been used to look at the formal authority structure and the informal friendship structure. The approach we have taken extends the use of networks to the examination of many other aspects of organizations including the resource allocation and the task structure. Characterizing the organization's structure in this manner is particularly useful when taking an information processing approach to modeling organizational behavior. However, we would suggest that this network based approach to structure is also useful in other empirical contexts.

Taking a network based approach lays bare the distinction between re-engineering and re-structuring. Re-engineering involves altering the task structure (the network of connections among tasks) and the resource-allocation/task assignment structure (who has the resources to do or is assigned which task). Restructuring involves altering the personnel structures (who reports to, has authority over, or communicates with whom). By distinguishing these change strategies in this way we can examine the relative impact on performance of the different types of change. Our results indicate that a consequence of the loose coupling between strategic and operational change is that adaptation strategies that work well for high performance organizations are different than the strategies used by low performance organizations. One question is whether low performance organizations can employ high performance strategies and become high performers. Although we have not explored this question directly, it is likely that the answer is no. The reason being that what strategy works best for the organization depends on its specific history of strategic change.

In this paper, the methodological approach we have taken is to engage in computational theorizing. Computational theorizing is particularly suited to theorizing about the dynamic behavior of complex non-linear systems such as organizations. The model described herein is descriptive in the sense that it embodies empirical results and theories about organizational behavior. Using this model we can then ask, if what we think we know about organizations is true, what will an adaptive organization look like? The results we have provided should be thought of as theoretical arguments about how organizations are likely to behave if they follow the processes specified, with all else being held constant.

The results from the proposed model are consistent with many of the findings and arguments in the literature: for example, that organization's need to balance exploration and exploitation (March, 1991), that there is a strong relationship between size, age and performance (Wholey, Engberg, & Bryce, 1997), that successful organizations can position themselves for success by acquiring the right resources, personnel, and knowledge (Cohen & Levinthal, 1990), that very high levels of either strategic homogeneity or strategic heterogeneity result in profitability (Dooley, Fowler, & Miller, 1996), and that risk taking affects performance (Pablo, Sitkin, & Jemison, 1996). What this research suggests is that these, and many others, results all follow from a set of simple learning processes. Moreover,
each of these results are special cases; that is, they do not represent panaceas that
if followed are guaranteed to improve organizational performance. Rather, we find
that the timing of the strategy, and when it is used in the organization's life cycle,
are critical to creating a sustained advantage. The same adaptation strategy may at
one point in time or for one organization be adaptive and at another point in time
or for another organizations be maladaptive.

The loose coupling between the operational and strategic level leads to different
patterns of adaptation on the part of high and low performers. The same simple
processes result in high performers being initially accurate and lucky in the long
term, and low performers being more advantaged by doing nothing. Interestingly,
our results suggest that high performance organizations can trade luck for accu-
ricy if they are willing to increase their propensity to take risks. However, if low
performance organizations try to respond to a changing environment by taking
risks, they may suffer massive degradations in performance. Since the strategies
for adaptation are different for high and low performers, low performers may be
better off mimicking the organizational form of the high performers rather than
their strategies for change. It is often argued that the competitive advantage
derived by employing best practices decreases as more organizations employ
those practices (Porter, 1996). We see evidence of this in our results. Moreover, we
also find that the mimicry of best practices can also have the deleterious effect of
destroying competence. Mimicry at the wrong time can be fatal.

In the foregoing analysis we were concerned with strategic choice and mimicry
at the structural level. Strategy was viewed as making choices about how to man-
age. This is surely one component of strategy. Another important element of stra-
gy, however, is making choices about which tasks to do (and so what other
companies to merge with or engage in some form of alliance with). An important
extension of this work would be to examine the way in which operational effec-
tiveness, strategic choice of organizational design, and strategic task choice inter-
act. Our expectation is that a sustained competitive advantage will require
balancing these three factors, and that mimicry at the task level will also only be
valuable if it occurs at the right time. An interesting question in this case will be
what strategies should be employed to determine the appropriate portfolio of tasks
and strategic partners.

Our results suggest that organizations are affected by, at least, three types of
strategic traps. The first is the structural trap; that is, the organization's current
design influences performance, expectations about future performance, and the
"cost" of change. The second trap is the mechanism trap; that is, organizations can
get trapped in patterns of change that have cumulative negative effects (such as
repeated downsizing). The third trap is the cognitive trap; that is, incorrect mental
models of what to do can build up over time. These three traps alter both what
adaptation strategies are tried and whether the strategy is successful. By under-
standing the way in which strategic and operational change inter-relate in an orga-
nization we can gain a better understanding of how that organization can learn strategies for adaptation and so achieve a sustained competitive advantage.

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NOTES

ORGHAHEAD can be characterized as a computational testbed for exploring the relative impact of various structural and cognitive constraints on organizational performance. It has been informed by empirical studies both on individual learning by humans and on adaptation within human organizations. ORGHAHEAD is a very versatile program in which the user can specify the initial organizational structure of the organization (or set of organizations), whether agents employ standard operating procedures or experience in making decisions, how much training agents receive, how much agents remember, the amount of information the agents can process, the type of strategic changes allowed, the initial likelihood of the allowable changes, the maximum frequency of change, the rate at which the organization becomes risk averse, the “function” the organization is trying to optimize (e.g., performance or performance subject to minimizing communication), the task environment, several types of “triggers” for change (such as change in task environment or destruction of resources), and a variety of other factors. There are a wide range of virtual experiments that can be run using ORGHAHEAD. Only one such experiment is presented herein. For others see Carley and Svoboda (1996), Carley (1997), and Carley (forthcoming).

1. In this paper we are using a simple 9 bit binary classification task that is completely decomposable and unbiased. ORGHAHEAD also supports more complex tasks; specifically, those that are non-decomposable (how the features are combined matters) and those that are biased. In fact, in the changed environment we discuss later, the task that is shifted to is a high bias task (that is, a task where a particular outcome A-widets, is more likely to occur).

2. The agents in these models use the same incremental learning procedure described in Carley (1992). The agents in these models make errors that are similar in kind to those made by humans; and, for hierarchical structures tends to approximate the behavior of lab teams (Carley 1996b). However, the realism of these agents has been increased in two ways. The agents used herein are limited in how much information they can keep track of. That is, their memory is imperfect and only depends on a limited number of tasks. Second, the agent’s memory exhibits both a primacy and a recency effect. That is, their behavior is based on the first set of tasks they examine and the most recent set of tasks they examine. Information in the middle tends to be overlooked.

3. If there are no agents in level A then the organizational decision is the majority vote of the agents at the next lowest level. If there are also no agents in level B, then the organizational decision is the majority vote of the agents in level C.

4. ORGHAHEAD is very flexible and many alternative cost functions, than that used in this paper, can be examined.
5. Annealing parameters were set such that the annealer would not completely freeze; that is, the organization never becomes completely risk adverse. This was done so that ORGAHEAD would always run through the 40,000th cycle. This ensured cross-organization comparability.

6. This more complex cooling schedule is known as the Medeiros cooling schedule.

REFERENCES

Dynamic Organizations


