Organizational Adaptation and Cognition

Kathleen M. Carley (kathleen.carley@cs.cmu.edu)
Dept. of Social and Decision Sciences
Carnegie Mellon University
Pittsburgh, PA 15213

Abstract

A view of organizations as complex, computational and adaptive systems in which knowledge and learning are embedded in multiple levels is presented. According to this perspective, activity at one level can interfere with or support activity at other levels. As such, organizational adaptation requires finding a balance between these levels. These ideas are illustrated using results from a computational model of organizational performance. Results suggest that organizations can trade knowledge and learning at one level for knowledge and learning at another. As such, for the organization performance becomes a balancing act between levels.

Introduction

Within the field of organizations a new view of organizations is emerging. The hallmark of this view is a recognition of organizations as inherently complex, computational and adaptive. Within this perspective is the recognition that organizational action results from not just the behavior of multiple agents, but also from the networks connecting these agents and the way in which knowledge, and even cognition is distributed among these agents. This perspective leads to a recognition that for organizations, knowledge and learning occurs at multiple levels. For example, they occur at both the individual and the group or structural level. But what has not been so obvious, and what this paper focuses on, is that there can be clashes between these levels. For example, although organizational performance generally improves as personnel stay, gather experience, and learn; changes in the environment may cause an organization to restructure and so make invalid the lessons of experience. Thus, organizational adaptation may result not just as an emergent phenomena from the details of individual exchange and learning, but may be the result of a clever balancing act between the forces of individual learning and group level or structural learning.

Organizations as Multi-leveled Systems

Organizational theorists have long recognized that different levels within the organization have agency and have the capability of effecting organizational performance. At the individual level, research suggests that there is a link between individual capability and performance. Specifically, organizations of more intelligent, more talented, more educated, more knowledgeable personnel typically perform better than those composed of a more challenged group of individuals. At the group level, research again suggests that the structure of the organization, the way in which individuals are linked together, the method of coordination, the procedures and routines, affect performance. Accordingly, better structured organizations perform better. In this case the knowledge, the cognition, the intelligence, is in the linkages. And the ability to learn is in the ability to alter and change these linkages. Few would contest that both processes, the individual and the structural, are going on simultaneously. Rather, the issue is what is the interaction between mechanisms at one level and mechanisms at the other. Two areas in which these clashes of the levels should occur are knowledge and learning. In terms of knowledge we might ask: is there an interaction between cognition and structure. In terms of learning we might ask: does experiential learning at the individual level and expectation based learning at the structural or group level interfere with each other.

In an earlier study, Carley, Prietula & Lin (forthcoming) demonstrated that there were interactions between agent cognition and organizational structure. In a study in which groups of humans, or groups of Soar agents, or groups of other artificial agents were given a simple classification task and structure (team and hierarchy, blocked or distributed access to information) they found that groups of humans performed the task better when information was distributed across group members and no two individuals saw exactly the same set of information; whereas, for groups of artificial agents who were capable of learning, the opposite was the case. Additionally, they found that for artificial agents teams typically outperformed hierarchies, often quite dramatically; whereas, for humans, there was less of a difference between team and hierarchies. These results suggest an interaction between cognition and structure. They suggest that organizations can treat not just the relations between agents, but cognition itself as a resource, and design organizations that make the best use of the types of agents and connections available. Moreover, these results suggest that knowledge is embedded in the linkages between agents as much as it is in the agents. What I want to suggest to you is that these results are also indicating that agent knowledge (embedded in agents) and structural knowledge (embedded in connections among agents) may be in conflict. Knowledge at one level and knowledge at another level may interfere with or possibly support knowledge at another level. Thus, the organization should be able to improve performance by finding the right balance between the two levels.

If this is indeed the case, that organizational cognition arises not just from agent cognition, not just from the interactions among agents, but also from the balance between the two, then what about learning? For organizational learning, like knowledge, also exists at both the individual and the structural level. At the individual level, such learning is embodied in the experiences of the agents within the organization. That is, individuals have tasks to do, do them, garner experience, and in general their task performance improves. Such experiential learning has been widely studied in both laboratories and in natural settings. By and large those studies indicate that individual performance improves with experience. At the group level, however, the relation of individual experience to group or organizational performance is less clear. Indeed, studies have shown both gains and losses in organizational performance as individuals gain experience.

At the group level, however, there is another way for organizations to learn. Organizations can learn how to structure themselves, how to coordinate individuals, which linkages to provide and not provide, so as to increase organizational performance. This can be thought of as strategic learning. The basis of strategic learning, the mechanisms that underlie it, appear to be different than for experiential learning. The idea here is not to anthropomorphise organizations, for the actions being taken are still by individuals. However, the results are knowledge embedded in formal linkages, routines, procedures, norms, and culture whose longevity may exceed that of their progenitor and which take on a "life of their own" separate from that of the individual. This strategic learning, rather than being based on experience is based on expectation. In this case, organizations alter their structures, the linkages between agents, not because experience has taught them such a change is correct, but because expectations suggest that such a change might improve performance.

These two levels of learning — individual and structural — are clearly different. For one, the lessons learned lay within the agents knowledge. For strategic learning, the lessons learned are structural. That is, the expectations become embedded in the linkages among agents. Further, the temporality of these mechanisms is different. That is, experiential learning occurs much more quickly than does strategic learning. Logically, the two types of learning might counteract each other. But do they? And if they do, what are there relative value for organizations?

Organizational learning theorists point to the existence of multiple levels of learning and have speculated on the importance of learning in multiple realms (Kim ,1993; Huber, 1996). Researchers in the organizational learning community have used computational models to explore the issue. Typically, these models examine either the impact of individual experiential learning on organizational performance (Carley, 1992; Lin & Carley, 1997; Carley & Lin, forthcoming; Verhagan & Masuch, 1994) or they examine group level, procedural or cultural learning (Lant, 1994; Harrison & Carrol, 1991; March, 1996), rather than examining the interaction among the two levels of learning. An interesting exception to this is the work by Cohen on organizational routines (1996). This paper speaks to this gap by using a computational model to look at organizational learning where both individual experiential and structural strategic learning are present.

This paper uses a computational model of organizations as multi-agent systems capable of learning at multiple levels to address the issue of learning clashes. The particular model that is used, ORGAHEAD, is described in detail in other venues (Carley & Svoboda, 1996). In this model knowledge is stored both with the agent (agent level) and between agents in the structure (structural level). Further, learning occurs at the agent level - experiential learning - and at the structural level - strategic learning.

At the agent level, organizational performance is determined by the actions of the individuals in the organization as they work on tasks. The specific model used is the CORP model of organizational performance (Carley 1992; Carley & Lin forthcoming). In this model, individual knowledge is stored effectively as a series of up dateable rules, structural knowledge is stored as the linkages between agents. Individual experiential learning occurs as agents gradually alter their rules given feedback. Essentially, agents are engaged in a classification task and through a series of trials they learn the classification rules. After each trial they are given feedback, and so learn from this feedback. Individual agents are boundedly rational at both the cognitive and the structural level. That is, from an information processing perspective they do not have the cognitive capability of doing the task by themselves. From an information access perspective they do not have access to all of the information necessary to perform the task as their role in the organization determines which information they can acquire. Organizational performance is measured in terms of accuracy as the percentage of tasks done correctly (pattern was correctly classified) during some period of time.

At the structural level, organizational actions are the result of anticipation and expectation based or strategic learning. Strategic learning is modeled as a simulated annealing process. Simulated annealing can be interpreted as a computational analog of the imperfect optimization process organizations (i.e., their CEO's and management team) appear to go through when they alter their design in an attempt to improve performance. Based on 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 appears to be an annealing process. In the proposed model the CE0 has knowledge about the task and about who knows what, the ability to anticipate the future (albeit faulty), and the ability to alter the organization's structure. The CEO has a set of options or strategies that can be enacted to change the organization such as hire new personnel, fire personnel, change who is doing what, and reassign personnel to new managers. Periodically the CEO tries to anticipate the future. The CEO considers a possible change in the

organizations structure. Engages in a though experiment about what might happen if that change were made. Then if the CEO thinks that the change is beneficial, that it will improve performance, that change is made. Importantly, even if the CEO is not convinced that the change will be beneficial the CEO still might make the change. That is, the organization might take a risk. The likelihood of these risks decreases with time as the organization becomes more staid. As mentioned, this process is carried out using a simulated annealing model in which decreasing the temperature corresponds to decreased likelihood of taking risks.

This model then contains both experiential learning at the individual level and strategic learning at the structural level. Using this model questions concerning clashes between the structural and the individual level can be addressed. Using this model and Monte Carlo techniques a series of virtual experiments were run to examine whether in fact learning at one level interfered with learning at another, the relative benefit to the organization of both types of learning in both stable and volatile environments.

Learning Clashes

When considering the relationship between individual experiential learning and structural strategic learning, the issue from an organizational standpoint is not whether or not people can learn from experience; but rather, whether or not the value of that experience gets lost to the organization when the organization restructures itself. To examine this, we want to contrast organizations that restructure themselves in which in some cases no experience is lost and in other cases it is possible to lose experience. If we have an organization of agents (possibly artificial) that act purely on the basis of standard operating procedures, that have no need to and cannot even learn, then we have an organization in which the lessons of experience at the individual level should be irrelevant. If we have another organization in which agents can and do learn from experience, in which when agents leave knowledge goes with them and when new agents arrive they bring no or at best different experience then we have an organization in which the lessons of experience should be relevant. If strategic learning is to interfere with experiential learning then performance should be higher in the former than the latter organizations. Results from a virtual experiment along these lines are shown in table 1.

What we find is that on average, strategic learning does interfere with experiential learning. However, this interference is slight. Indeed, on average, the overall drop in performance when both types of learning are active is less than 1%. Interestingly if we look at the fraction of organizations that show very significant improvement in performance over what might be expected by chance, we see that the fraction of organizations with at least a 70% improvement is higher when both strategic learning and experiential learning are present. In other words, the clash of levels does not manifest itself exclusively as interference. At times the duality of learning at the individual and the structural level may be compensating for each other: or, is in this example, when the both types of learning are in effect overall performance is lower and the number of high performers is higher. Thus, it appears that the organization can trade experiential learning for strategic learning.

Table 1. Experiential and Expectation Based Learning

	Structural: Strategic Only	Structural & Agent: Strategic & Experiential
Avg. Performance Overall	79.69%	79.46%
Number of high performers	137	156
Avg. Performance of Top Performers	87.20%	86.94%

To examine this proposition a second virtual experiment was run in which the degree of experience an individual agent could retain was varied. These organizations varied in the number of changes they made in their structure over time. The results indicate that there are multiple ways to organize to achieve high performance and that indeed organizations can trade experiential learning for strategic learning. To illustrate these results a simple multiple regression showing the relative impact of the types of change and the degree of experience of the personnel are shown. Regression is used here as an illustrative device. The true model is highly non-linear and the full effects of the various features cannot be captured in a single regression model. The point here is merely to show the general trends in the way the theoretical constructs of concern operate.

As can be seen in table 2 it is the interaction between change and experience that affects performance. (In table 2, only standardized coefficients are shown.) It should be noted that if the interactions were not included then indeed performance would have degraded with fires, improved with change, and was unaffected by experience. The fact that performance degrades with fires is indicative of the earlier point that some types of structural change cause the organization to loose the benefits of personnel experience. The key, however, is to note the interaction between the degree of change and degree of experience (see Figure 1). What this is indicating is that high performing organizations either rarely change their structure and utilize personnel with a relatively high degree of experience or they change the structure constantly in which case the degree of personnel experience is somewhat irrelevant.

Table 2. Illustration of Impact of Change and Experience on Performance

Variable	Coefficient	Coefficient
Fires	0.091	-0.001
Change	0.117	0.105
Experience	0.010	-0.065
Fires * Experience	-0.715 ***	-0.613 ***
Change * Experience	0.505 ***	0.509 ***
Complexity		-0.962 *
Fires * Complexity		0.463
Change * Complexity		0.325
Complexity * Experience		0.681 *
Change * Complexity * Experience		-0.604 ***
R^2	0.152	0.210

P (2 Tail) * < .05, ** < .01, *** < .005

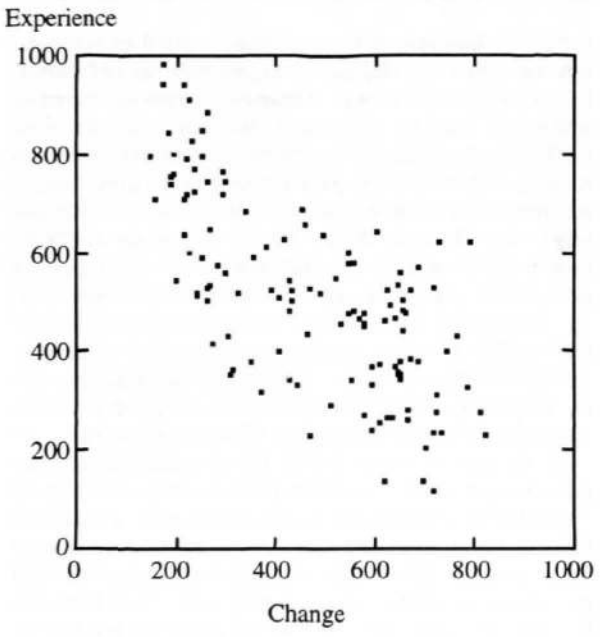

Figure 1. Interaction Between Experience and Change

But why is the degree of personnel experience somewhat irrelevant? The answer may lie in how complex a task the agents are doing. A measure of the complexity of the task faced by each agent, that takes into account both the information processing requirements due to processing both direct task knowledge and indirect information provided by others is the density of the overall network. The higher the density (more links) the higher the complexity. What we find is that the more complex the task faced by the average agent the lower the overall performance. Finally, the organization can reduce the task load on the agents or utilize agents with greater experience and still retain the same performance level.

Learning and Environmental Volatility

What this line of research is suggesting is that organizations can treat agent cognition and learning as well as knowledge and learning at the structural level as resources. At the organizational level one can make trades between the agent and the structural level. Overall organizational performance then becomes an act of balancing the two levels. But does this balancing act depend on the environment. As noted before change is going on simultaneously at many levels. In a stable environment, or for routine tasks, one might expect experiential learning to be most effective as with stability the value of feedback increases and so the lessons learned through experience is more likely to be correct. Whereas, in the volatile or rapidly changing environment one might expect structural change to be more effective. In a volatile environment feedback is less likely to be meaningful and so experiential learning is less likely to improve performance.

Another virtual experiment was run in which the degree of volatility in the environment was varied. In the stable environment, the organization faces a sequence of tasks all drawn randomly from the same distribution. In the low volatility environment, the environment oscillated slowly between two sets of tasks. In the high volatility environment the environment oscillated rapidly between two sets of tasks. If strategic learning is more critical as volatility increases then we would expect to see the high performing organizations to have higher levels of structural change as the level of volatility increases. And indeed this is the case (Figure 2). In Figure 2 the degree of change in personnel for the 5% of the 1000 organizations simulated that had the highest performance are shown. As the volatility of the environment increases the degree of change increases, albeit slightly.

Summary

A view of organizations in which cognition and learning occur at multiple levels is presented. In terms of knowledge cognition is seen as existing not just within the agent but as an emergent phenomena from the interactions among and negotiations between multiple agents. At the organizational level we can think of this structural cognition as a socially shared cognition (Hutchins 1990, 1991). Learning becomes a process of altering individual cognitive models as well as altering socially shared cognitive or team models and the processes, routines, and structures that influence what the individual learns and what is shared. A key element of this view is that the individual and the structural co-evolve and

this co-evolution occurs both in the cognitive models (individual and socially shared) and in the social structures in which the agents operate. To understand organizational cognition and learning it will be necessary to attend to both the knowledge level and the social or interactive level at the same time.

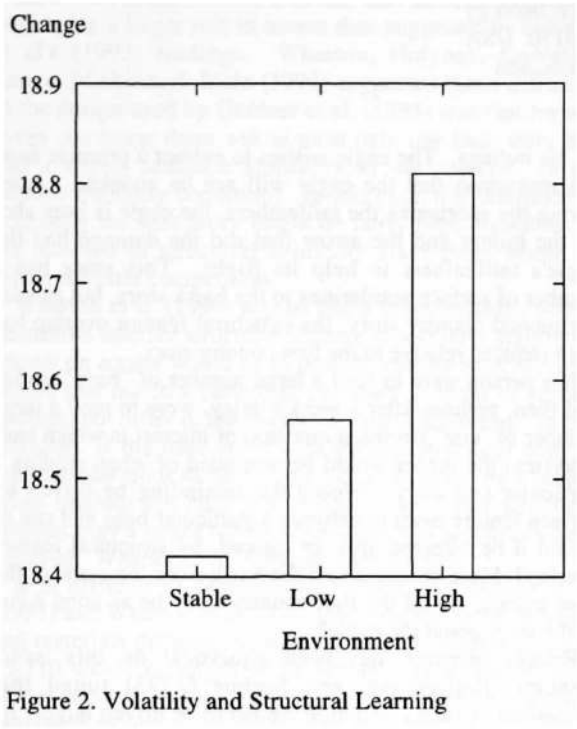

Figure 2. Volatility and Structural Learning

Herein, a step in this direction was taken. Using a computational model, the potential interaction between the individual level and the structural level, between the knowledge level and the interactive level, was examined. The results indicate that the individual and the structural interfere with each other; but, they can also augment each other. At the organizational level, in order to achieve high levels of performance the organization must balance change in the two levels; however, the nature of that balance depends on change at yet another level - the environmental level. In particular, as strategic change increases the value to the organization of experiential change decreases, and as environmental change increases the value of strategic change further increases.

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