Assessing Group Decision Support Systems for Emergency Response Using Gaming Simulation

by

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Abstract

In very low frequency, high-consequence events such as earthquakes or those resulting from malfunctions at commercial nuclear power generating facilities, one's experience with crisis events will certainly influence judgments and behavior. Written plans and procedures have been shown to serve the valuable purposes of training and familiarization for new organizations, individuals, and public officials. It has been demonstrated repeatedly that when emergency operations are conducted in accordance with existing plans, reaction time is reduced and coordination improved with fewer casualties, less property damage, and higher socioeconomic capability. These plans and procedures provide a normative model for simulation scenarios in the context of education and training activities. Such simulations can provide a field laboratory for evaluation of new technologies for training or for operational decision-making.

The purpose of this paper is to report on the design and use of a gaming simulation as a means of assessing one group decision support system (GDSS) for emergency response. We will review past work and focus on our recent experience conducting quasi-experiments to assess **E**mergency **M**anagement im**PROV**iser (EMPROV), a GDSS for improvisation in emergency response operations. The process of designing a gaming simulation, determining the experimental protocol, and coordinating the sessions with emergency response personnel from the Port of Rotterdam will be described. Finally, we conclude with suggestions on how to improve the benefit of gaming simulations for training and operations.

Keywords: emergency response, improvisation, decision support systems, gaming simulation

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Introduction

The objective of a response to an emergency is to minimize the negative consequences and insure that the emergency will not escalate into disaster. The events that trigger emergencies and the possibility of a disaster are difficult to anticipate and may have extremely high consequences to individuals and social systems. When these emergency events do occur, they place unique burdens, both new and expanded, on existing decision-making systems (1). These events also generate a feeling of crisis due to the lack of congruence between the between the available resources and the demands placed on the emergency response organization (ERO). However, these potential negative consequences may be mitigated and stress reduced, by timely, effective decision-making and implementation. Computer-based decision support systems have been found to be valuable aids in providing support for response activities.

Emergency response relies on one or more contingency plans. The proper execution of the plans is managed by a command and control center. A commander at the scene coordinates the activities of the units fighting the emergency. The on-scene commander and support staff gather and analyze data, make decisions, and monitor their implementation and consequences. The activities required to respond to an incident are dangerous and must be performed under time pressure (5).

Activation of emergency plans is based upon assessment of the potential impacts of an accident and the courses of action needed to eliminate or at least mitigate this impact. These contingency plans can rarely be executed as expected, as the case of the Exxon Valdez accident showed (11). Flexible approaches to emergency management are therefore required. Any such approach must be able to deal with an uncertain and changing environment and allow for revision of planned courses of action. Moreover, the approach must be able to support emergency managers in improvising when no standard operating procedure can alleviate the catastrophe (14).

However, both research and practical experience has shown that written plans and procedures serve the valuable purposes of training and familiarization for new organizations, individuals, and public officials (10). When emergency operations are conducted in accordance with existing plans, reaction time is reduced and coordination improved with fewer casualties, less property damage, and higher socioeconomic capability.

These plans and procedures serve as the “normative model” for education and training activities (16). In particular, they provide the model upon which simulation scenarios are based. In turn these simulation exercises provide a means for evaluating the plans and procedures. An additional and equally important benefit of such simulations is that they can provide a field laboratory for experimentation.

We were fortunate enough to participate in the serendipitous evaluation of a gaming simulation and found that the realism of the crisis environment was replicated both in terms of organizational responses and those of the individual (3). In our evaluation we collected data on a training exercise held by the U.S. Nuclear Regulatory Commission and the Federal Emergency Management Agency at the Robert A.F. Genet Nuclear Facility in upstate New York, USA. Four days after the simulation an actual incident occurred which involved the activation of all emergency response activities throughout the state. This provided us with an opportunity to evaluate the benefit of simulations. We found that the realism of the crisis environment was well replicated, both organizationally and its impact on the individuals. Stress levels were found to be similar between the simulation and the actual event. Communications were similar during the beginning of the crisis, but there were some differences during the latter stages of the exercise, in particular those decisions concerned with recovery. This we feel was due to the participants in the gaming simulation being aware of the need to end the exercise before the end of the working day.

There has been a strong move to develop and implement computer-based decision aids, decision support systems, as part of the response tools available to emergency managers (18). These decision aids contain emergency procedures, response equipment, and GIS/GPS capabilities, and may include models to provide additional decision support to process data and provide recommendations for emergency response courses of action. However, since emergencies themselves are infrequent and those emergencies that result in catastrophic impact, i.e., disasters, are extremely rare, evaluation of these decision support systems cannot rely on traditional means of systems analysis, design and assessment.

The purpose of this paper is to report on the use of gaming simulation as a means of assessing group decision support systems (GDSS) for emergency response. We will review past work and focus on our recent experience conducting quasi-experiments to assess Emergency Management imPROViser, a GDSS for improvisation in emergency response operations. The process of designing the gaming simulation, determining the experimental protocol, and coordinating the sessions with emergency response personnel from the Port of Rotterdam will be described. We will conclude with suggestions on how to improve gaming simulations in terms of both training and their use for testing decision technologies.

Gaming Simulations for Assessing Decision Aids

The use of experimentation has been touted by researchers in the social sciences – and criticized (10). Of particular concern was the need to ensure correct scientific conduct of the experiments. However, in order to make experiments realistic, the decision setting becomes so unique that it is extremely difficult to generalize the results. But in a laboratory study using, for example, students, the hypotheses postulated may not correspond to the phenomena actually encountered by the emergency manager. In addition, many times the emergency manager cannot control the events or activities that are controlled in a laboratory setting. Therefore, there needs to be a quasi-experimental approach that does provide where possible, statistical power, but also enables one to generalize to a variety of emergency response settings.

We have conducted experiments to assess decision support technologies in field settings. For example, we tested decision aids for:

- transporting hazardous materials with truck drivers at a training facility (7),
- emergency medical personnel at an emergency operations center (4),
- advising air commanders on targeting with air force officers at an air base (13), and
- computer diagnostic personnel at a support center (12); and

- piloting vessels in close waters at a training facility (9).

One approach to assessing group decision support systems to use existing training programs, for example, those at U.S. Federal Emergency Management Agency Training Institute (FEMA) at Emmitsburg, Maryland, USA. The participants in these programs are typically emergency preparedness personnel from offices throughout the U.S. These training programs typically use or are every amendable to the use of gaming simulations.

The FEMA facility was used to assess a decision aid designed to provide support to emergency managers called upon to respond to an incident at a nuclear power generation facility (2). We were able to get 32 managers to participate in a three-hour evening session. Based on biographical information from the participants, we designed a quasi-experimental setting by assigning them to each of four groups with two of the groups using the decision support system. The simulation involved the assignment of roles typical to that of an emergency-operating center; for example, "county director of disaster preparedness" was one of the roles. The participants all had experienced emergency situations. They were able to note deficiencies in the decision support system and yet did recognize its usefulness. We found statistical evidence to support our hypothesis that the decision aid did contribute to better decision-making. In addition to the small size of our samples, i.e., approximately 8 in each group, we found the group to be very homogeneous in terms of age and educational background. The technical experience of the group in terms of prior computer background was modest. We did find that approximately half of our subjects had at least one tour of duty in the military. Those characteristics are probably true of most emergency managers in the U.S. at that time, early 1980's.

Advances in multimedia and other human-computer interface technologies such as virtual reality are providing the capability to replicate environments found in actual crisis situations (17, 8). However, at the present time, developing and implementing such environments is expensive and time consuming.

An Illustrative Example: Assessing a Group Decision Support System with Emergency Responders at Port of Rotterdam

As noted, emergency response organizations (EROs) must have the flexibility to be able to deal with contingencies that are not addressed by emergency plans and procedures. These contingencies may be due to unforeseen occurrences or just the overwhelming nature of the event. Our present research is addressing this issue by providing a group decision support system, Emergency Management improviser (EMPROV), to support EROs in improvising; that is, to rework their knowledge in a novel way in time to fit the requirements of the current situation. In this section, we will describe the design of a gaming simulation held in a training facility in the Port of Rotterdam; a previous presentation and paper described the logic embedded in EMPROV (14).

The elements of the decision making process of an ERO are as follows. Knowledge is typically divided among various experts and decisions are often routed through the commander of the

ERO, who is responsible for selecting and assembling posted actions; and solutions or recommendations are typically broadcast for discussion to the group as a whole. All this takes place in a stressful, time constrained setting.

Quasi-experiments were conducted at two training sites at the Port of Rotterdam in The Netherlands. In order to conduct the experiments properly, all material and communications had to be translated into Dutch, the participants' native language. This required close and frequent collaboration with port management and with numerous assistants to ensure accuracy the translations. Upon completion of the experiments, all native-language data (e.g., audio and video recordings, computer logs, questionnaires, meeting notes) were professionally translated into English and transcribed before being analyzed.

Participants in the experiments met in a room designed to resemble the portable field office, know as the Command Center at the Scene (CCAS), used during emergency responses, which require coordination among numerous port services. The CCAS is staffed with one representative from each of the services involved, as well as a commander responsible for coordinating these services. The CCAS is typically equipped with portable phones, radios and supporting information such as chemical hazards manuals and phone books. For the experiments, participants convened in the round and had access to a flip chart, scratch paper and individual laptop computers (the introduction of laptop computers is seen as the next phase in the development of the CCAS). In addition to containing software for decision support, these computers were used to send messages to participants and to store their responses. During the experiments, only participants and one audio/visual technician were present in the experiment room. All experiment personnel were in a separate room out of participants' view.

Participants

A vital component of this research is the inclusion of experienced emergency response practitioners as session participants. Voluntary participation was solicited by port management officials through an internal memo sent to individuals from key emergency management services within the port. In addition to the role of commanding officer (CO) of the group, there were five roles to be filled, as follows: (1) Police Department: PD; (2) Fire Department FD; (3) Chemical Advisor CA; (4) Medical Officer MO; (5) Port Management PM.

A large number of personnel expressed interest in participating; thirty-nine actually participated. With some exceptions, an individual from the respective service filled each role. These exceptions arose in last minute, sometimes harrowing, situations. At least two scheduled individuals could not participate since they were involved in responding to an actual emergency. Similarly, during another session one of the participants had to leave the group and communicate by phone with field personnel responding to an actual emergency. When less than six participants were present, the group decided amongst themselves who was to take on an additional or substitute role. An example of taking an additional role occurred in session one, when the CO took on the roles of CO and CA. An example of taking a substitute role occurred only once, in session four, when a member of Port Management acted only as CA and not as PM.

In total, there were nine sessions, six of which are included in this analysis. The excluded sessions either had too few participants (sessions 3 and 6) or was somehow rendered inadmissible as data (session 7).[1] The following table summarizes participation in the experiments.

Table 1: Summary of Experiments

Session	Group Number	Group Size	Participants	Support?
1	1	4	CO+CA, PD, PM, FD	N
2	2	5	CA, CO+MO, FD, PD, PM	N
3		2	PD+MO, PM+FD+MO	N
4	3	5	PM as CA, FD, PD, CO+MO, PM	Y
5	4	6	CA, CO, FD, PD, PM, MO	Y
6		2	PD+MO, PM+FD+MO	Y
7		5	CA, CO+PD, FD, PM, MO	Y
8	5	4	CO+MO+CA, FD, PD, PM	Y
9	6	6	CA, CO, FD, PD, PM, MO	Y

In questionnaires submitted at the conclusion of the experiments, participants described their qualifications. On average, participants had 19.4 years of experience at the port. Experience in actual emergency responses was fairly high (groups two and four each had a member who reported having participated in over 100 emergency responses). Group 5 was the least experienced judging by these measures. Groups 2 and 4 perhaps had the most experience. However, no group averaged less than 11 years' experience with the port – an important characteristic for our research.

Procedure

Participants were welcomed to the training facility, thanked for their participation and shown to seats in the experiment room. A trainer from port services and a coordinator from the research team each spoke to the group. The trainer emphasized that the format of the experiment would differ from that of the training sessions to which all were accustomed. This was necessary since the trainer anticipated that participants would expect their customary format. The trainer then left the room and the coordinator discussed the elements of the computer interface, allowed participants to manipulate the interface then answered any questions. The introduction concluded once participants seemed to be comfortable with the interface and could perform the requisite tasks for manipulating it (i.e., typing and mouse-clicking).

Participants were then told that they had been called in as consultants to another port on an emergency situation. They were also told that all information available to them would be presented on-screen, but that they might occasionally receive additional messages. They were shown a countdown clock on the wall (also shown on their laptop screens) and told to monitor

[1] In Session 7, a miscommunication between experiment personnel and participants resulted in a non-participant being present in the experiment room and influencing participants' decision making.

the time remaining. The experiment began when each screen was set to the case description and the countdown commenced. The coordinator left the room at this point.

Each group solved two cases and each case had two phases. In phase one, participants were told only to plan for the activities necessary to address the emergency and were given 10 minutes to do so. At the conclusion of phase one, participants were given further information about the unavailability of certain resources and the availability of certain alternative resources. As phase two began, the time-constrained element of the experiment was introduced: participants were told that activities had to be *planned-for* and *completable* within 50 minutes, at which time an event with potential for catastrophic impact was anticipated. A scale on the map allowed participants to estimate the travel time between points on the map. Given the nature of the phase two-time constraint, it was essential that participants account simultaneously for planning and execution times.

Participants worked on each phase until it was completed or until time ran out. If participants completed a case before time ran out, the audio/visual technician signaled the coordinator to enter the room.

At the conclusion of phase two of each case, participants evaluated their decisions. Once both cases had been solved, participants filled out a final questionnaire concerning their qualifications, the design of the system and their satisfaction with group processes. Finally, the trainer and the coordinator conducted an informal debriefing with the group. The debriefing was intended to elicit participants' opinions in a less structured way.

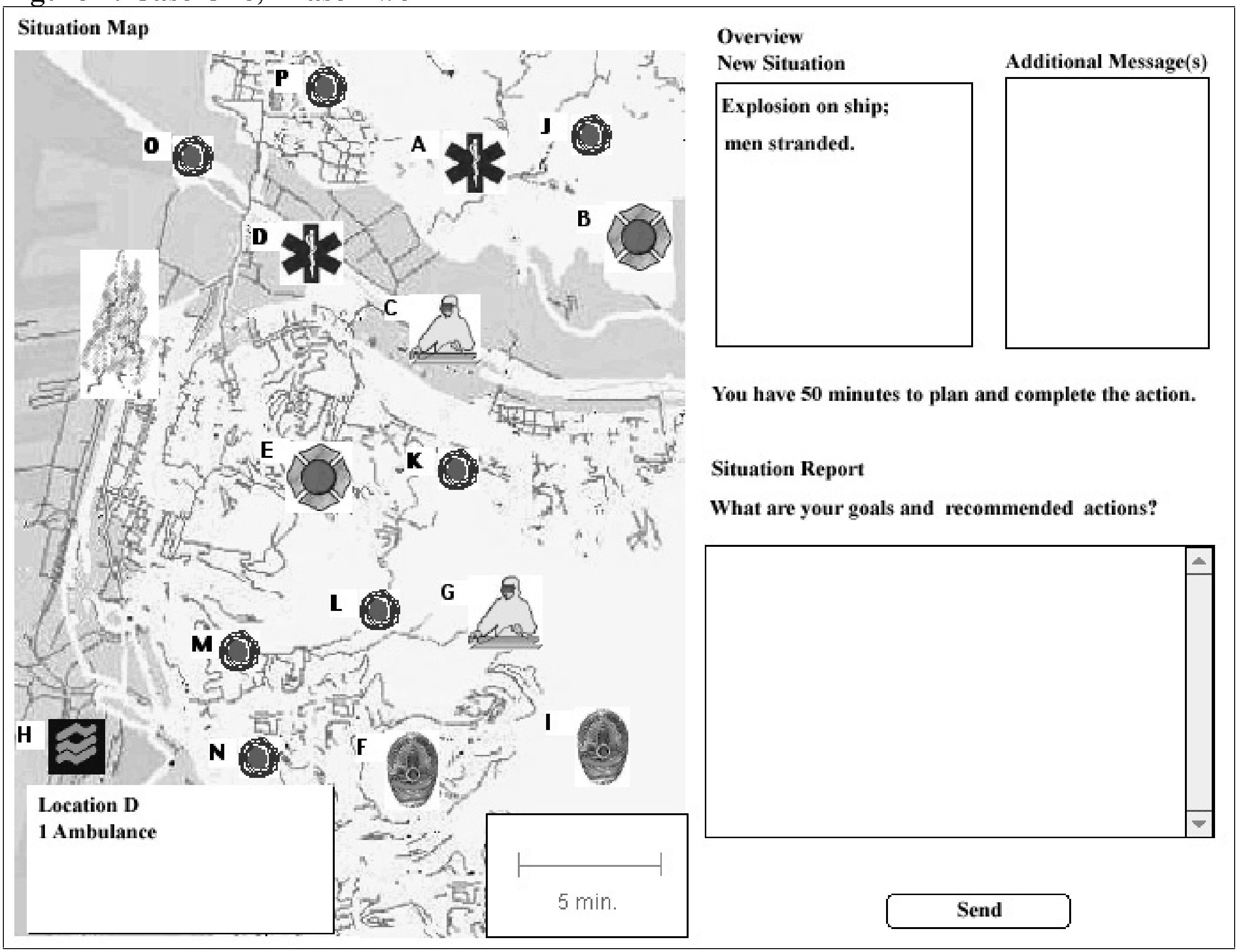
Cases

In designing the cases, we sought to create plausible stories around problems that were relevant to participants' expertise but not specific to the Port of Rotterdam. After consulting with port personnel, two logistics problems were developed. The problems involved mobilizing resources under time constraints and risk and required participants to share information. Each case was designed for the six roles mentioned previously.

In phase one, participants planned a response using standard resources: that is, resources typically controlled by the services themselves. Participants were told they had ten minutes within which to plan the response. On-screen information consisted of a map, a scale, the sites where resources were held, the organizations responsible for those resources and certain messages. Messages and site information varied according to role. So, for example, FD received information from fire department had submitted a solution.

In phase two, the coordinator told participants that some standard resources had become unavailable but that other, non-standard resources were available. Additionally, messages to the group specified constraints that could not be satisfied using standard resources. Therefore, groups had to improvise in order to satisfy the constraints. Non-standard resources were those not typically controlled by the services themselves (e.g., a gymnasium at a high school) and were visible to all participants. Participants were informed that the situation threatened to escalate if actions could not be completed within fifty minutes. Therefore, as discussed previously, participants during phase two had to account both for planning and execution times. The phase one and phase two interfaces differed only in that messages had been updated to reflect the new situation and in that sites having alternative resources had been added. A view of the phase two interface from the first case is given in the following figure:

Figure 1: Case One, Phase Two



Decision support was provided only during phase two. Supported groups had visual displays and were given recommended procedures, which had to be assembled to form a solution. Unsupported groups received no assistance aside from visual displays.

Preliminary Results and Discussion

The two assessment questions concerned the effectiveness and uniqueness of group solutions: the first is whether supported groups provide more effective solutions than unsupported ones; the second is whether supported groups' solutions are more creative.

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Preliminary Results and Discussion

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The first measures of goodness relate to planning and execution times. It is assumed that groups strive to solve the problem as quickly as possible (that is, to minimize planning time) and to bring resources to the scene as quickly as possible (that is, to minimize execution time, at least until the first response). Planning time is defined here as the time between a group's receiving the problem definition and the CO's submitting of a solution. At the start of phase two, each group was given 50 minutes in which planning and execution activities could occur. Consider a group that submitted its plan at the end of the tenth minute. Approximately 40 minutes would be available for executing this plan. *Planning* time for the group (that is, the amount of time spent by the group in developing the actions before submitting them to field commanders) would be 10 minutes. If all actions could be completed within 34 minutes (i.e., the *max* time used below), then the *slack* in the plan would be 6 minutes. The time to complete the shortest task is denoted *min*: this is the time until the first resource arrives at the incident location. *Total* time refers to the utilization of resources in executing the plan (i.e., the total amount of resource-minutes). So, if the group proposed only two activities—a fire truck traveling 10 minutes from its station to the incident location, and a police car traveling 34 minutes from its location to the incident—then the value of *total* for this group would be 44 resource-minutes. The following table summarizes average planning and execution times for unsupported and supported groups.

Table 2: Planning and Execution Times

		Unsupported	Supported
Case 1, Phase 2	*max*	34.0	33.5
time allotted = 50 min.	*min*	14.5	15.5
	total	94.5	159.3
	planning	16.5	22.8
	slack	-0.5	-6.3
Case 1, Phase 2	*max*	24.5	29.5
time allotted = 50 min.	*min*	7.5	6.5
	total	82	115.25
	planning	26	19.75
	slack	-0.5	0.75

where

max = time to completion of last task (minutes),
min = time to completion of first task (minutes),
total = total time spent on tasks (resource-minutes),
planning = time spent on developing the plan (minutes) and

slack = time allotted – *max* (minutes).

In case one, groups two through five had negative slack times; in case two, groups two, four and six had negative slack times. However, the results suggest that supported groups required less time to plan for each minute of activity, as indicated by differences in *total* time between supported and unsupported groups (the difference is significant only for case two, with p=0.09).

To assess solution creativity, participants were asked to assess organizational improvisation for their actions as a whole in each case. Each group's level of expertise in addressing phase two of the each case was also assessed but no appreciable differences were found between unsupported and supported groups. Similar results were found when an outside evaluator familiar with port operations answered the same questions. These preliminary results suggest that groups were approximately equal with respect to organizational knowledge.

Organizational improvisation questions asked group members to assess the extent to which the submitted actions were improvised. The following table summarizes responses to the organizational improvisation questions (15).

Table 3: Self-evaluation of Organizational Improvisation with Respect to Phase Two Actions

	Case 1		**Case 2**		
Question	**Unsupported**	**Supported**	**Unsupported**	**Supported**	**Question Topic**
					Rate the Action
1	3.4	4.0	3.2	3.8	1. Figured out the action as we went along — 7. Action followed a strict plan as it was taken
2	3.9	3.4	3.0	4.1	1. Improvised in carrying out this action — 7. Strictly followed our plan in carrying out this action

Differences between supported and unsupported groups were not statistically significant. However, the responses to these questions suggest that supported groups felt less strongly than unsupported groups that they were improvising.

Concluding Comments

How can we measure and assess the "performance" of a group decision support system in a gaming simulation? There are two components of the assessment: the performance of the technology and its impact on the group decision processes. We would like to understand how the technology affects the group processes even if its performance in terms of "better" decisions is not demonstrated. Since many decisions are influenced by factors outside of our control, having a more efficient and effective group decision making process may be as valuable as “better” decisions.

A variety of data can be collected prior to the simulation, subject only to the patience of the participants. Biographical data are certainly available – and may be needed for designing the experiment. We have collected data on cognitive style for example, prior to the exercise and used the results to design our experiment. However, it is important not to deluge the participants to an extensive battery of questionnaires because it may create apprehension, alter their behavior or magnify the lack of realism of the simulation.

Unobtrusive measures for data collection by the computer can be devised to record the activities engaged in by the participants. All communications can be routed through the computer or logs kept of phone messages, including recording sender, receiver, length of message and content. These data can be collected for each sample run and categorized in a variety of ways. The participants will communicate with outsiders, or with insiders who are not part of the experiment, but are with the training group.

Measures can be built into the exercise such as recording time and measuring the difference between the times an event was initiated and the appropriate responses made for the degree of correctness. Every initiated event can have a set of appropriate decisions that should be made.

In addition to maintaining a record of the activities of the participants in the game, many times simulations lend themselves to observation. The participants in the exercise can be observed in a very structured manner with pre-designed questionnaires to be completed by trained observers. These observers can be debriefed after the gaming exercise for their assessment of the appropriateness of the decision aid.

Videotaping can be used, but usually needs to be electronically transcripted for analysis – resulting in a great deal of qualitative data which may require extensive effort to analyze. Various techniques such as protocol analysis has been found useful for research purposes, but the benefits of their use must outweigh the costs since they are so time consuming. Behavioral coding of group interactions can be done both in real-time or from the videotapes. Here training of the coders is crucial.

After the simulation run, participants can complete self-reporting questionnaires. These can be done as part of, or immediately after the activity, and recorded on the computer. The participants can also be asked to describe and rate each other’s behavior on a variety of dimensions. Participants can also be asked to record their interactions with each other during the course of the exercise. Both preceding and following the exercise, interviews can be conducted with each of the participants.

The degree of realism of a game is extremely important, not only from the point of view of evaluating the decision aid per se, but in maintaining the interest and enhancing the educational benefits of the simulation. Such validity can be easily ascertained by having experienced emergency managers walk through the simulation prior to the actual exercises. The practicality of using gaming simulation depends on the situation. Simulations are being used in training facilities for emergency response organizations and are often mandated by oversight government agencies. The question of practicality is important if one is going to design a simulation specifically to evaluate a particular decision support system.

The last and perhaps more complex is the question: do participants treat the simulation as realistic? We found that there was some in-game playing in that the recovery activity in the simulation we not compared with the real event did taper off; in fact it ended dramatically at 4:00 p.m. (3). This was not obviously the case with the real event. However, it has been our experience that simulations can be designed as learning experiences and that the participants understand that training is very important as a precursor to the possibility of managing an actual emergency. Therefore, gaming simulations have the potential for assessing a decision support system and its impact on the group it is designed to support.

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