A Theoretical Evaluation of Information Processing Resources during Organizational Crisis

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ABSTRACT

The purpose of this paper is to present a model for testing different organizational learning characteristics and their effects on performance rate in times of an unexpected temporary increase in workload. Drawing on the theoretical frameworks of Yerkes-Dodson law, the stress-buffering effect of coping resources, and established crisis management models, the authors examine the hypotheses of curvilinear and interactional influence of single and double-loop learning on stress levels during crises. Using a simulation model, we identify thresholds in single and double-loop learning environments, where increases in workload lead to dysfunctional effects of stress. The findings indicate support for the hypothesis that an organization that employs double-loop learning is less susceptible to negative stress in times of a crisis. Overall, the study highlights the characteristics of different learning types and its effects on stress. It is suggested that experiments with a simulation model lead to a better understanding of how information processing resources that people have access to in stress events, buffers or protects them from negative effects

Keywords

Stress, single-loop learning, double-loop learning, Yerkes-Dodson law, crisis.

INTRODUCTION

Crises by definition are low frequency high consequence events. This means that when a crisis does occur, it may be the first time such an event has impacted the organization. Low frequency also means that even if the organization has experienced a disaster before, the next event might not look anything like the last event. As a result, the organization probably does not have sufficient experience to learn from in order to help decision makers properly structure the problem and generate alternative policies for dealing with it. The high consequence nature of crises means that the degree of stress experienced by decision makers is significantly higher than what decision makers typically experience in routine situations.

A crisis is characterized by extreme threats to important assets, intense time pressure, high stress, and the need for rapid, yet careful decision making (Billings, 1980). Business crises are broadly defined as turning points in which a situation of impending danger to the organization runs the risk of escalating in intensity, interfering with the normal operations of the business, jeopardizing the organization's public image, and damaging the organization's financial performance (Fink, 1986; Lerbinger, 1986; Mitroff, 1984).

Crises, unfortunately, do not resolve themselves. They can only be resolved when appropriate policies and plans are in place and when these plans are properly implemented. Key to an organization's successful management of a crisis is a framework that can help them deal with problems that accompany all crises, such as information overload and stress. Brynjolfsson (2002) defines information overload as a function of processing capabilities of individuals as well as the procedures and supporting network configuration of the organization. Stress on the other hand leads to the narrowing of cognitive processes. With decreasing levels of cognitive capability, behavior becomes less adaptive and the resulting decision is often of poor quality (Belardo, Karwan and Wallace 1984).

The literature is replete with crisis management approaches designed to help organizations resolve crises. While some of the existing conceptual crises frameworks (e.g. Smart and Vertinsky, 1997; Martin, 1977; Rudolp and

Repenning, 2002) capture the effect of information overload and stress on decision making, other models (e.g. Pearson and Mitroff, 1993) discuss the effect of learning during organizational crisis.

This paper explores a theoretical concept of information processing resources to mitigate the escalating effect of stress during organizational crises. The concept described in this paper is based on the stress-buffering model of Cohen and Wills, to broaden concepts described by Smart and Vertinsky (1977), Mitroff (1984) and the quantitative induced model of frequent short term interruptions by Rudolp and Repenning (2002).

CRISIS MANAGEMENT FRAMEWORKS

Crisis management is a complex and challenging field and unfortunately most research is lacking statistical rigor. As Horlick-Jones et al. (1991) conclude: "Evidence for the significance of disaster clusters is difficult to find. This stems from the high consequence – low probability nature of disasters and resulting sparse data sets, and from difficulties in the interpretation of data that are incomplete, prone to error and influenced by subjective factors". Faced with such a problem it is necessary that we look at the following crisis management models from a conceptual perspective.

Pearson and Mitroff (1993) provide a comprehensive framework for crisis management in an *effort* to explain how organizations may actually contribute to their own crises. Their framework provides recommendation concerning what can be done to avert human-induced disasters, and provides guidance to manage those that still occur. Their framework was the result of a five-year research effort that studied how human-induced crises should be managed. The Pearson and Mitroff framework consists of five sequential phases: Signal Detection, Preparation/Prevention, Containment/Damage Limitation, Recovery, and Learning. While the first four phases of the model are sequentially arranged, the last phase "Learning" feeds back into the first phase "Signal Detection". Thus the feedback loop suggests that organizations should learn as they reflect on the experiences that encounter during a crisis.

Cook (2003) identifies learning as a cycle of continuous organizational improvement that will not only reduce incident severity but will also reduce the risk of disaster. In his paper, Cook describes a system dynamics model of an incident learning system designed to test different polices. Using an actual case of a mine disaster as base line Cook simulates different polices to show how an incident learning system can improve an organization's response to a crisis. He concludes that an effective incident learning system can help an organization reduce the severity of incidents over time.

Pearson and Mitroff as well as Cook emphasize learning as a mean to help reduce the risk of organizational breakdown in times of crises. In both models, learning feeds back into the signal detection stage, though Cook uses the term "quality of incident investigations", which we contend is synonymous with improving an organization's ability to analyze information when crises occur.

In examining existing frameworks, we have identified the following limitations: Pearson and Mitroff's conceptualization is essentially a sequential, almost engineering driven framework of crisis management, where learning (explicitly expressed) takes place after or during recovery. Their model neither captures the effects of stress nor takes into consideration that learning could also feedback during the "Preparation/Prevention" or "Containment/Damage Limitation" phases. While Cook's model emphasizes learning as a cycle of continuous organizational improvement, the effects of stress and information overload are not explicitly represented.

STRESS AND STRESS-BUFFERING

In the conventional view of stress it is generally believed that stress can have a significant dysfunctional effect on performance once a certain threshold is reached. While moderate levels of stress may increase performance too much of it will cause a performance to be negatively affected. Yerkes-Dodson's law, which posits an inverted U-shaped relationship, between stress and performance on moderate to difficult tasks (Miller, 1978; Mandler, 1984; Fisher, 1986) is used to identify the tipping point, that point where stress becomes dysfunctional. The Yerkes-Dodson law is based on the notion that stress could be positive, improving productivity until stress reaches a certain level (the tipping point) at which point stress causes a negative, deteriorating effect (see. Figure 1). Researchers agree that extreme stress invariably results in erosion of job performance and job-related attitudes, (cf. Jamal 1984, 1985; Singh, Goolsby, and Rhoads 1994) while moderate stress may increase performance because stress simulates people to excel (Selye 1976).

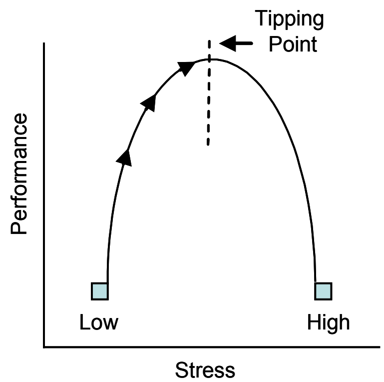

Figure 1. U-Shape Relationship between Performance and Stress

According to this U-shaped relationship between performance and stress, a person's performance is at a suboptional level at both high and low levels of stress because performance can be adversely affected by a lack of alertness or activation in the low stress condition or by over-activation in the high stress level situation (Singh 1986). During an organizational crisis, a high stress level result from information overload, which stems from an imbalance between processing capacity and resources or the supportive network. Karasek (1979) suggests that one way to deal with dysfunctional levels stress is through the proper use of information.

This view accords well with the resource-based rationale of the buffering hypothesis. The stress-buffering model of Cohen and Wills (1985) posits a relationship among levels of stress, coping resources and adjustment. According to this model, the resources that people have access to when facing stressful events buffers or protects them from the negative effects of stress. However, Singh (1986) suggests that if the person is already exposed to high levels of stress, the additional stress sources deplete any unused coping resources and overwhelm him or her. The implication of this suggests that coping resources have the highest leverage around the tipping point.

While the preceding research studies investigate multiple resource-based dimensions to buffer stress levels, we focus the role of obtaining information as a way of dealing with stress-induced situations. In the context of a crisis situation, we define obtaining information as having access to a repository of knowledge, which could help a person to improve the quality of the decisions being made. As previously stated, the conventional view of learning is that it helps reduce the risk of organizational breakdown in times of crises. Argyris (1995) proposed three major types of organizational learning: Single-loop learning, which involves detecting and correcting "errors" (performance gaps) so an organization can carry on or achieves its present policies or objectives. This is learning type is perceived as reacting to a problem. The second type is double-loop learning, also referred to a higher-level learning, or learning to expand an organization's capabilities. The third type in Argyris learning taxonomy is deuteron-learning, which refers to a proactive learning process where there is a continuous effort to strive for perfection.

While some crisis management models include learning as a mean of helping reduce the risk of organizational breakdown in times of crises, neither of the models mentioned above disaggregates learning into the different types nor considers the buffering-effect of having access to resources to moderate the stress levels. Using the preceding as a basis, we have established the following two propositions:

Proposition 1. Depending on learning type, an organization will be less susceptible to lose control over the processing resources when a crisis occurs.

Proposition 2. Double-loop learning will help an organization reduce the dysfunctional effects of job performance during a crisis.

These propositions will be examined using a system dynamics approach. Substantive interpretation of testing the learning policies with the simulation model will be discussed.

METHODOLOGY

The main objective of this study is to build a system dynamics model that represents the dynamic nature of a crisis within an organizational context. The model is designed to test different learning types in order to understand interactions among various factors which influence the performance rate of an actor during crisis situation. This paper provides a theoretical framework for a non-linear and dynamic view of the causes and effects of different learning types that influence the stress levels and subsequently the performance rate of a person.

As Zuboff (1988) concluded, "behind every method is a belief." Our belief is that system dynamics is well suited not only to theory development but also to understanding complex behavior associated with organizational crises. Our belief is based upon the following assumptions: (1) time is an important element in constructing a conceptual framework for capturing the interactions and interventions during a crisis; (2) while longitudinal process models employed in research often provide a limited (linear) perspective on time (Abbot 1995), a non-linear method such as system dynamics consists of multiple measurements of both independent and dependent variables and graphs the resulting data over time; (3) predictions made using a non linear modeling approach are more qualitative than the predictions made using traditional approaches (Svyantek and Brown 2000); (4) an actor's interpretation of an action and its effect is part of a larger dynamic context (Sterman 1989); (5) system dynamics models have long been associated with the notion that complex systems are counterintuitive – that the behavior of a complex system is often different from what one expects (Forrester 1961). In the following section we present a model, which builds upon Rudolp and Repenning and extends their conceptual view by integrating the stress-buffering theory of Cohen and Wills.

MODEL STRUCTURE

One of the structural elements in our model is based upon the theory of interruptions described by Rudolph and Repenning (2002). Their theory is based upon Mandler's (1982) notion of a crisis as the result of interruptions to ongoing activities where any unanticipated event, external to the individual that temporarily or permanently prevents completion of some organized action, causes an increase in stress levels.

Our model is based on a number of assumptions. We assume that people in organizations during a crisis are faced with a continual stream of information or signals that they are able to process until the arrival rate of signals reaches a certain level, causing information overload and hence stress that can lead to diminished decision quality. The signal arrival rate we are using in the model is an artificial numerical value, which is not grounded on empirical research. However, we are able to capture the tipping point, when incoming signals cause a stress level where people are no longer able to process information. To capture the idea of information processing capabilities, we define an individual's normal processing rate as the number of information units per day. However, we generalize that all incoming information units require the same processing time, an assumption, which does not reflect the real behavior in a system.

Figure 2 captures the process of signal arrival (inflow), accumulation (signals to be processed) and dissipation (signal process rate). The diagram represents a stock and flow structure in which flow variables are signified as "pipes" with "valves" (Sterman 2000). Incoming signals, is represented as a flow variable (signal arrival rate) that is not processed instantaneously but, instead accumulates in the stock of signals to be processed. Thus the stock represents the number or amount of signal units that arrived but have not been processed.

$$\text{Signals to be processed } (t) = \int_t [\text{Signal arrival rate (s)} - \text{Signal process rate (s)}]ds + \text{Signals to be processed } (t_0)$$

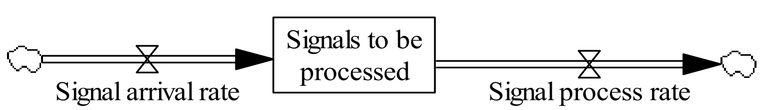

Figure 2. Stock and flow structure of signals to be processed

The stock of signals to be processed is then reduced by the outflow process rate, which is determined by the maximum processing rate. To define the signal arrival rate, we use an arbitrarily value, representing the incoming signal units per day. Because this variable cannot be constant, we account for variance in the number of incoming signal units in the form of pink noise.

Under normal conditions, the signal process rate is equal to the arrival rate of incoming signals. Under these conditions an individual is capable of resolving the accumulation of signal units to be processed. When the number of incoming signal units is higher that the maximum signal processing capacity we have a backlog of unprocessed signals, causing information overload, which increases the level of stress.

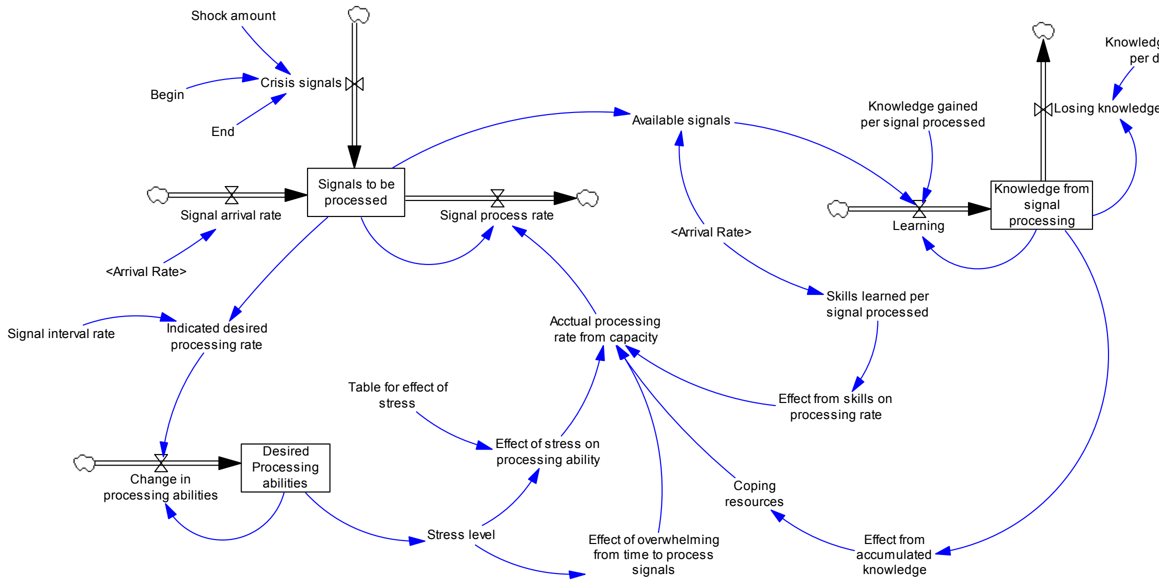

Figure 3. Structure of System Dynamics Model

Figure 3 shows a highly aggregated view of the simulation model in which we omit a few moderating variables, e.g. table and smooth functions. We use Rudolph and Repenning's (2002) conceptual linkage between the stress created by a large stock of unprocessed information and the process rate. Yerkes-Dodson's law, which posits an inverted U-shaped relationship, between stress and performance on moderate to difficult tasks (Miller, 1978; Mandler, 1984; Fisher, 1986) is used to identify the tipping point. The Yerkes-Dodson U-curve is conceptualized with the following two table functions.

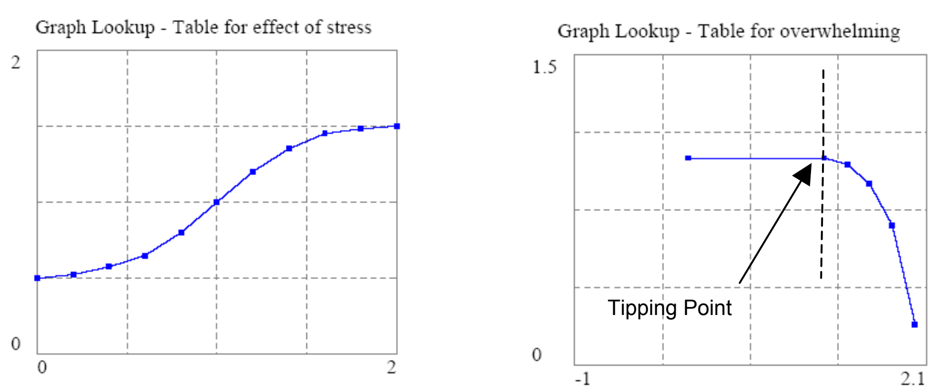

Figure 4. Nonlinear representation of stress according to Rudolph and Repenning

The representation of a positive or negative effect of information overload is captured in the two non linear functions shown in figure 4. The tipping point shown in the graph on the right indicates when positive stress switches to cause a negative effect. An information overload of 40% higher (meaning incoming signal units are 0.4 times higher than the maximum signal processing capacity) still results in a positive stress. After this point is reached, however, we are on the downward-slope of the Yerkes-Dodosn curve. The result is negative stress. However, it is suggested that an organizational learning system should extend the time it takes to reach the tipping point.

Processing rate

As shows in Figure 3, the rate to process accumulated signals (or information) is dependent on the stress level, positive or negative, the learning rate, and access to coping resources. We conceptualize single-loop learning in the model as a function of skills learned per signal processed, which means that every time one information unit is processed, an actor in the system learns a defined learning unit (the parameter in the model is set to 1.1, with units of skill/signals/Day). In contrast, double-loop learning is conceptualized as a function of accumulating knowledge, based on signals processed, which means that every time one information unit is processed, knowledge is accumulated (we select a value for the parameter "Knowledge gained per signal processed" of 0.5, with units of knowledge/signals/Day). In accordance with the theory of double-loop learning, we have conceptualized this learning type as higher-level learning that will expand an organization's capabilities. While the level of detail in conceptualizing the two learning types is highly aggregated, we contend that the structural framework enables us to test different learning policies.

Coping resources, acting as a stress-buffer, is a function of accumulated knowledge from signals processed. We use a table function, shown in figure 5, to capture the theory that if the person is already exposed to high levels of stress, the additional stress sources deplete any unused coping resources and overwhelm him or her.

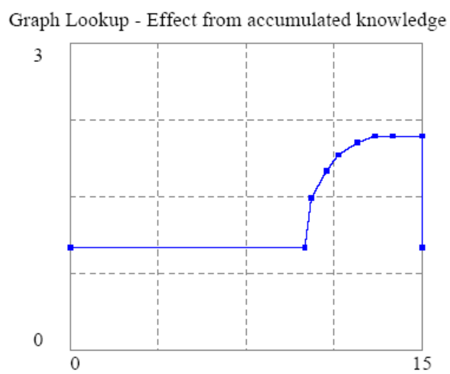

Figure 5. Non-linear function of coping resources

We define a neutral point at 10/1, which implies that when accumulated knowledge is in equilibrium, at 10 knowledge units, the effect of accumulated knowledge is 1 (multiplying by 1 does not cause any change in the system). The curve-linear shape of the table function depicts the theory that coping resources have the highest leverage around the tipping point. When the tipping point is reached the effect of coping resources becomes neutral. However, we do not have any empirical evidence to justify the shape of the curve but a theory. From a conceptual standpoint, such effects are plausible for two reasons. First, coping resources have a buffering-effect on stress, as previously discussed. Second, there is an over-stimulating effect, so that additional resources do not help to buffer stress but overwhelm a person. In contrast, the effect from skills on processing rate is conceptualized as a normal learning curve, which means that with every signal processed, we gain a skill unit.

SIMULATION OF DIFFERENT LEARNING TYPES

Organizations are exposed to a continuous stream of information signals, which have to be processed as resource for decision-makers. The graph in figure 6a shows the stock of incoming signals in our simulation model. The graph portrays a system that begins in equilibrium, which means that the inflow of the stock of signals to be processed equals the outflow process rate. At time 5, we add randomness because we contend that the rate of incoming signal units cannot be constant. The initial value of incoming signals is an arbitrarily value of 10 signal units per day, which oscillates for the pink noise added to the variable. We assume in our model that the strengths of the signal units do not change, only the number of incoming signals per day, by adding randomness. In the real world, signal strength would also be an influential factor that determines the signal process rate.

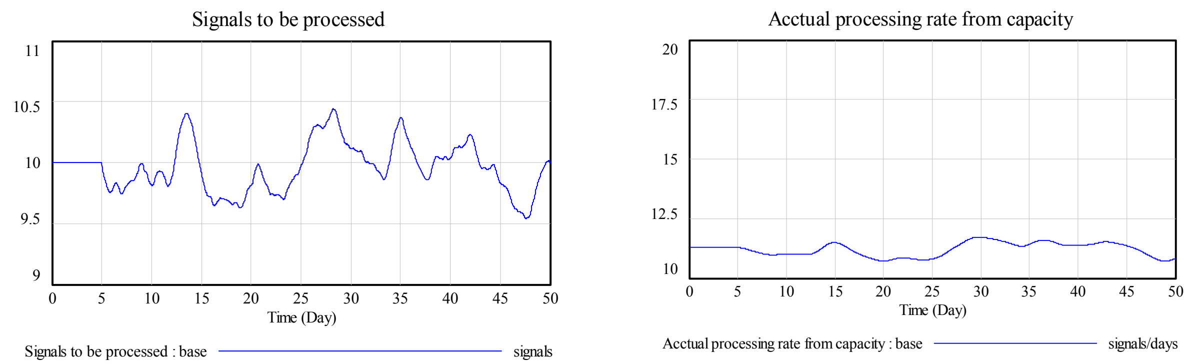

Figure 6 a&b. Model behavior under base conditions

The base line in our simulation shows that the organization is able to process the stock of signals to be processed with the available processing abilities (as shown in figure 6b). The normal process rate per day is 10, which suggests that an actor in the system is able to process 10 information units per day. Thus, under normal conditions, the system remains in equilibrium.

By using a step function, we increase the number of signals by 20 percent over a time period of 20 days, (from t=15 to t=35) to simulate the increased flow of incoming signals during a single event crisis. The result of this experiment is shown in figure 7 a&b.

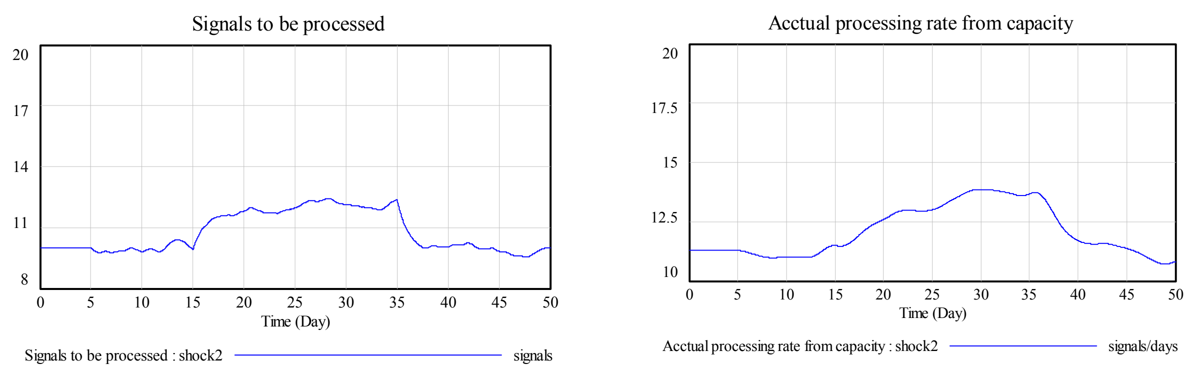

Figure 7 a&b. System behavior of minor crisis

While the number of signals to be processed increases over a period of time (Figure 7a), the processing rate (Figure 7b) is also increasing as long as the stress level is on the upward slope of the Yerkes-Dodosn curve. In this policy test, single-loop learning takes place, capturing an organizational environment following routine and repetitive jobs.

To understand this behavior, consider the following situation. On June 22, 1997 at a Shell Chemical Company plant in Deer Park, Texas, the drive shaft blew out of a check valve causing the release of a large quantity of flammable gas. The resulting explosion and fire caused extensive damage and several workers suffered minor injuries. Fortunately, no one was killed. The EPA and OSHA investigation noted that there had been several prior incidents involving a similar mode of failure of this particular check valve at this and other Shell facilities, but the lessons learned from these prior incidents were not adequately identified, shared and implemented (Cooke, 2003). As noted by the EPA and OSHA, Shell went through a number of minor incidents and the outcomes from these incidents met the norms and expectations of the company to confirm that the action taken was positive. Thus, it is suggested Shell operated in a single-loop learning environment. While the incident seems to have been a random technical event, we assume that at the time of the explosion, the degree of stress experienced by decision makers was significantly high since prior incidents were not taken as lessons learned, else the organization would have questioned the long-term assumptions of operating its equipment.

In the next experiment, we simulate the behavior of a major crisis and compare the performance rate under single-loop leaning viz. double-loop learning conditions. In order to compare the simulation runs, we have an "On/Off" switch in the model, which activates the parameter "coping resources" (see Figure 3).

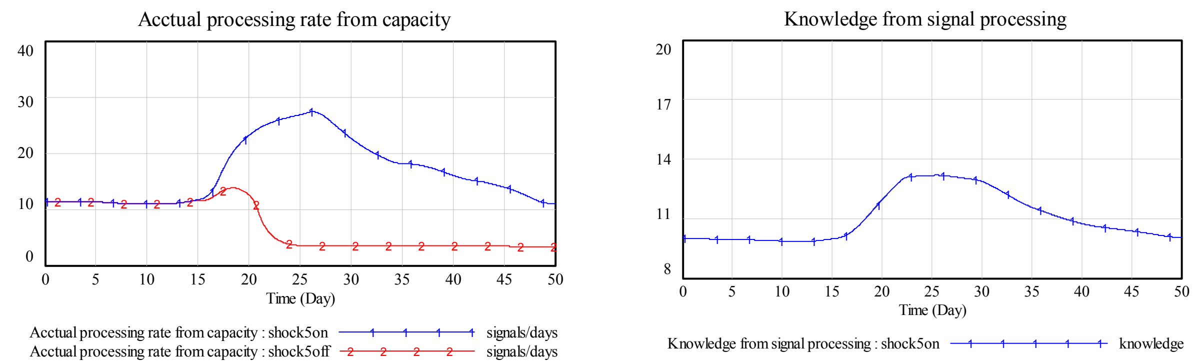

Figure 8 a&b. Comparing processing rate with different learning types

We increase the number of incoming signals by 50 percent over a time period of 10 days (from t=15 to t=25) to simulate the event of a major crisis. In one simulation, we activate the parameter "coping resources" to imply a double-loop learning environment (graph 1: shock5on, in Figure 8a) and in the second simulation, this parameter is deactivated to simulate the effect of single-loop learning. As shown in Figure 8a, the processing rate increases substantially when "coping resources" is activated (graph 1) while in a single-loop learning environment, the stress level past the tipping point and the performance declines (graph 2). As previously stated, one of the factors to mitigate dysfunctional stress levels is to obtain information that aids in dealing with stress-induced situations. In Figure 8b, we show the stock of knowledge, which increases when additional signals are processed. This knowledge then can be accessed in times of a crisis to act as stress-buffer.

While the previous experiments only capture the behavior of one sequence in increasing the crisis signals, the following Monte-Carlo analysis aims to identify the processing rate tipping point between single-loop and double-loop learning. We perform 500 simulations for each learning type with a shock level between 1 and 9, using a random uniform distribution.

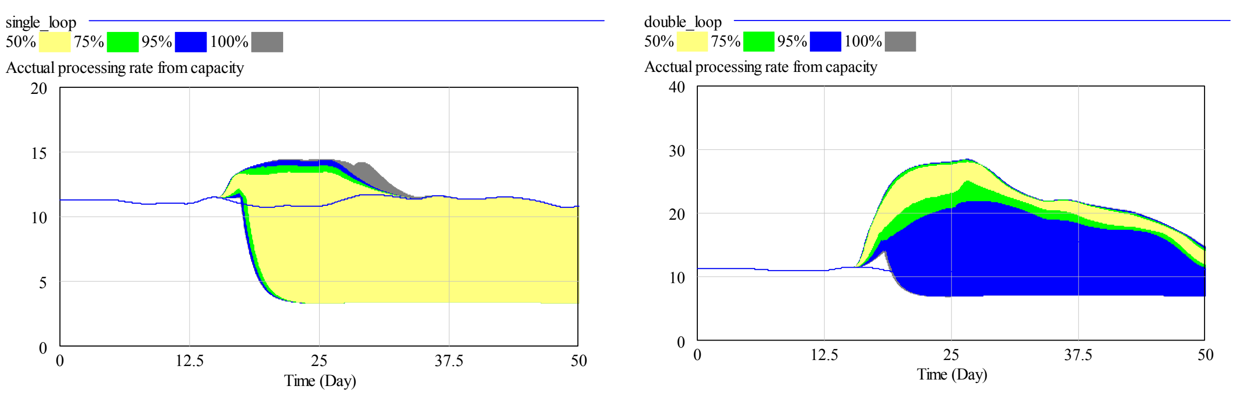

Figure 9 a&b. Monte-Carlo Analysis with the parameter "processing rate"

The result suggests that a double-loop learning environment is less susceptible to the dysfunctional (negative) effect of stress during a crisis situation. Figure 9b depicts the range of processing rate when the level of signals to be processed increases. As a result of the stress-buffering effect from coping resources, the processing rate is substantially higher, which enables us to keep the stock of signals to be processed under control longer. In contrast, Figure 9a shows the range for the processing rate when single-loop leaning is imposed. It is, however, noteworthy that both learning types eventually will move beyond the stress tipping point and collapse.

Based on the characterization of the model, the Monte-Carlo experiments suggests that the tipping point for the single-loop learning condition is reached when we increase the level of signals by 4.36, which means that a temporary increase in workload (signals to be processed) of about 44 percent causes a permanent decline in the system's performance. The tipping point for the double-loop learning environment is reached when we temporarily increase the workload by 8.43 or 85 percent over the normal rate.

DISCUSSION

The model described in this paper is intended to help us evaluate how different learning types influence the processing resources in times of an unexpected temporary increase in workload, which normally occurs during a crisis. By extending existing crisis management frameworks and incorporate conceptual elements from Rudolph and Repenning's disaster dynamics model, we present a theory to explain the effect of different learning types on the information processing rate during a single event crisis. While the model discussed in this paper is highly aggregated, the results suggest that coping resources, or access to knowledge, moderate the stress levels during a temporary increase in workload. Central to our model is the belief that an organization can reduce the dysfunctional effect of a crisis depending on the learning types (single and double-loop), that they employ. Rudolph and Repenning conclude in their research, that performance in quantity-induced crises continues to increase until the system reaches the peak of the Yerkes-Dodson curve and if stress continues to increase, the system moves over the peak and collapse.

Our findings, however, suggest that coping resources can extend the time it takes for a system under stress to move over the tipping point. One application of the theory, presented in this paper, is for an organization to create stress buffering capabilities that decision makers can call upon to help ensure that the stress threshold, that is critical to decision making performance is not exceeded. This proposition, while theoretically plausible, is empirically untested but it opens the window to new perspectives and possible research.

Several limitations of this research must be recognized in a balanced discussion of its findings. First, the model presented in this paper examines theoretical constructs and thus parameters are largely untested in previous research. Future replications and extensions of parameter values and non-linear constructs are necessary to circumscribe the generalizability and applicability of findings reported here. Such future studies should involve finding parameter values for the stress-buffering function to obtain greater validity in this construct. Second, the model can be expanded to include other boundary-spanning variables and contextual characteristics of an organization. Nevertheless, the results provide new insights about trade-offs in the effects of learning characteristics during a crisis situation.

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