Error Analysis Using Organizational Simulation

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Organizational simulations have been used by project organizations in civil and aerospace industries to identify work processes and organizational structures that are likely to fail under certain conditions. Using a simulation system based on Galbraith's information-processing theory and Simon's notion of bounded-rationality, we retrospectively modeled a chemotherapy administration error that occurred in a hospital setting. Our simulation suggested that when there is a high rate of unexpected events, the oncology fellow was differentially backlogged with work when compared with other organizational members. Alternative scenarios suggested that providing more knowledge resources to the oncology fellow improved her performance more effectively than adding additional staff to the organization. Although it is not possible to know whether this might have prevented the error, organizational simulation may be an effective tool to prospectively evaluate organizational "weak links", and explore alternative scenarios to correct potential organizational problems before they generate errors.

INTRODUCTION

The Institute of Medicine estimates that up to 98,000 patients die each year as a result of patient care errors[1]. Although the sentinel error event can be obvious and dramatic, often it is a series of smaller, undetected errors that culminate in serious errors and which result in poor outcomes. Researchers in error analysis, suggest that most errors result from faulty systems, not faulty people. To reduce patient care errors, we must study the process in which patient care is delivered [1, 2].

In other industries in which the costs of errors can be high, researchers have used organizational simulations to evaluate how well a particular organization responds to unexpected events [3, 4]. For example, organizational simulations in the aerospace industry have successfully identified error-prone processes prior to the development and manufacture of satellite launch vehicles[5]. These simulation experiments identified the work activities and organizational participants that were more susceptible to errors, and could have permit managers to make interventions before significant errors occur.

Previous work in medical organizational simulation suggests that to use simulation techniques in medical organizations requires extending organization theory and developing new simulation behaviors[6,7]. Building on the simulation experiences in other industries, we have used a simulation system, based on information-processing theory, to examine error-prone processes in medical care.

INFORMATION-PROCESSING ORGANIZATIONAL SIMULATIONS

Information-processing theory and the concept of bounded rationality forms the basis of the behaviors in our simulation. Information-processing theory abstracts activities into a volume of work that is assigned to an organizational member[8]. The structure of the organization serves to coordinate the organizational members, and to resolve unexpected events or exceptions as they arise. For example, in an academic medical center, the attending physician coordinates the team of residents and students taking care of patients, and when problems arise, serves as an information resource and decision-maker. In work processes in which all questions have been properly resolved and in which all relevant information has been exchanged, information-processing theory predicts organizational members will make better decisions and have higher quality processes.

In our simulations, we have linked information-processing theory to Simon's notion of bounded rationality[9]. Simon suggests that organizational members are cognitively limited in their ability to process information. In contrast to information-processing theory, more information may not always lead to better decisions or higher quality processes. If organizational members become overloaded with work, they may miss important communications, and make errors.

Using these two theories in a simulation environment, we can explore how different organizational structures, actor skills, and work processes interact to enhance or impede the ability of organizational members to process this information. Not all ways of structuring an organization or work process are equal, and using simulation, we can explore alternative ways of structuring organizations and the work organizations do.

To create an information-processing framework, we abstract all activities to a volume of work for which an organizational participant is responsible. Errors are modeled as exceptions—unexpected events that occur stochastically, based on characteristics of an activity. In addition to errors, exceptions also represent requests for information, or notification events that are not part of the usual work process. Exceptions require time to be evaluated by an actor and are time-limited—exceptions will expire if not attended to promptly by an actor. When ignored or not attended to, the actor requesting the information will make a decision by default. Decisions made by default are considered error prone, and raise the probability of future exceptions. Our simulation model consists of a model of the organization (actors, skills, and supervisory relationships), a model of the clinical work process (activities, exceptions, and successor/predecessor relationships), and responsible-for links that connect the organization and work process.

When the organizational model is executed, the simulation breaks each task down into subtasks, and places these subtasks into the responsible actor's inbox for processing. Actors with more skill or expertise in a given task will be faster at completing their assigned subtasks. When a subtask is completed, the simulation stochastically determines if an exception or communication must be generated and calculates the time until the communication or exception expires. For example, a communication sent via phone will have a short expiration time; one that uses the medical record to communicate will last longer. All communications and exceptions are placed in the actor's inbox with the other tasks for processing. If tasks are being added faster than the actor can process them, the actor backlog will increase, and the chance that tasks or communications will expire before it is attended to increases. When the work process is examined, those actors with higher backlogs in their inbox will be more likely to miss important communications, and may be more likely to make errors.

AN ERROR CASE ANALYSIS

To test our simulation model of patient care errors, we investigated an error that occurred during the administration of chemotherapy in a clinical trial protocol. An patient who was enrolled in a clinical trial protocol, was scheduled for her third dose of chemotherapy. The chemotherapy was to be administered by the inpatient services, under the supervision and guidance of the outpatient team. The chemotherapy consisted of two courses of low dose chemotherapy over three days, followed by two courses of high dose chemotherapy delivered in a single dose. Both the oncology fellow and the clinical nurse specialist provided specialized knowledge about the clinical trial protocol, and were responsible for conveying this information to the inpatient services. In this organization, the clinical nurse specialist position was not filled, leaving the

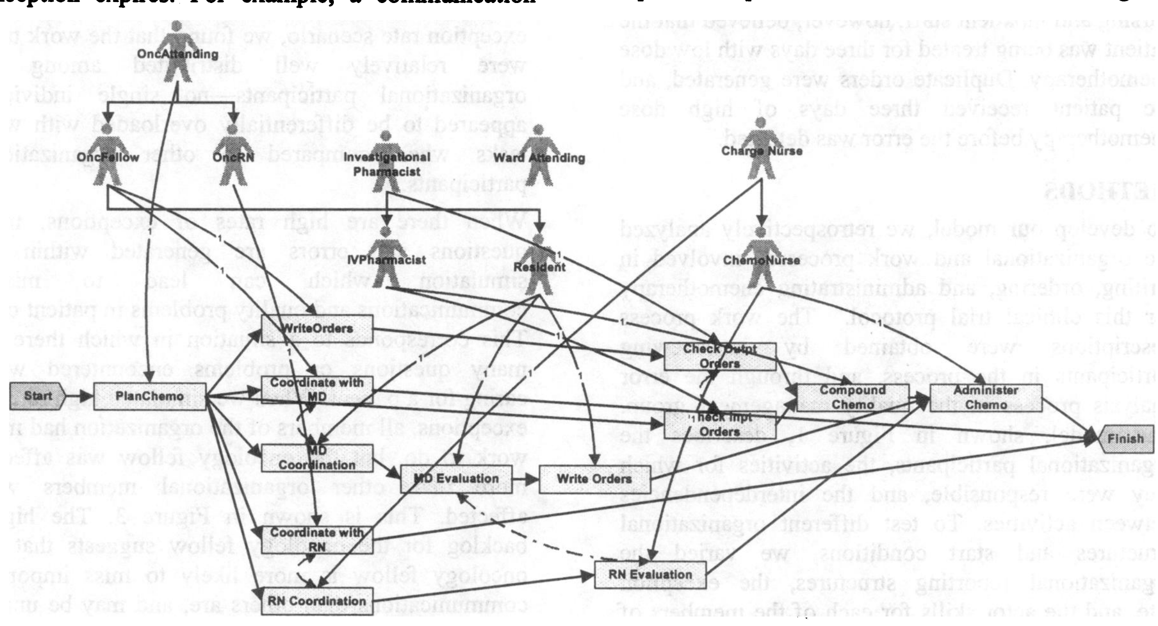

Figure 1. A model of chemotherapy administration. This work process model describes the administration of chemotherapy in an inpatient service. The oncology service is responsible for writing the orders and explicitly coordinating the inpatient care. Arrows between actors and activities define responsible-for relationships.

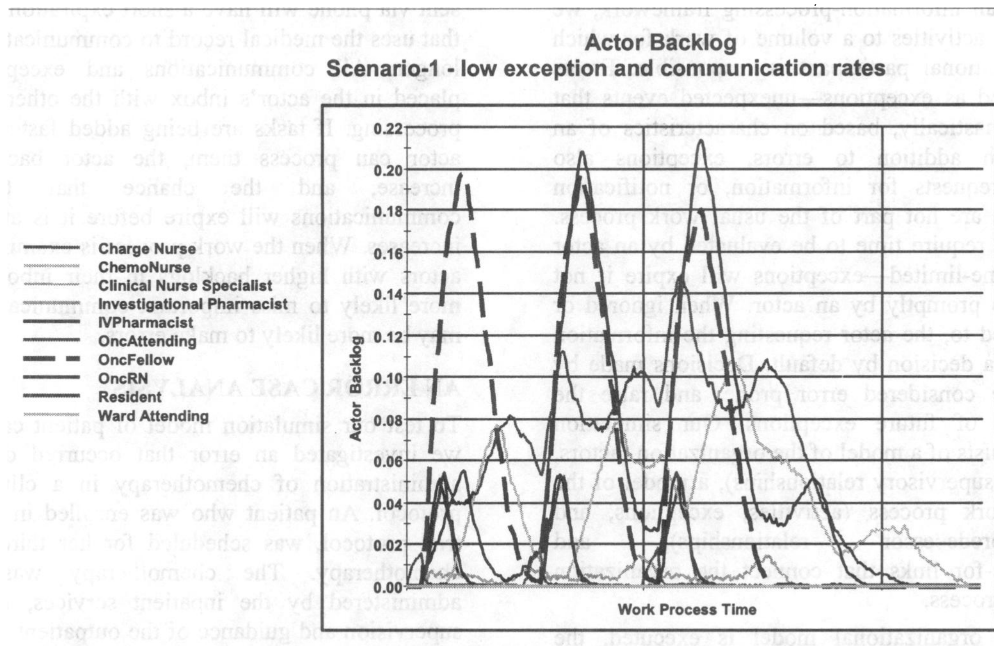

Figure 2. Actor backlog with low exception and communication rate. This figure shows the backlog for each actor in the model for three patients admitted to the hospital. The three peaks shown for the oncology fellow correspond to the time of admission for each of the three patients. No single actor is significantly backlogged.

oncology fellow as the principal coordinating agent in the organization.

In the case we examined to develop our model, the oncology fellow, believing the patient was on cycle three, wrote orders for high dose chemotherapy. The nursing and inpatient staff, however, believed that the patient was being treated for three days with low dose chemotherapy. Duplicate orders were generated, and the patient received three days of high dose chemotherapy before the error was detected.

METHODS

To develop our model, we retrospectively analyzed the organizational and work processes involved in writing, ordering, and administrating chemotherapy for this clinical trial protocol. The work process descriptions were obtained by interviewing participants in the process, and through the error analysis process in the quality management group. The model, shown in Figure 1, describes the organizational participants, the activities for which they were responsible, and the interdependencies between activities. To test different organizational structures and start conditions, we varied the organizational reporting structures, the exception rate, and the actor skills for each of the members of the outpatient team. Each scenario was stochastically simulated 100 times, and the results of each scenario aggregated prior to analysis.

RESULTS

Figure 2 shows the actor backlog when low rates of exceptions are used in the model. With low exception rates patient care is proceeding smoothly, and there are few problems that must be addressed. In the low exception rate scenario, we found that the work tasks were relatively well distributed among the organizational participants—no single individual appeared to be differentially overloaded with work tasks when compared to other organizational participants.

When there are high rates of exceptions, more questions and errors are generated within the simulation, which can lead to missed communications and quality problems in patient care. This corresponds to a situation in which there are many questions or problems encountered while caring for a patient. When we simulated high rates of exceptions, all members of the organization had more work to do, but the oncology fellow was affected more than other organizational members were affected. This is shown in Figure 3. The higher backlog for the oncology fellow suggests that the oncology fellow is more likely to miss important communications than others are, and may be unable to effectively manage or detect potential errors.

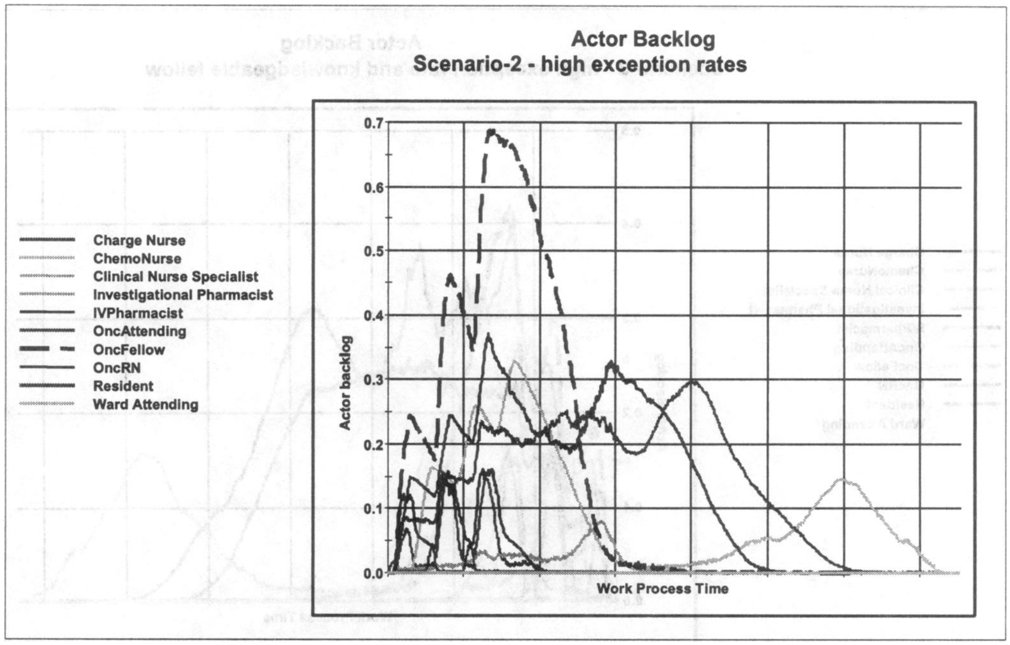

Figure 3. High rates of exceptions and communications. This graph demonstrates the effect of high rates of exceptions and communications on the actors in the simulation. In this scenario, the oncology fellow is affected more by the high rates of exceptions than other members of the organization. This suggests that when many exceptions occur within an organization, the oncology fellow is more at risk for overload and missed communications and errors.

We then examined alternative organizational strategies to reduce the differential burden on the oncology fellow. Adding a clinical nurse specialist, or changing the reporting relationships of the oncology fellow had little effect on oncology fellow's backlog. However, increasing the oncology fellow's knowledge about the protocol (and thus his speed and accuracy in the task), normalized the distribution of work within the organization, and suggests the oncology fellow would be more effective in managing and detecting errors. This is shown in Figure 4.

DISCUSSION

In this study, we modeled a work process that resulted in a medication error, simulated it at low and high exception rates, and analyzed which elements of the model were most likely to be overloaded and error-prone. The base case simulation reproduced the actual experience of the organization, and identified the oncology fellow as the person who, in the face of high levels of exceptions, was overworked more than other members of the team. Although the clinical nurse specialist was absent, the largest improvement in the oncology fellow's performance came with increasing her protocol knowledge, rather than adding the clinical nurse specialist into the work process.

Medical organizations use a variety of means to identify errors and improve patient care. The Joint Commission on Accreditation of Healthcare Organizations for example, is a mechanism to evaluate organizational performance. Unfortunately, the Joint Commission uses a retrospective evaluation of an organizational performance, and it is likely that poor outcomes have already occurred by the time that the problems are identified.

Organizational simulation however, allows managers to evaluate the "weak links" in their organization before problems occur, and identify potential solutions. In the pharmacy error example, we identified that improving the knowledge of the oncology fellow was more effective in reducing the oncology fellow's actor backlog than adding additional staff. This suggests that adding knowledge sources for the oncology fellow would improve her ability to resolve questions regarding patient care more efficiently and effectively than other interventions.

It is important to note that using these simulation techniques we cannot predict all the ways in which a process might fail. Perrow and other organization theorists would suggest that it is impossible to predict "normal failures" within an organization[10]. However, simulation can be used to prospectively test the parts of the organization or work processes that are most

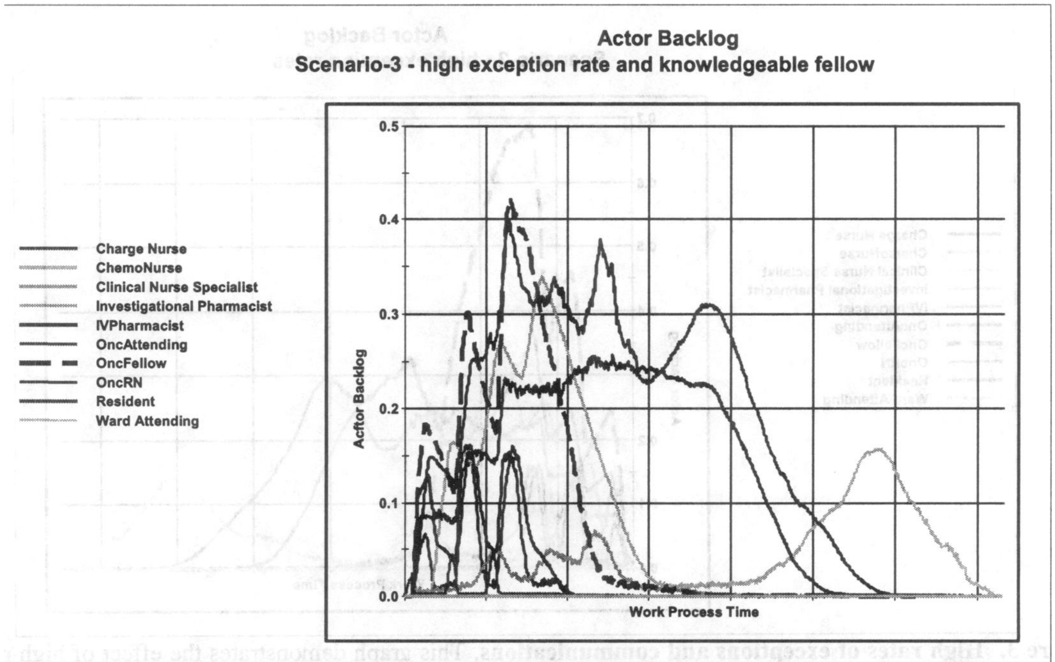

Figure 4. High exception rate with a knowledgeable fellow. In this graph, increasing the protocol knowledge of the fellow reduced the fellow backlog more significantly than adding a clinical nurse specialist to the organization.

prone to failure, and a way to explore alternatives to solve those problems. As an organizational "stress test", simulations that are based in organizational theory hold the promise to improve organization performance before catastrophic failures occur. Additional work is needed to test each of the input parameters and link them to real organizations. Further experience with simulations—both prospective and retrospective—will improve the usefulness of simulation tools, and provide another means of evaluation and testing of work processes within health care organizations.

ACKNOWLEDGEMENTS

This research is supported by a postdoctoral fellowship in Medical Informatics at the Veterans Affairs Palo Alto Health Care System, and by NSF grant number IIS-9907403.

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