The Link between Organizational Errors and Adverse Consequences: The Role of Error-Correcting and Error-Amplifying Feedback Processes

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Abstract

We examine when and how organizations experience major adverse outcomes as a result of latent errors in their operations—i.e., unintended deviations from pre-specified rules and standard operating procedures that can potentially generate adverse outcomes of organizational significance. To address these questions, we develop a conceptual framework around organizational feedback processes for error correction and error amplification and their organizational antecedents. We illustrate the framework using two contrasting cases. In one case set in an investment bank, several recognizable precursors of errors were present over an extended period of time and eventually contributed to losses in excess of $1 billion. In the other case set in a hospital that adopted several recommended practices for effective error management, errors nevertheless caused the preventable deaths of three infants. We discuss the challenges and opportunities for future research about the role of organizational feedback processes in linking latent errors and adverse consequences.

This chapter examines the link between latent errors and adverse organizational consequences. By latent errors, we refer to unintended deviations from pre-specified expectations (e.g., rules, standard operating procedures) that can potentially generate adverse outcomes of organizational significance (Ramanujam & Goodman, 2003). One example of a latent error in a bank's securities trading operations would be the failure to periodically review the trading transactions as required by internal rules and external regulations. This error may allow a buildup of unauthorized trades that can potentially generate huge losses (Basel Committee on Banking Supervision, 2008). Another example of a latent error, in a hospital's routine medication administration processes, would be a failure to verify the correctness of the drug and its dose before administering it to a patient (Institute of Medicine, 1999). This error makes it more likely that a wrong drug or a wrong dose will be given to the patient, which can seriously harm or even kill the patient. Latent errors occur in a wide range of organizational settings including nuclear power plants, aviation, coal mines, chemical plants, and space shuttle launch operations (*cf* Reason, 1998). Given their prevalence and potential for undermining organizational effectiveness, there is growing interest in understanding how organizational structures and processes contribute to latent errors and adverse outcomes (Reason, 2008; Hofmann & Frese, this volume).

In this chapter, we examine when and how latent errors actually generate organizationally significant adverse outcomes. Our core premise is that latent errors and adverse outcomes represent two separate concepts that are only loosely-linked. For instance, although equivalent latent errors have been observed across the securities trading operations of several financial institutions, these errors contributed to multi-million dollar losses in only a few of these organizations such as Barings (Ramanujam & Goodman, 2003). Similarly, although identical

latent errors have been reported across the medication administration processes of several hospitals, these errors caused serious harm only in a few of these hospitals and that too only to a few patients (Institute of Medicine, 1999). Therefore, given that latent errors occur in the operations of all organizations, this invites a basic question: what are the organizational processes that cause latent errors to generate major adverse consequences in some organizations rather than in others?

By addressing this question, which is rarely discussed in the organizational literature, we intend to make several contributions. First, we clarify the frequently-blurred distinction between latent errors and adverse outcomes. Currently, it is hard to distinguish the organizational explanations of errors from the organizational explanations of outcomes such as accidents. By formally separating these explanations, we identify several unexplored research questions that may help to better understand the organizational origins of the link between errors and adverse outcomes. Second, we offer a new conceptualization of the role of organizational antecedents that complements, but is different from current approaches in a couple of important respects. We primarily focus on the antecedents of the feedback processes that link errors and adverse outcomes. Moreover, whereas prior discussions tended to focus exclusively either on the negative feedback processes that reduce errors (e.g., Weick & Roberts, 1993) or on the positive feedback processes that amplify errors (e.g., Vaughan, 1996), we examine the interaction between these two sets of feedback processes. Our conceptualization can potentially help explain the puzzling phenomenon of even highly reliable organizations—i.e., organizations that have strong safety goals, safety climate, and error management processes—occasionally experiencing major adverse outcomes (Blatt, Christianson, Sutcliffe & Rosenthal, 2006).

Third, in developing our arguments, we draw attention to the important need for conceptualizing latent errors at the organizational level of analysis. Given that errors entail the actions of individuals, most organizational studies understandably draw from prior research on individual-level errors. However, few studies have explored whether and how studying errors at the organizational level of analysis differs from studying the organizational antecedents and consequences of individual level errors that occur in organizational settings. By proposing a couple of different ways to conceptualize errors at the organizational level of analysis, we wish to advance research about errors as an organizational-level phenomenon.

Finally, we present a conceptual framework that can potentially serve as the basis for bringing together the insights from the fragmented organizational studies of accidents (e.g., Perrow, 1984), high reliability (e.g., Bigley & Roberts, 2001), mindful organizing (e.g., Weick & Sutcliffe, 2006), safety climate (e.g., Hofmann & Mark, 2006), and error management (e.g., van Dyck, Frese, Baer, & Sonnentag, 2005; Keith & Frese, 2008). In developing this framework, we draw on the findings from these disparate studies and point out the interconnections among these different literatures.

This chapter is organized as follows. To start with we delineate latent errors from related concepts such as violations, risk, and adverse outcomes such as accidents, safety, and reliability, and discuss the distinctive features of latent errors that are organizational. Next, we introduce a conceptual framework about the role of organizational feedback processes in linking latent errors and adverse consequences. We then present two contrasting cases of latent errors that produced adverse outcomes-one in an investment bank and the other in a hospital. In the investment bank, several precursors of errors and adverse outcomes that are frequently discussed in the literature (e.g., strong production goals, underdeveloped error management processes) were present. It was

an accident waiting to happen. By contrast, the hospital was doing all the "right things" in terms of the recommendations for effective error management and high reliability that are discussed in the literature (e.g., strong safety goals, strong safety training). Yet in each case not only were latent errors present but they also proliferated, and eventually generated major adverse outcomes—$1.3 billion in losses and bankruptcy for the investment bank's bank; preventable deaths of three prematurely born babies in the hospital's neo-natal intensive care unit. We use these cases to both to illustrate the framework and to generate research questions. We conclude with a discussion of the challenges and opportunities for future organizational research about the role of feedback processes in the linkage between latent errors and adverse consequences.

Delineating Latent Errors and Adverse Outcomes

Latent errors refer to unintended deviations from pre-specified expectations that can potentially lead to adverse outcomes of organizational significance (Ramanujam & Goodman, 2003). Let us consider the various components of this definition starting with expectations. It is meaningful to talk about errors only in reference to a pre-specified standard or expectation. In an organizational context, such expectations are conveyed through rules, regulations, standard operating procedures, and normative expectations that contain specific prescriptions and proscriptions about how work must or must not be carried out (Scott, 2003). Such expectations govern actions in the setting most relevant to studying errors–the daily operations of an organization's technical core where most actions tend to be rule-based (March, 1997). However, even in these settings, there may be situations where the expectations are unavailable, unknown, not well understood, or even incorrectly specified i.e., conforming to the expectations can be detrimental to the organization (Reason, 1998). Although such situations too are a reality in organizational life, to simplify our initial analysis, we focus on situations where organizational

members have shared knowledge and understanding about expectations. For instance, without exception, employees in the back office operations of a financial institution understand they are required to check every trading transaction and nurses in a hospital understand they are expected to verify medication details prior to administering medication to patients. Latent errors in such situations have contributed to major adverse outcomes in diverse organizational settings (Reason, 2008).

The second component of latent errors is deviations, which refer to the unintended actions of organizational members that do not conform to the pre-specified expectations. We focus here on the actions of individuals who are acting in their formal organizational roles (e.g., manager responsible for checking trading transactions, a nurse responsible for administering medications to patients) and oriented toward organizational goals (e.g., maintaining effective internal control over securities trading; ensuring the safety of patients). Deviations that are deliberately intended to subvert the organization (e.g., sabotage) or solely benefit the individual employee (e.g., employee theft) are beyond the scope of our discussion.

The third component underscores what is latent in these deviations, their potential, as yet unrealized, for causing organizationally significant adverse outcomes. These often are foreseeable outcomes that the pre-specified expectations were specifically designed to help avoid in the first place. The rules requiring the verification of trading transactions in a bank or medications in a hospital are designed to avert the foreseeable adverse outcomes that may result if verifications are not carried out. The word "potential" signifies that adverse outcomes may or may not occur. A nurse's failure to verify the medication does not always produce adverse consequence. If, as a result, however, the nurse administers an overdose of a high-risk drug to a high-risk patient, this error can seriously harm, even kill, the patient and generate additional

adverse consequences for the hospital (e.g., litigation, reputation loss). This error can also generate even more serious outcomes if it combines or interacts with other latent errors. The point is that latent errors can potentially contribute to a wide range of organizationally significant adverse consequences such as loss of life, injury, damage to physical equipment, disruptions to production schedule, costly product recalls and litigation, negative publicity, steep decline in sales, regulatory sanctions, financial losses, and bankruptcy (Reason, 2008).

Latent errors must be distinguished from related concepts such as violations, risk, safety, reliability, and accidents. Whereas errors refer to deviations that are unintended, violations refer to deviations that are intentional (Hofmann & Frese, this volume). Although errors and violations are hard to tell apart from the viewpoint of observable behaviors, their underlying intra -personal psychological mechanisms are different. Errors result from problems in cognitive processes such as attention, memory, and understanding that cause individuals to forget rules or select the wrong rule or incorrectly execute the correct rule (Rasmussen, 1997). In contrast, violations result from choice-based reasoning wherein individuals deliberately choose, to deviate from known rules. Latent errors differ from risk in that errors refer primarily to the actions that deviate from a standard while risk refers to the assessment, actual or perceived, of the likelihood and the magnitude of the adverse outcomes that could result from such actions (Hofmann & Frese, this volume).

Finally, latent errors differ from but are related to organizational outcomes such as accidents (Perrow, 1984), high-reliability (Roberts, 1993), and safety (Sagan, 1993). Latent errors sometimes precede and contribute to accidents, which are rare system-level events with adverse outcomes. However, accidents can also occur in the absence of errors because of violations, unexpected events, etc. In other words, latent errors are neither necessary nor

sufficient for the occurrence of accidents. Similarly, with their inherent potential for adverse consequences, latent errors pose a major threat to reliability—i.e., the extended absence of adverse outcomes in organizations that operate complex hazardous technologies—and safety—i.e., the sustained avoidance of physical harm to organizational stakeholders. However, it is conceivable that organizations may continue to deliver reliable and safe outcomes despite the widespread presence of latent errors or that organizations may produce unreliable or unsafe outcomes despite a low incidence of errors.

In our discussion so far we have not made any explicit reference to the level of analysis. However, we are primarily interested in studying errors as an organizational level phenomenon. Therefore, one important question is what it means to study errors—which are primarily the actions of individuals—at the organizational level of analysis. Surprisingly, this question is seldom discussed in the literature where studying errors as an organizational level phenomenon is often implicitly equated to studying the organizational-level antecedents and/or the organizational-level consequences of individual-level errors in organizational settings. However, from the viewpoint of advancing the study of errors as an organizational level-phenomenon, it is necessary to not only identify their organizational-level causes and consequences, but to also develop a meaningful representation of errors at organizational level of analysis.

We propose two complementary ways to think about errors at the unit-level of organizational level of analysis. First, some errors possess features that render them inherently organizational. Second, the composition of errors may be helpful in systematically differentiating and comparing the incidence of latent errors between different work-units or organizations. As previously discussed, latent errors in an organization entail the actions of individuals that deviate from pre-specified expectations. In this sense, every latent error begins

as an individual-level error. However, some latent errors acquire organizational characteristics. For instance, rather than a single individual deviating from expectations, multiple participants deviate from expectations. Moreover, individuals share a collective understanding (implicit or explicit) that others in the organization are deviating from these expectations. Further, the organizational conditions that give rise to the deviations and to the shared understanding persist over time.

Consider, for example, two different scenarios in a hospital unit with ten nurses. In the first scenario, a single nurse fails to verify the medication as required by the unit's operating procedures. In the second scenario, seven of the ten nurses fail to verify the medication as required. We would argue that the first scenario illustrates an individual-level error that could be potentially explained in terms of characteristics of the particular nurse committing the error (e.g., a distracting personal family situation). By contrast, the second scenario illustrates an organizational error in that the errors were committed by multiple nurses and it is highly unlikely that these errors can be explained in terms of the idiosyncratic characteristics of the seven nurses. That is, organizational errors cannot be adequately explained without taking into account some organizational-level antecedents. Moreover, these antecedents operate through social processes that link the individual actions of the nurses to their shared understanding that others in the unit are also deviating from the expectation about medication verification. It could be that the unit is understaffed, and there is considerable time pressure to deal with patients quickly. These beliefs are shared by the unit members.

A second way to represent organizational errors is as a dynamic mix (e.g., frequency, severity, variety) of errors feeding or interacting with each other at the unit or organizational level. To start with, the *frequency* of latent errors can differ between organizations. For instance,

the number of instances that trading transactions should have been verified but were not can be higher in some financial institutions than in others. Next, latent errors can also differ in their *severity* or risk. The failure to verify trading transactions represents a more severe latent error in a financial institution where the size and volume of trading transactions in relation to the firm's capital base are large rather than small. Additionally, the mix of latent errors can also be characterized in terms of their *variety*. For instance, latent errors can occur in the execution of primary work activities e.g., securities trader exceeding the limits while executing a trade; or in the monitoring of the execution of work-related activities in order to detect and correct the errors in execution; or in the infrastructure i.e., the stable set of pre-specified arrangements for carrying out work. For instance, one well known rule about structuring securities trading operations is that the responsibilities for trading and for booking the trades should be assigned to two independent sets of people. Assigning these responsibilities to the same person would be an example of an infrastructure error. Low variety means there are fewer different types of latent errors in an organization, while high variety means there are many more different types of latent errors.

Why introduce the three metrics of latent errors? The reason is that at the unit or organizational level these features may interact with each other and increase the magnitude, frequency or variety of errors. Let's return to the financial example and the trading room. Some of the traders notice a number of trades are exceeding the limits. This continues over time. A number of the traders believe the limits may not be so fixed and begin to trade over the limits. This "normalization of deviance" (Vaughan, 1996) has at least two consequences. More traders begin to trade over limits and the magnitude increases. In this case, initial frequency of deviations is contributing to greater frequency and also the magnitudes of the deviations. In a

related but different example, let's assume the variety of errors increases. This means that not only are execution errors (i.e., trading limit deviations) are increasing, but the same is true for monitoring and infrastructure errors. As monitoring errors increase, as an example, it would be more likely to observe more execution errors. Monitoring, to some extent, provides controls for detecting execution latent errors. Therefore, when monitoring errors result in reduced tracking of adherence to standard operating procedures, an increase in the frequency and magnitude of trading deviations is more likely.

The theoretical picture we are drawing includes a system of latent errors, which vary in frequency, magnitude, and variety. Each feature is interactive with the others at the unit or organizational level. Changes in frequency can lead to changes in magnitude and/or variety. The obverse also is true. Also, one should note that it is at least a two directional system. Decreases (increases) in frequency of latent errors could lead to a decrease (increase) in magnitude and/or variety. We view this system of interacting types of errors as a unit or organizational-level phenomena.

Following are some of the implications of our conceptualization of latent errors, adverse outcomes, and organizational errors. First, focusing on latent errors moves us away from studying extremely rare error-related events such as accidents, which have been typically the focus of the literature. It is much harder to build and test theories about very infrequent events. Second, a related point, it makes its possible to study errors using *ex ante* research design. By focusing on extremely rare events, prior studies tend to sample on the dependent variable (i.e., study only organizations that experienced adverse outcomes) and are prone to hindsight bias. The basic assumption underlying latent errors is that they occur frequently in all types of organizations. In other words, they are not rare events limited to organizations operating

hazardous technologies such as nuclear power plants or air traffic control. By asserting they occur in all types of organizations one can design *ex ante* vs. *ex post* studies. The former seems a more productive way to build and test new theory. Third, we treat the concept of adverse consequences broadly. Initially in this literature it was tied to physical loss (e.g., *Challenger*, *Bhopal*). More recently latent errors have been tied to other indicators of adverse consequences, such as financial loss and reputation loss (Ramanujam & Goodman, 2003). We adopt a broad view of organizational effectiveness and substantial declines in any of these indicators would be measures of adverse consequences.

Lastly, this conceptual distinction between individual and organizational errors is important because these levels of analysis are often confused in the literature or not made explicit. In this chapter, we focus primarily on errors at the organizational level of analysis, which have received little attention.

Linking Latent Errors and Adverse Consequences: A Conceptual Framework

In the light of our foregoing discussion about latent errors and adverse consequences, we turn to the central questions in this chapter: When and how do latent errors generate organizationally significant adverse outcomes? We introduce a conceptual framework (see Figure 1) to capture the various elements and their interrelationships that are essential for addressing these questions. We will briefly define the basic concepts in this model and then proceed to some examples from which we will develop a more complex representation of the model.

*** Place Figure 1 about here***

At the center of this framework are latent errors represented in terms of both their mix (i.e., frequency, variety, and severity) as well as their organizational features (i.e., involvement

of multiple individuals). To its right, the framework contains organizationally significant adverse outcomes linked to these errors. The central part of our framework focuses on two mechanisms or processes – error amplification feedback or error correcting feedback. These two processes act on the frequency, severity, and variety of errors. Error correcting processes enable the organization to detect, correct, and contain latent errors. By contrast, error amplifying processes promote an accelerated build up of errors. As this mix of errors increases, so does the probabilities of adverse consequences, which would be activated by internal (to the organization) or external triggers. Most researchers have looked at the linkage between antecedent factors and adverse outcomes. Our framework links antecedent factors to the two feedback mechanisms then to latent errors and eventually adverse outcomes. Being more specific about the mediating mechanisms can enhance our ability to predict latent errors and adverse outcomes.

Error-correcting Feedback Systems. An important component of our model is error-correcting feedback processes. The key features of any error-correcting feedback system include (1) a pre-specified standard, rule or procedure, (2) a measurement system that detects deviations from that standard, and (3) an organizational mechanism that would eliminate or correct the deviation. All three features are critical. One must have an operational standard that is an explicit part of the organization's input process or outcome systems. There needs to be a measurement system that detects deviations and makes that information available to the appropriate organizational unit. Then there needs to be a review process that both diagnoses the reasons for the deviation and initiates organizational processes to rectify the deviation. Organizations have multiple error-correcting feedback systems and their basic role is to keep the organization in equilibrium by reducing the number of latent errors (Reason, 1998). Consider the body shop in a computerized

automobile assembly plant. Robots pick up sheets of metal and form the basic body of the automobile. What is critical in this process is achieving dimensional quality. That is, the different pieces forming the body must meet specific dimensional standards. If there are deviations, the automobile will be difficult to assemble. In this setting, there is an independent, real-time system measuring dimensional quality of specific components (e.g., door, hood). These data are sent to the operator of the robots and quality control and are reviewed. If deviations are identified, corrective actions are initiated at the end of this review meeting.

Given our premise that latent errors are found in all organizations, the error-correcting feedback systems are in place to identify and correct the causes of the deviations (see negative sign between error-correcting feedback systems and latent errors – Figure 1). Of course, the effectiveness of the error-correcting feedback systems depends on whether the standard is clear and shared, whether the measurement system captures the relevant deviations, and lastly, whether there is some system in place that will review the data and act to achieve the expected equilibrium. These are likely to be cases where error-correcting feedback systems work effectively and reduce the number of latent errors. It also is likely that one or more of the three features of error-correcting feedback systems are not met and the latent errors are not affected.

Early studies of high-reliability organizations identified three organizational characteristics that were especially seen as contributing to the organizational capabilities for error correction—redundancy, flexible structures, and culture. Roberts (1990) for example refers to the 'many pairs of eyes' on an aircraft carrier flight deck, and Rochlin et al (1987) to the large number of people 'just watching' others perform their jobs. In high tempo operations this redundancy substitutes for time: laborious checking by one or two individuals is precluded by the rapidly developing situations that must be managed, but redundancy allows quick checking by

many individuals simultaneously. Moreover, there can be redundancy in ideas as well as resources. Bigley and Roberts (2001) describe how incident command systems 'appear able to structure and restructure themselves on a moment-to-moment basis, and … oscillate effectively between various pre-planned organizational solutions to the more predictable aspects … and improvisation for the unforeseen and novel complications...'. Schulman (1993) argues that a culture of high reliability culture is especially critical for actions that are unconstrained by formal structures because it allows the possibility of interpretation, improvisation and unique action.

In recent studies, *mindfulness* has emerged as a process that is central to high-reliability organizing (Weick & Sutcliffe, 2006). Mindfulness entails an 'enriched awareness . . . [through] active differentiation and refinement of existing categories and distinctions . . . creation of new discontinuous categories out of the continuous stream of events . . . and a more nuanced appreciation of context and alternative ways to deal with it' (Weick, Sutcliffe, & Obstfeld,., 1999, p. 90). It enables organizations to more readily detect weak signals from interactively complex environments earlier and respond to them more effectively. It also loosens tight coupling by creating alternative paths of action. Recent studies have identified various specific processes that contribute to mindful organizing in workgroups and organizations e.g., reluctance to simplify interpretations, sensitivity to operations, commitment to resilience, under-specification of structures, and preoccupation with failure (cf., Weick & Sutcliffe, 2006; Vogus & Sutcliffe, 2007). Together, the findings from studies of high reliability organizations and mindful organizing provide a rich description of the feedback processes that enable organizations to detect, correct, contain, and effectively respond to errors.

Error-amplifying Feedback Processes. This component acts in the opposite way from error-correcting feedback systems. In this component, changes in one variable lead to changes in a second variable, which, in turn, leads to changes in the first variable. In our discussion of the features of latent errors, we proposed these features may mirror a error-amplifying feedback system. Changes in frequency of latent errors might lead to changes in the magnitude of these errors, which, in turn, could increase the frequency. Also, the variety of errors may change as a function of changes in frequency or magnitude of latent errors.

The role of error-amplifying feedback systems and its contrast with error-correcting feedback systems is well illustrated in a study by Rudolph and Repenning (2002). They used a systems-dynamic model to explore the relationships among interruptions, stress, and performance. Initially, their model shows that interruptions that cause deviations from standard operating procedures are recognized and resolved (error-correcting feedback system). Over time, if interruptions increase, the organization remains resilient and finds new ways to resolve the interruptions. However, there is a tipping point where the error-correcting feedback systems no longer work and the organization begins to collapse. There are accumulative interruptions, which increases the level of stress, which, in turn, reduces the ability to resolve the deviations created by the interruptions, which leads to a greater accumulation of interruptions, which leads to greater stress. This vicious cycle accelerates with increases in interruptions and stress and corollary declines in performance. In this accelerating downward cycle, there are no mechanisms to stop the downward cycle and move the organization to its original equilibrium. The final consequence is the collapse of the organization.

In discussing the role of positive feedback loops, we focused on error-amplifying processes. That is, we discussed how increases in interruptions could increase stress, which, in

turn, could decrease the ability to manage deviations from interruptions, which, in turn, could increase stress. However, positive feedback loops can also operate in the opposite direction. That is, decreases in interruptions could decrease stress, which, in turn, could increase the ability to manage deviations, which, in turn, should reduce stress. Our primary focus will be on how these feedback systems increase latent errors and how they contribute to the link between increasing latent errors and adverse organizational consequences. The positive sign between error-amplifying feedback systems and latent errors signals this idea (see Figure 1).

Another feature of error-amplifying feedback systems is the rate of acceleration among variables. Rate refers to the amount of change and the timing of changes. In several studies (Rudolph and Repenning, 2002; Sterman, 1994), the initial reciprocal changes between variables are small, but over time, the frequency and magnitude of changes accelerates. The label "vicious downward cycle" means the changes (e.g., interruptions, stress, performance) are increasing in rate, and in magnitude, over time, until the demise of the organization.

Organizational studies of accidents elaborate on several error-amplifying feedback processes. First, Vaughan's (1996) account of normalization of deviance details the processes that cause organizational members regularly deviate from rules and procedures while viewing such deviations as normal. Checking for gas in a coal mine is a standard procedure to avoid explosions. Normalization of deviance would mean miners in a particular mine do not regularly check for concentrations of gas. It's the normal thing to do. Snook (2000) proposes a similar explanation for how the challenges of communicating across highly specialized and differentiated work can make operational drift—gradual straying from standard procedures—not only more likely but also more difficult to detect. Second, Perrow (1984) suggests that multiple independent errors can produce accidents when they interact in unexpected ways. Such

interactions are more likely when the technology is interactively complex as well as tightly coupled. Third, Rudolph & Repenning's (2002) draw attention to the role of feedback loops in accidents. They suggest that dynamic relationship between errors and stress—where stress leads to errors, which, in turn, leads to more stress, and so on—can lead to a "quantity" effect whereby the stress from a buildup of errors makes accidents increasingly likely over time.

The Interaction between Error-correcting and Error-amplifying Processes. These two processes interact with each other. Although they have important independent effects, their interaction accounts for the development of organizational errors and the acceleration of latent errors. Consider the recent disaster in a West Virginia coal mine where 29 people lost their lives. Mining to begin with is a dangerous work environment (New York Times, 2010). One of the risks is the level of methane gas, which can lead to explosions. One of the standardized procedures is to check for gas levels in multiple places at multiple times. Starting with the error correction mechanism, there are standards, measurement instruments, and corrective procedures if gas levels are too high. From an individual level error perspective, one could see an individual miner not doing a check at a particular work area or routinely not doing gas checks. This represents an individual error. Throughout a mine there are multiple people doing these gas checks, and there are federal and state inspectors doing these checks. In this case, there is redundancy in monitoring.

A different scenario is other "monitors" see this miner not doing gas level checks, and there are no consequences. Others then begin this practice. A related scenario is that the monitoring occurs, but there is no feedback or corrective action. In either scenario, latent errors are increasing. Over time at least two things can happen. First, a general understanding

develops that monitoring and/or corrective actions are not necessary. Second, deviations from other standard operating procedures (e.g., check the roof) begin to occur.

As feedback and corrective processes begin to diminish, the amplification processes begin to increase. As more "monitors" deviate from this standard practice, we are dealing with organizational errors, not individual level errors. As the amplification processes become more predominant, the organizational latent errors begin to increase, at an even faster rate. The probabilities for adverse consequences increase.

Let's clarify this picture of latent errors and adverse consequences. The failure of the miner to check for methane could lead to an explosion. But we have argued that latent errors lead to potential adverse consequences, not actual consequences. On the other hand, as deviations from checking gas levels become more normal, the increase in these deviations puts the whole mine at risk, not a work section, and the chances of adverse consequences increases. The failure in the error correcting mechanism can lead to negative outcomes. However, the combination of the failure of error correcting mechanisms and error amplification processes spell danger for the organization.

Organizational Antecedents of Feedback Processes. Our analysis occurs in an organizational context. There are many possible organizational antecedents of errors (*cf* Vaughan, 1999). Our goal is to illustrate the link between antecedents to the error correcting and amplifying mechanisms, which in turn affect the frequency of latent errors and eventual adverse outcomes. We want to explore the central linkages rather than do a comprehensive review of the literature.

Organizational goals are important signaling devices. Since organizations have multiple goals, one question is which goals are more salient or emphasized. If production goals have

primacy over safety goals, this should indicate what work activities are dominant (Vaughan, 2005). In a trading company where revenue or profitability is dominant, there may be fewer monitoring or corrective activities on trades over some pre-specified limits. The more other traders see limits being deviating from, we would expect to see more deviations around this activity.

The structure of work is another class of antecedents (Ramanujam & Goodman, 2003). Take one dimension – work being done fact to face or distributed. The former case is an excellent setting for learning. One nurse sees other nurses not following the standard procedures for dispensing narcotic medications. Seeing relevant others not doing can legitimate this nurse from not following the procedures. The visibility of the work setting facilitates normalization of deviance and stimulates error amplification processes. In the distributed setting, visibility is restricted. One can exchange verbal communications, but the visibility of others' behavior is limited, and the opportunity to learn about deviations. In this case, there are at least two lessons. First, it is harder to observe others' behaviors and normalization of deviation is more difficult. However, being in a distributed work setting also restricts monitoring behavior. So deviations could be occurring without any opportunity for a monitoring corrective mechanism to work.

A different antecedent is change. All organizations are experiencing different forms and levels of change. Change is relevant in this context because it uses up attentional resources (Ramanujam, 2003). One of our key mechanisms is errors correcting processes. If change demands a lot of attentional resources, and these are in limited supply, we would expect to see a decrease in monitoring behaviors, which in turn should increase latent errors. As argued above, as error correcting mechanisms decline, error amplification mechanisms can increase.

Another class of antecedents deals with perceived safety culture (Vaughan, 1996). This can include beliefs about the openness and supportiveness of discussing errors and find new solutions (Edmondson, 1996). In the context of our framework, a strong culture to be open to errors and to find creative solutions should facilitate the error correcting feedback process and reduce errors and not stimulate error amplification processes.

There are at least three lessons from this discussion of antecedents. First, we wanted to illustrate some linkages rather than generate an exhaustive list of antecedents. Second, we tied the antecedents to the two error correcting and error amplifying processes rather than to latent errors or adverse outcomes. We did this because we think these two processes directly affect the frequency, magnitude, and type of latent error. It is clear the antecedents facilitate or hamper these processes. But the first questions we would ask about the mine disaster, given there were SOPs about monitoring, include: were there deviations in monitoring, were multiple miners deviating, and were corrective actions initiated when there were deviations from monitoring. Answers to these questions would indicate whether we are dealing with individual or unit or organizational errors and whether the errors were related to monitoring or feedback and corrective action, or all three. This information would direct us to possible relevant antecedents. Third, most research focuses on a specific antecedent such as safety culture or change. But the reality is that multiple antecedents are affecting two critical processes. The challenge is to trace through whether the antecedents have a synergistic effect on the two main processes or are they in conflict with each other.

Linking Latent Errors to Adverse Consequences—Two Cases

In this next section we explore these and other issues in the context of two cases. They capture the relationship between organizational latent errors and adverse outcomes in different ways.

Barings Bank. This was the oldest investment bank in the United Kingdom with total assets of 9.37 billion and 4000 employees worldwide. After the deregulation of London's financial markets in 1986, Barings set up a subsidiary to trade in securities and derivatives. In early 1992, Barings sent Nick Leeson to Singapore to set up a settlement process in their security trading subsidiary. Shortly after coming to Singapore, Leeson also had the responsibility for trading. By 1994 the Singapore operation was generating substantial profits for the firm (i.e., $30 million in the first 2 months of 1994 vs. $16 million for all of 1992). Much of this success was attributed to Leeson, and he was considered a star performer in the securities subsidiary. During this period, Leeson trading volume increased. By the end of 1994 Leeson had accumulated over 28,000 contracts valued close to 29 billion dollars. Most of these were unhedged positions betting on the upward movement of the Japanese stock prices and interest rates. On January 16, 1995 an earthquake in Japan led to a steep drop in Japanese stock prices and interest rates. Within a month Barings was exposed to losses of 1.3 billion and was forced into bankruptcy.

This initial description sets the stage for some basic research questions. First, what were the latent errors in this case? When Leeson began trading, he also was in control of the settlement process. In Baring and in other financial institutions, settlement and trading are separate operations done by different people. This division of labor is really a control mechanism to insure the trader is following the standard rules. In this case, an internal audit team from Barings identified this deviation (infrastructure latent error) but in subsequent negotiations Barings security subsidiary prevailed and Leeson continued to trade and settle. At

this time, Barings Securities and Leeson were major contributors to Barings' profitability and they wanted to maintain control over their operation.

There were other examples of latent errors. All traders had to respect certain trading limits. Also traders are required to hedge positions. This means at the end of the day if a trader had over-sold a position he had to buy additional securities so that there were no open positions. Leeson deviated frequently from these two rules and therefore generated execution errors. All during this time there were deviations from standard monetary procedures but there was no rectification of these deviations. There were indications of infrastructure, execution and monitoring errors. These continued to accelerate over time. One reason is the interactive nature of the errors among themselves. If Leeson could settle and trade it was easier to violate the trading limit and hedge standard operation procedures. Infrastructure errors then facilitate the frequency and magnitude of execution errors.

Another question is whether this example is about individual or organizational errors. Some have construed the Barings case as an example of the "rogue trader" – an individual level error. Our distinction between organizational and individual errors was based on the idea there are multiple participants involved in errors and these may occur over time. This is clearly the case at Barings. Leeson was clearly involved in trading errors. However the management of Barings also was involved in deviations. They permitted Leeson to trade and settle. Also, when he had generated significant unhedged positions, Barings gave the Singapore Mercantile Exchange funds to cover his position. The amount of funds provided to cover margins deviated from the level of funds permitted by Bank of England. Also, there were internal audit teams, and account reconciliation procedures. None of these monitoring mechanisms were successful either

when Leeson was making profits or the hedge losses which brought down the Bank. The point is there were many deviations enacted by many players over time.

A third question concerns why the error-correcting feedback systems were not more effective. Error-correcting feedback systems require a clear standard, effective measurement systems, and organizational units and processes responsible for reviewing the deviations and moving the organization back to its equilibrium position. While the standards were clear the effectiveness of the measurement systems and response mechanisms were less clear. In a power struggle, Barings Securities subsidiary was able to retain its control over settlement and trading. Why they won this battle is probably tied to the salience of profitability where the subsidiary was the major contributor, the star performer status of Leeson, and the subsidiary's desire to maintain its own independence from the parent company. While settling and trading gave Leeson the capacity to mask some of the deviations, there were still monitoring mechanisms in place to track the frequency and magnitude of trades. But an argument about error-correcting feedback systems is that monitoring is not enough. One still needs an organizational unit and processes to rectify the deviations. Yet these were absent. The primacy of non "safety goals" (i.e., less incentive for vigilance and change), the distributed nature of work (i.e., Singapore is distant from London in both space and time), and the lack of a collaborative culture which has open discussions about why errors occur and how to eliminate them and improve the operation all contributed to an ineffective error-correcting feedback system. Without these systems the organization becomes very vulnerable to accelerating latent errors.

What is the role of error-amplifying feedback systems? As the effectiveness of the error-correcting feedback systems declined, the role of error-amplifying feedback systems became more dominant. We can see this at the individual and organizational levels. For Leeson initial

success in trading accelerated the frequency and magnitude of trades, many in violation of trading limits and hedging positions. As his luck changed and he began to experience losses the same positive cycle continued. Losses in trading accelerated trading behavior to recoup the losses. This cycle of escalation of commitment leads to greater frequency and magnitude of trades, most violating trading limits and hedged positions.

At the organizational level, senior management provided the subsidiary 790 million dollars to cover margin requirements, thus reinforcing the position of the subsidiary and Leeson's trading behaviors. Other regulating institutions both in Europe and Singapore inquired about the subsidiary's large unhedged positions. In these cases senior management assured these regulatory institutions there was no risk. All these behaviors by senior management at Barings accelerated the autonomy of the subsidiary and Leeson's trading behaviors.

What were the drivers of the positively accelerating spiral of deviations? The primacy of non safety goals contributed to the accelerated trading behaviors. Both more profits and more losses stimulated trading behavior. In the latter case the motivation was to recoup losses and achieve profitability. This affected the behaviors of both Leeson and senior management. The organization of work created two quite independent entities – Barings and the subsidiary. There was no common work or need to coordinate. Only the bottom line involved both organizations. This independence for the Singapore subsidiary created the conditions for error-amplifying feedback systems to flourish. Also, the two entities did not embrace a common culture of cooperation and problem solving. The absence of this type of culture facilitated the error-amplifying feedback cycles in the subsidiary.

Over time we see (1) the frequency, magnitude, and variety of latent errors accelerating on their own, (2) a error-correcting feedback system, which should decrease latent errors,

becoming less effective, (3) a error-amplifying feedback system accelerating the frequency, magnitude, and variety of errors, and (4) all these changes supported by an organizational context which supports non safety or non compliance goals, an organization of work which makes monitoring and redesign more difficult, an inadequate control system and a culture which does not support focusing on and solving deviations from standard operating values and procedures.

It clearly was a trigger event--the earthquake in Japan—that affected the economic system and led to a drop in the stock market and interest rates. This exposed Barings to over one billion dollars in losses. On the one hand, this exogenous trigger event led to the collapse of Barings. On the other hand, the four themes in this summary paragraph above indicate Barings was headed for disaster. In this particular case, it was the earthquake. But one could postulate other external regulatory agencies would have created serious adverse consequences for Barings. Or there could have been internal forces such as a change in senior management that acknowledged the problem and accepted large losses as a way to make the bank viable. The basic argument is that the conditions in the bank were out of control, and internal or external triggers might have caused large negative consequences.

Mid-Western Hospital. This hospital is one of three hospital facilities operated by a health care group in a mid-western state. MWH is a tertiary care facility that offers specialty treatment for its patients. Many of its units appear routinely in the *US News and World Report* rankings of top hospital departments. Over a weekend in 2006, five different nurses administered a thousand-fold overdose of the blood thinner heparin to six infants in the hospital's neonatal unit. As a result, three infants died. Three other infants recovered subsequently but the effects of the overdose on their long-term health were unclear.

Before we analyze the specific situation in the hospital and its neonatal unit, let us look at the broader context. For several years before this incident, many of the government or standard setting officials had taken public positions on the risks of Heparin. The Institute of Medicine, the Joint Commission that accredits hospitals, United States Pharmacopoeia, a standard-setting agency for drugs manufactured in the US all had issued advisories about Heparin and, in general, how to reduce medication errors. An Institute of Medicine panel had identified Heparin as one of the 5 drugs contributing to 28% of medication errors. From an institutional perspective, hospitals and their employees were receiving lots of warnings about Heparin.

Heparin was a high-risk medication for a variety of reasons. First, it was a colorless liquid, and different levels of the drug were indistinguishable. The packaging of the drug also did not differentiate dosage levels. So reading the label was critical to determine the dosage on hand. Second, different levels of the dosage were used to treat different types of patients with very different medical conditions. In the neonatal unit 10 units/ml Heparin solution was used to flush intravenous catheters to prevent closing. A 10,000 unit/ml dosage would be appropriate for treating adults, but it would be very dangerous or fatal to an infant in a neonatal unit.

MWH was one of the first hospitals in its region in 2000 to set up a safety program on medical errors. There was a major review and modification of the processes for medication distribution. At that time, nurses on the floor were responsible for selecting the correct dosage from a set of vials that contained different levels of Heparin. Part of the new safety program was a campaign to sensitize nurses for the need to verify medication.

In 2001, a nurse administered an overdose of Heparin to two infants. Fortunately, following some intensive medical procedures, the infants recovered. An investigation followed with a set of new recommendations to prevent these errors. These included: (1) patient floors

would no longer stock multiple doses; (2) medication carts of the neonatal unit only would be stocked with 10 unit/ml dosage; (3) the pharmacy would stock different dosages in different bins; and (4) the pharmacist would carry out multiple verifications in stocking and dispensing.

In addition to these specific actions, which were well publicized within the hospital, MWH initiated a series of other safety initiatives including a two-day safety training programs for nurses. All of these efforts were to make safety more salient. One aspect of safety was medical verification. The picture we want to draw is a hospital with clear goals on safety and a strong climate of safety culture. When the heparin incidents occurred there was instant diagnosis and new interventions to improve safety. The hospital and the neonatal unit were proactive and reactive in regard to safety.

The big question is why multiple nurses administered the wrong dosage, and three children died. One important factor can be tied to the error-correcting feedback systems. The verification process was not measured. While this is a formal expectation, measuring verification would require some monitoring system to identify if the nurse matched the vial to the medication requirements for the patient. This happens in the patient's room and the nurse verification process is not a highly visible activity and is harder to measure. The absence of measuring this verification process leaves the system in a very vulnerable position. We do not know if verification is happening intermittently or not at all. But we do know that multiple nurses gave the medicine to different infants. It is unlikely they all failed to verify on one particular day. A more likely scenario is the multiple nurses were deviating over time and in this particular instance, the pharmacist sent the fatal dosage.

The role of the error-amplifying feedback systems is less clear in this case. In Barings there were clear examples of accelerating latent errors. We have no information about this for

the hospital although it is apparent that at some point in time multiple nurses in the NICU stopped routinely checking the heparin dose prior to administration. Similarly, there was no external trigger event in this case comparable to the earthquake in the Barings case. Instead, the trigger event that linked the errors to adverse outcomes was itself an error that occurred in a different part of the organization (i.e., the pharmacy technician stocking the NICU medication cart with vials containing an incorrect dose of heparin),

The organizational antecedents play an important role in understanding this situation. First, there were clear goals for safety and a climate that was very proactive and reactive about safety. The organizational arrangements provide an interesting clue. There is strong interdependence between the pharmacy and the neonatal units. The new procedure of storing different levels of Heparin in different bins and requiring the pharmacist to do different verification was a workable solution. Over time the pharmacy delivered the 10 unit/ml vials only to the neonatal unit all the time. It was perceived to be a highly reliable innovation. In MWH all of these antecedent features predict no adverse consequences. Yet three infants died, and the other three were injured.

Discussion

The central question in this chapter is: what are the mechanisms that predict and explain the relationship between latent errors and adverse organizational consequences? We begin with latent errors because they provide a newer approach to the research on organizational errors. Latent errors are found in all types of organizations and vary across units in some systematic ways. Actual errors, which lead to immediate adverse consequences, are more rare events. Also, when they occur, researchers are forced into *ex post* explanations of why the adverse consequences occurred. The basic assumptions of latent errors is that (1) they can cause adverse

effects and (2) they occur with sufficient frequency that we can study them *ex ante* versus sampling on the dependent variable.

Given this position, the central question of this chapter becomes quite important. Our framework (figure 1) provides the mechanisms to explain when latent errors will have no adverse effects. There are at least two key mechanisms or feedback processes. First, the error correction mechanism is most important. Basically, this says (1) there are some pre-specified standard rules or procedures, (2) a measurement system exists that detects deviations from that standard, and (3) there is an organizational mechanism that would eliminate and correct the deviation. All three features are critical. If an error correction system measured the deviation, but there is no mechanism to correct the deviation, the error correction system is not operable. Or if there were no measurement of the desired behaviors, but strong mechanisms to return the organization to its equilibrium again, the system would not be operable.

The other mechanism is error amplification systems. In this scenario, an increase in latent errors stimulates the increase of other latent errors, which is turn leads to an increase in other latent errors. Changes in the frequency of errors could lead to an increase in the magnitude of errors, which could stimulate greater frequencies. The key idea, well illustrated in the Barings case, is the amplification of errors, and over time the amplification is at an increasing rate.

There is a common condition underlying both of these mechanisms – they both lead to more latent errors, if the error correction mechanism is not working, and the error amplification system is working. Consider nurses in a unit who are not verifying medication levels to the patient's requirements. If there is no error correction mechanism, these behaviors will continue. If other nurses who rotate across units observe this type of deviation, latent errors can spread

throughout the hospital. The "normalization of deviance" would be a form of error amplification, and increasing numbers of latent errors would appear in the second example.

What are the consequences of this increase in latent errors? One consequence is that the probability of adverse effects increases. In the case of the nurse who is not verifying medication level to patient requirements, the chances of a mismatch over time is more likely, which can have adverse implications for the patient and the hospital. In MWH, when the pharmacist sent the wrong dosage, and the nurses were not verifying, the adverse consequences were devastating. In the Barings case where there was a huge accumulation of errors, any event external or internal to the bank could have led to its demise. In this case, it was an earthquake and a drop in the Japanese stock index, but there could have been many triggers. Barings was becoming more vulnerable over time.

Table 1 frames this analysis in terms of our two cases. Barings represents one extreme. The error correction system is not operative while the error amplification system is. All of the antecedents support the increase in latent errors. The goals are focused on financial performance versus reliability. Work is distributed, which makes monitoring difficult. Also, there is no culture supporting vigilance and high reliability.

Place Table 1 about here

At MWH, the opposite is true. They have strong safety goals and culture. Work is face to face and in general, they have a strong control system. What is missing is an error correction system tied to the medication verification process. Specifically, there was no measurement of the verification process. There was a standard and an organizational mechanism to correct deviations. The lack of a measurement system is not surprising. Organizations cannot measure

all relevant behaviors, and this particular behavior, whether nurses verify, is hard to assess. You really have to be in the patient's room.

What can we learn from Table 1 relevant to our central question? First, Midwest Hospital had all the features of a highly reliable and safe system. There are strong goals and culture about safety. There has been a series of structural and process interventions to minimize errors. Yet three infants died and others required extra treatments. Second, the strong safety culture can have dysfunctional effects. If you know structural changes to minimize errors (e.g., sorting different levels of Heparin in bins) have been put in place and they work well, personal vigilance may decline, and latent errors or verification may increase. In one sense, a prevention system can be too successful. Remember a nurse's job is full of activities, interruptions and time demands. They need to make choices of time allocations. If delivery from the pharmacy is accurate over time, then verification of medication might not be a priority. Third, the absence of an error measurement process meant that there was no knowledge whether medicine verification was going on and, therefore, no ways to rectify the situation.

A minimal condition for latent errors to lead to adverse consequences is when the error correction system is not working. An important qualification is that the error correction system needs to be focused on a high risk, central behavior. In the case of Midwest Hospital, it was administering a high risk drug to a very vulnerable patient. We can think of other latent errors in a hospital (e.g., lock medication drawer), which are relevant but not high risk challenges to the patient.

The Barings case demonstrates optimal conditions for major adverse consequences. The error correction system doesn't work, and the error amplification system is operating. Also, all

the antecedent factors facilitate the accumulation of errors. This situation is ripe for adverse consequences. What is difficult to predict is the time frame or triggering agent.

Our analysis has focused on the error correction and error amplification mechanisms. The literature has placed more emphasis on the direct antecedents of errors (cf Vaughan, 1999). A review of Table 1 shows that many of the factors in the literature such as emphasis on safety goals and safety climate should lead to little or no adverse consequences. But despite these conditions, serious adverse consequences occurred. Our argument is that one needs to understand in detail the error correction and error amplification mechanisms in regards high risk or vulnerability behaviors. At MWH there weren't working correction mechanisms for the heparin administration.

Research Opportunities

One contribution of this chapter is identifying some areas for future research. Instead of providing a list of questions, we will explain a few opportunities. There are many others than the ones enumerated. The framework in Figure 1 is our starting point. We think it explains the processes between latent errors and adverse outcomes. However, we do not think testing the model itself is very productive. Rather, our preference is to select relationships within the framework for more empirical investigation.

One possible issue concerns the content of the latent error. For example, in Midwest Hospital, the general behavior was verification of medicines. But the specific behavior was verification of Heparin, a drug related to fatalities in hospitals. This was a high risk transaction, particularly in a neonatal unit. We pointed out that there were other standard operating procedures, such as locking the medication drawer so others (nurses or patients) could not access the medication. Or not leaving the room during administration of medications to insure patients

take their right medications. Both of these examples can be consequential to the hospital, but not at the same risk level as giving the wrong dose of Heparin to a patient, because of lack of verification. The challenge here is to classify latent errors on their propensity to create adverse consequences and then collect data on this classification scheme to verify the content effects on adverse consequences. More generally, there is an opportunity to think about focusing on latent errors in terms of frequency, severity, and variety. For instance, what are the antecedents of frequency rather than variety?

On a related note, the link between errors at the individual and at the organizational level of analysis provides interesting opportunities for future research. For instance, through what processes do individual-level errors give rise to organizational errors? What are the organizational conditions that facilitate or impede the link between individual-level and unit- or organizational-level errors? Such questions remain largely unaddressed in the organizational research on errors and point to a second set of research opportunities. A related issue is whether organizational errors are more likely to lead to more adverse consequences than individual-level errors. There are at least two considerations. First, there are more people deviating. Second, the implicit understanding that others are deviating from expectations with respect to some activities might lead to latent errors in other activities. These factors can increase the frequency, severity, and variety of errors that can facilitate adverse consequences.

The MWH case provides an interesting illustration of dysfunctional learning. After a death in a neonatal unit from an overdose of Heparin, there was a flurry of safety activities. One initial lesson was to be sure to verify heparin administrations. Another later lesson was that the changes were successful, the units always received the correct vials, and over time, the nurses might have assumed that they need not be so vigilant. That is, if the system is working 100%

(which it was), one lesson is that administering Heparin is quite straightforward. There is no need to be as vigilant about what the pharmacy sends. We do not know exactly how the learning took place. One scenario is that frequent conversations among the nurses about high quality of the new system might have begun the creation of a collective understanding about not verifying. Another scenario is that one nurse observed another skipping verification and that person eventually adopted this practice. The underlying concept is the "normalization of deviance" (Vaughan, 1996) via learning.

Another interesting issue, again from the Midwest Hospital case is the interplay between the antecedents and nurse behaviors. There were strong goals and culture supporting safe behavior. Yet we know nurses were not doing the verification process. Our theories about strong climates and culture are that they do influence employee behavior. In the literature we cited earlier, the implications are that building an organization with safety goals and safety culture should lead to fewer errors, safety mishaps or other adverse consequences. But that did not occur at Midwest Hospital. Indeed one possible inference from our analysis is that the system was too reliable. The doses of Heparin always were correct. This might have led to less vigilance in the verification process. But there obviously are other possible explanations. High levels of stress could divert the nurses' attention from the verification process. Given the organization of a hospital, we could visualize a strong headquarters culture, but variations in unit culture with respect to safety. The research challenge is acknowledging the strong safety goals and cultures as desirable, but we have mentioned alternative factors that could offset the effects of culture. Exploring the effects between organizational antecedents with conflicting impacts would be a different research option.

There are dynamic and temporal dimensions underlying our analysis. We know little how they work. The picture of Barings was an accelerating accumulation of latent errors. Our assumption was that this acceleration would continue until a trigger led to adverse consequences. But another scenario might have been the acceleration of latent errors slowed and then moved in the opposite direction. One could imagine changes in managerial personnel or reorganization of the trading operation could create such changes. A related issue is predicting when adverse consequences would occur. Is there some tipping point where triggers are more likely to create adverse consequences? If the earthquake had not occurred, and the accumulation of errors had continued, when would have Barings collapsed? Or if the pharmacy at Midwest Hospital had not delivered the high dose of Heparin, and nurses did not verify, when would adverse consequences have occurred? Here we are not talking about specific times (e.g., dates) but ranges of time. A related question is whether we can predict the emergence of adverse consequences.

Another potentially interesting research opportunity is examining the link between organizational antecedents and feedback processes. In figure, the lines connecting these variables are indicated with arrows that go both ways. In our discussion, we focused on how antecedents such as emphasis on production goals can weaken error correcting feedback processes and promote error-amplifying feedback processes. It is also conceivable that the feedback processes may alter the antecedents. For instance, given a strong production goal, if negative feedback processes detect several severe errors, the organization might respond by reducing the emphasis on production. Or, if the positive feedback processes are dominant and if the buildup of errors is accompanied by increased productivity or profits but not adverse outcomes, then the organization may further increase its emphasis on production goals.

Therefore, one interesting research opportunity is about identifying the conditions under which feedback processes affect antecedents.

A last and very different question: when do latent errors lead to positive outcomes? Let's think of a situation where there are strong SOPs in an organization. Latent errors are prevalent for some of these procedures. An error correction system is in place. It identifies the deviations and implements a corrective action. However, during the analysis of the latent errors, evidence is presented that the SOP is no longer functional. It was in the past where the context and technology were different. This discovery leads to abandoning the SOP giving people more time for other critical activities. The research question then is: can we predict where latent errors no longer lead to adverse outcomes?

Conclusion

Our goal in this chapter was to draw attention to complex links between latent organizational errors and adverse outcomes in organizations. From an organizational research perspective, it is important to focus on when and how frequently occurring latent errors result in rare but organizationally significant adverse outcomes. We presented a framework to explain how organizational mechanisms interact dynamically to shape the link between latent errors and adverse outcomes. An important feature of this framework is that it provides a basis for bringing together the findings and insights from currently fragmented organizational research on errors, accidents, safety climate, and reliability. Our discussion also identified several implications for future research. Understanding the role of organizational antecedents and mechanisms in the link between latent errors and adverse outcomes is critical to understanding what is "organizational" about errors.

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Figure 1: An Organizational Framework for the Link between Latent Errors and Adverse Consequences

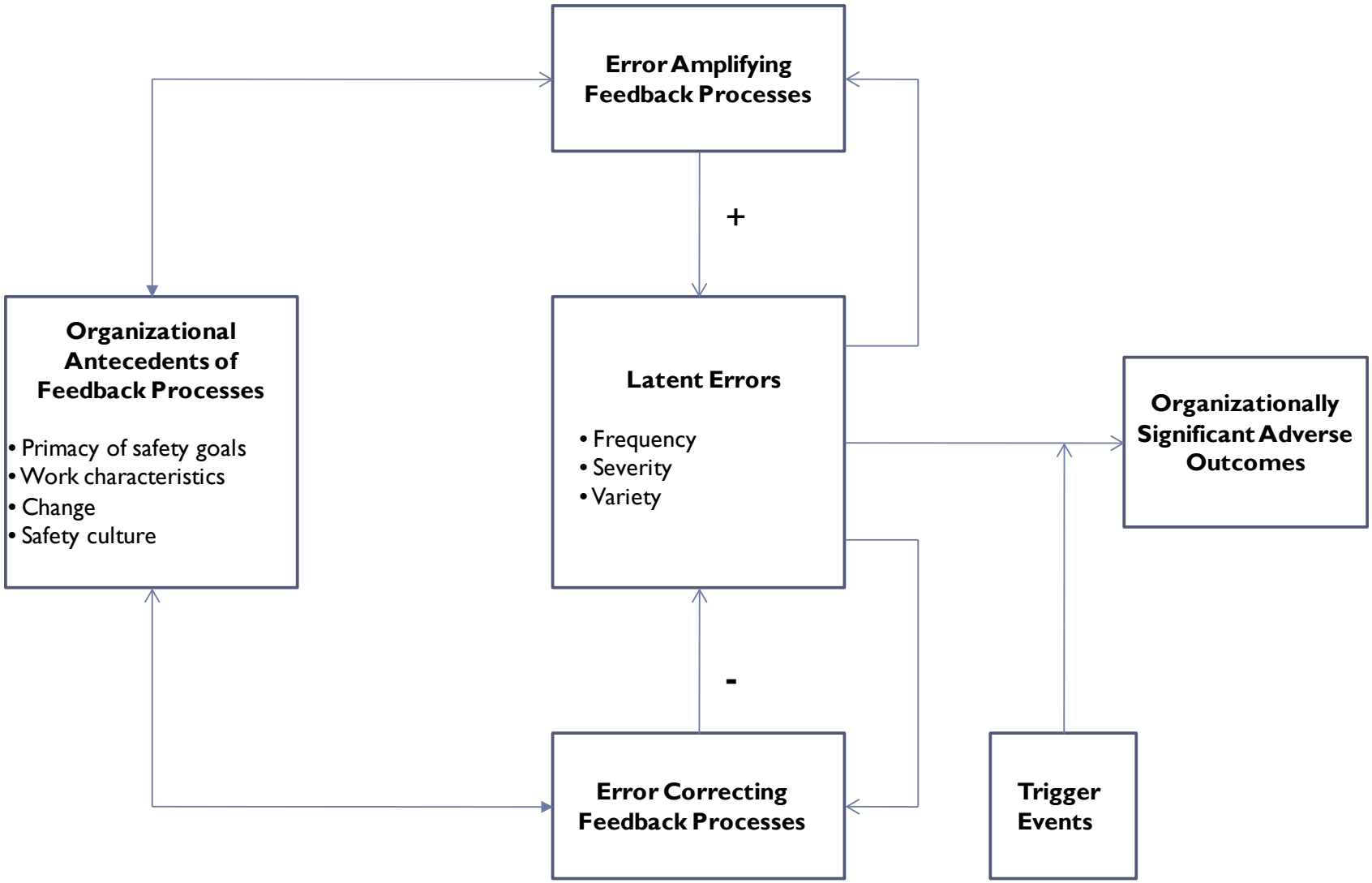

Table 1

Contrasting Barings and Midwest Hospital

Mechanism	Barings	Midwest Hospital
Errors Correction	No	No
Error Amplification	Yes	No
Antecedent Safety Goals	No	Yes
Nature of Work	Distributed	Face to Face
Control	Weak	Strong
Safety Culture	No	Yes