The Worst that Can Happen: Creating Realistic Emergency Management Scenarios

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ABSTRACT

In the typical scenario development process, learning objectives center on performing tasks according to established procedure. However, emergency managers must make effective, life-saving decisions in fast-paced, rapidly changing, ambiguous, and uncertain situations while acting within legal, cultural, and social constraints. High-stakes critical incidents are infrequent, thus decision makers seldom have opportunity to gain real-life experience. Instead, they gather experience through simulated exercises that immerse the learner in authentic, realistic situations. Generating realistic, cognitively relevant scenarios that meet the often-conflicting objectives found in emergency events requires a combination of psychological research methods and instructional design practices.

In this paper, we present our methodology for creating management level emergency scenarios for a computer based, multi-player simulation-training program using a combination of standard instructional design practices, Cognitive Task Analysis (CTA) and computer-based scenario development techniques. We discuss the use of CTA to capture the macrocognitive functions and processes decision makers use in actual events, the analysis of this data to understand critical decision points, actions, and strategies, and the transfer of this information into a computer-based multi-agency training simulation. We will discuss a project in which we designed scenarios to exercise emergency managers who respond to airport emergencies. The goal of this work, sponsored by the Airport Cooperative Research Panel (ACRP), was to streamline decisions, improve communication between and within agencies, and increase effective response during critical airport incidents.

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INTRODUCTION

In classic instructional design methodology, learning objectives are directly linked to assessment, thus evaluating learning effectiveness is a straightforward process. In an immersive learning simulation (ILS) however, human reactions take nearly endless forms, making assessment a challenge. In addition, the content for the learning objective is not merely a set of facts; instead, the scenario should embody the objective implicitly. For example, when scenario developers train participants to mitigate an aviation hazard, they do not simply *tell* a player the signs of a possible hazard. They must present the cues that indicate a hazard and then construct pathways to determine if the player recognized these cues and effectively mitigated the situation. In the typical scenario development process, learning objectives center on performing tasks according to established procedure. Generating realistic, cognitively relevant scenarios that meet these often-conflicting objectives requires a combination of psychological research methods and instructional design practices.

High-stakes critical incidents are infrequent, thus decision makers seldom have opportunity to gain real-life experience. Instead, they gather experience through simulated exercises that immerse the learner in authentic, realistic situations. Training using realistic simulations provides learners with the opportunity to experience the time-pressure and uncertainty encountered in actual events. They must deal with ambiguity and information overload, continually interpret changing conditions, and make decisions with incomplete information while acting within legal, cultural, and social constraints.

To benefit from simulations, learners must experience the consequences of their decisions, thus simulations should provide feedback by reacting to the learners actions. This feedback should include both positive and negative consequences to each action, allowing learners to weigh and evaluate for themselves the costs and benefits of the actions they choose.

In this paper, we will describe a process to capture the critical cognitive components of emergency response, incorporate instructional design to maximize learning, and create realistic training scenarios for emergency managers from multiple agencies (see Figure 1). To do this, we will present our methodology for creating management level emergency scenarios for a computer based, multi-player simulation-training program using a combination of standard instructional design practices, Cognitive Task Analysis (CTA) and computer-based scenario development techniques. This paper is novel insomuch as it presents the synthesis of guidelines used to develop cognitively authentic scenarios for high-fidelity simulation-based architectures. Unlike with low-fidelity simulations, high-fidelity simulations are complex with multiple facets and interactive components. Often the cognitive complexities of real-life are not adequately represented in high-fidelity simulations. We have taken the complexity out of designing/developing simulation-based content by presenting a streamlined methodology that incorporates findings from CTA with basic instructional design concepts to create a high-fidelity simulation environment.

We will present this information by using as an example a project, named AEROS (Airport Emergency Response Operating System) in which we designed scenarios to exercise emergency managers who respond to airport emergencies. The goal of the AEROS project, sponsored by the Airport Cooperative Research Panel (ACRP), was to streamline decisions, improve communication between and within agencies, and increase effective response during critical airport incidents.

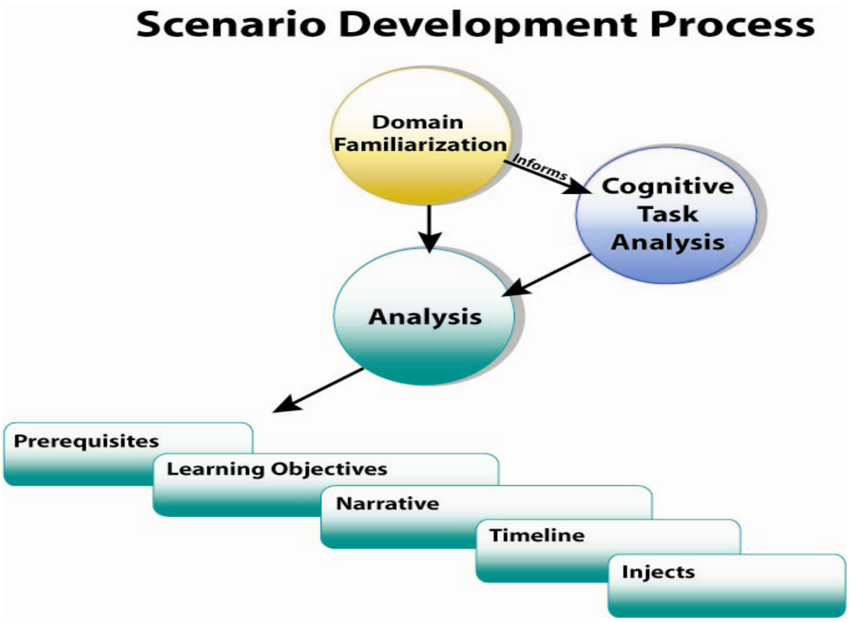

Figure 1. The scenario development process

SCENARIO DEVELOPMENT PREREQUISITES

Domain Familiarization

The first step in generating a scenario-based simulation that enhances the decision-making of emergency managers is to understand the demands of their position. We need to know the physical tasks and procedural demands placed on emergency managers from each responding agency, and we need to understand the cognitive demands present in high-stakes command environments. These responders can only achieve proficient task performance by mastering both the physical and cognitive demands placed on them. The physical tasks present in emergency operations centers (EOCs) and incident command (IC) are different from emergency personnel who respond directly to the scene. Live and computerized scenarios often focus on those who respond directly to the emergency. The personnel who manage the incident for their agencies are often located away from the actual incident.

Their physical demands include lack of sleep, group coordination, keen observation, and heightened alertness. The stimuli they deal with include such things as incoming phone calls and e-mails, listening and responding to staff, calling for and attending meetings, responding to demands from commanders, and fielding requests from other agencies. It is from these physical stimuli that the cognitive demands arise. Thus, a cognitively relevant training scenario should include physical demands, and environmental cues that place typical cognitive demands on the learners.

The cognitive demands in emergency command situations include activities such as sensemaking, decision-making, judgment, planning/replanning, and problem solving. These cognitive demands drive the course of the physical actions decision makers take in response to events. Decision makers must make sense of emerging situations, identify feasible courses of action, and change plans in response to changing situations in order to accomplish the mission. Simulations should provide learners the opportunity to take a range of actions, including actions typically taken by inexperienced decision makers along with the actions experience decision makers tend to make. To understand typical novice actions, we review procedures, policies, and literature associated with the domain. It is not feasible to embed all possible action choices into a scenario; however, by reviewing the documents familiar to novices, a scenario developer can include the likely procedural responses. Less experienced decision makers tend to make decisions that follow procedure and are less apt to break procedure to take novel actions. Experienced decision makers, on the other hand, tend to make fluid decisions in response to changing situations. These decisions do not necessarily follow procedure, but are extremely effective in resolving situations (Klein, Phillips, Rall, & Peluso, 2007). While document, policy and procedure reviews provide the possible actions of less

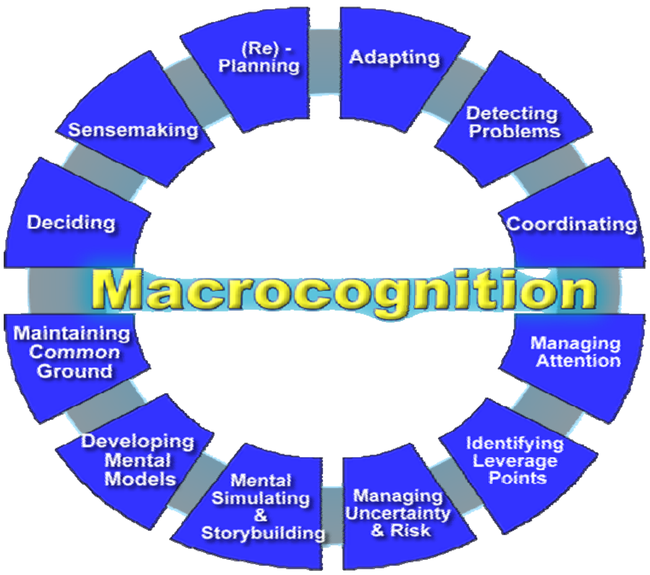

Figure 2. Macrocognition Wheel

experienced decision makers, to understand the possible actions experienced decision makers might take in a given situation, more complex knowledge elicitation is required.

Cognitive Task Analysis

To create realistic training scenarios that address more than standard procedures, scenario developers need to know the tough decisions, critical tasks, strategies, and common errors that occur in actual incidents. We gather this information by asking individuals experienced at handling critical incidents in the domain of interest. When creating multiple-player training for participants from diverse agencies, it is important to understand their individual roles, but also how their individual tasks interact with the tasks of other responders. These interactions are important for creating scenarios that demonstrate the consequences of working in, or not in, collaboration with other agencies.

A key to developing cognitively authentic scenarios is to provide learners the opportunity to engage in the macrocognitive functions and processes that challenge them in real life. Macrocognition is a term used to describe the cognitive functions used to perform tasks in natural, rather than laboratory, environments (Figure 2). These macrocognitive abilities develop with experience. Thus, we gather from experienced decision makers descriptions of what they must accomplish at a cognitive level, these make up the cognitive functions, such as sensemaking, planning, and problem detection. From this, we identify the cognitive processes that allow the decision makers to achieve the tasks, such as mental simulation, managing attention, and identifying leverage points. This allows us to incorporate realistic stimulus into training scenarios (Crandall, Klein & Hoffman, 2006; Klein, et al., 2003).

We use CTA to understand the cognitive complexities of a domain. CTA is a set of tools and methods used to elicit general and specific knowledge about the cognitive skills and strategies that underlie performance (Crandall, et al., 2006). CTA allows researchers to gather knowledge that goes beyond procedural knowledge and tactical level response.

In the AEROS project, our goal was to understand the difficulties airport emergency commanders face when making decisions in multi-agency emergency response environments. We used a CTA interview protocol created for this project that combined Knowledge Audit (KA) methodologies with the probing questions often used in the Critical Decision Method (Crandall, et al., 2006; Klein, Caldwood, & MacGregor, 1989). Our objective was to identify critical tasks, challenges to coordination efforts and response, and cues and factors that contribute to effective response in the airport emergency domain. We also needed to clarify current training needs and gaps in responder training to airport critical incidents. We asked participants to identify decision skills that need enhancing and training scenarios that would benefit command-level critical incident training. We interviewed experienced command-level airport personnel and emergency commanders from local fire and police agencies. The purpose of the interviews was to “get inside the heads” of airport emergency responders to understand the cognitive maps that guide their decision-making processes. These maps are agency specific, but intertwine to varying degrees within the EOC and IC. We needed to understand this interaction to create a multi-player simulation.

Through the interview sessions, we gathered information about how emergency managers view their environments, and what critical cues, expectancies, and goals they require to make good decisions. Participants discussed topics such as, when/how they determine to set up the EOC, how they gather, sort, and filter the continuous stream of information, their processes for gaining situational awareness, and how they coordinate with other agencies within and outside the EOC.

Decision or Judgment	Why Difficult	Cues/Factors	Strategies	Novice Errors
1. Establishing effective lines of communication	◊ Mutual aid responders use different communications ◊ Difficult to receive communication from IC out in the field		◊ With centrally located IC, can visually see where to go w/o need for communications	◊ Don't know how to communicate differently with different players
2. Determine the most practical location for the incident command center	◊ A place families can get to ◊ Finding a safe area for responders to land/park ◊ Limited staff on hand ◊ Responders can't get to site	◊ Soft ground ◊ No clear landing spot ◊ Roadways blocked ◊ Night/weekend reduces staff	◊ Put IC in a spot where incoming responders can see out lights ◊ Position the Mobile Command Center where it is visible	◊ Not familiar with operations ◊ Not familiar with layout of airport, how to get to a particular site
3. Which areas need critical response first	◊ Deciding who gets medical	◊ Heavy damage ◊ Injuries ◊ Roof collapse ◊ Gas leak	◊ Prioritize the most critical areas ◊ Direct incoming responders to the most critical areas	◊ Doesn't bring in different players to help make decisions

Table 1. Decision Requirements Table Example

These experience-based interviews elicited experiences from participants in order to extract critical decision points and reasoning behind various action choices. Decision makers are not always aware of this information at a conscious level; therefore, we use interview techniques that use cognitive enhancement techniques that support verbalization of tacit knowledge (Klein 1998). Questions in the KA incorporate cognitive techniques that promote interviewees' ability to access and report tacit rather than declarative, or procedural, knowledge (Klein & Militello, 2000). By providing a context based on individual experiences, the interviewers have context in which they can frame questions and participants have actual experiences to draw on for their responses. We asked participants to recount challenging emergency events they faced previously.

Analysis

When analyzing qualitative data, researchers categorize information, starting with large categories and refining down into smaller sub-categories (Strauss & Corbin, 1998). We use this technique to identify the critical points within an event and then to understand the critical tasks, decision points, and strategies used to deal with these critical points. Interview transcripts are reviewed to find data points for decisions or judgments, special difficulties, cues, strategies employed (whether effective or not), and common novice errors. We organize this data in decision requirement tables (DRTs). The categories represented in DRTs include:

- Decision or Judgment
- Why difficult
- Cues and Factors
- Strategies
- Novice Errors

This analysis usually produces many consistencies across participants. Participant consensus provides a guide for creating accurate scenarios. From the DRTs, we can make a variety of data comparisons. For example, we group the DRTs by role and evaluate for within-role consistencies and differences. Table 1 provides an example excerpt from a DRT created in the AEROS project.

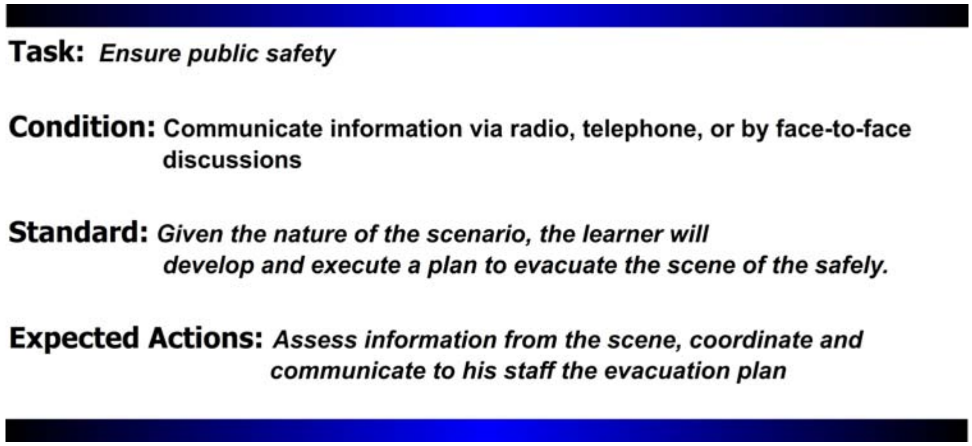

Figure 3. Example of a Command-Level Task, Conditions, and Standards with Expected Actions

INSTRUCTIONAL DESIGN TO CREATE SCENARIOS

Learning Objectives

During the scenario design phase, we use learning objectives to define and measure the actions we expect learners to take given direct or indirect instruction. Learning objectives guide scenario developers in the overall planning and delivery of the content. Learning objectives have three major components:

- *Tasks* are a description of the actions learners will perform
- *Conditions* are criteria for measuring how the tasks will be performed
- *Standards* are guidelines for how the tasks should be performed

The tasks, conditions, and standards (TCSs) provide a method for aligning the learning objectives with the overarching goals of the scenario and for clarifying measurement standards. TCSs provide scenario developers a metric for determining if the learning objectives are realistic, attainable, and appropriate for the level of the learner.

Simulating wide-ranging and complex events can quickly become unmanageable. Each decision made in a scenario may or may not have a set of consequences. The complexity of the scenario makes enumerating all possible paths unreasonable, thereby limiting allowable decisions. The TCSs help track and drive the decisions and actions that should be present in the simulation. They also allow the system to evaluate players against a set of expected actions. Scenario developers can embed prompts to guide learners toward the expected actions. TCSs also guide simulated entities to perform the expected actions of humans in those roles. Careful programming of simulated entities allows learners to conduct simulations, regardless of how many players are available, or from what agencies.

In Figure 3, the command-level *task* is to ensure public safety. The *condition* establishing how to accomplish this task is to communicate information to his/her staff via radio, telephone, or by face-to-face discussions. The action (or inaction) as well as the latency between stimuli presentation and action are recorded by the simulation system and presented in an after-action review report to the learner at the end of the simulation. The *expected actions* comprise the evaluation conditions that indicate overall simulation results.

Before creating scenarios, developers must define the actions that players may take to accomplish a task. This information is contained in an expected action. Teams or individual players can perform expected actions using one command, multiple commands, or one command from a set of several viable options. For example, a task to obtain situational awareness of an incident appears while playing in the simulation. The expected actions involve multiple commands, such as to seek out information sources such as news stories, emails, and telephone calls, in order to piece together the segments of the situation and gain a better overall understanding.

From the DRTs in the AEROS project, we determined that a critical decision for EOC Commanders is when to stand up the EOC. The learning objective for this decision is: Upon learning of an airport incident that meets the criteria for establishing an EOC, the learner will take appropriate action to stand up the EOC. Some expected actions programmed into the simulation include:

- ✓ Use telephone or radio to call in staff to operate the EOC.
- ✓ Ensure that EOC staff has liaisons who communicate with their counterparts in the field.
- ✓ Anticipate and expedite the delivery of resources by creating a plan for several hours out (i.e., 12 hours).
- ✓ Task a note-taker to ensure flow of and access to information, by posting relevant information on white board.
- ✓ Task the Public Information Officer to set up phone banks for public inquiries.

If learners do not take expected actions within a specified timeframe, an event will occur to remind them that an action is required. Reminders come in as they would in real world situations, such as an e-mail request or a radio call from staff. There may also be a severe consequence such as loss of life or exacerbation of the disaster. These reminders allow learners to discover what actions they should take and when they should take them. From this feedback, they learn to recognize when situations call for certain actions before they reach critical points.

Bloom's taxonomy states that there are three fundamental learning domains: Cognitive, Psychomotor, and Affective (Bloom, 1956). For the purpose of the AEROS project, we developed the learning objectives from key decision points in the DRTs that focus on the cognitive domain. These decision points become the body of the learning objective while the verb(s) used in the learning objective indicate the learning level and action of the user. For instance, a learning objective from the decision point, "stabilize the scene" as shown in the DRT presented in Table 1 may look like the following example:

Identify a location for the incident command center that responders can locate easily and access readily.

The tasks, standards, and conditions are identifiable from the DRT and in the learning objective itself, along with users' interactions with the simulation. For example, the *task* in the above learning objective is: choose a location for the incident command center. The *standard* is quality of the location, as indicated by how easily and readily responders can locate and access the incident command center. We determine the standards using the information in the Strategies column of the DRT. If the user does not choose an acceptable location, the scenario will present consequences, such as responders reporting inability to locate or access the incident command center. The information in the Why Difficult and Novice Error columns of the DRT determine the consequences we present to the users. The *condition* indicates how users accomplish the task while interacting with the simulation. For example, use of diagrams, maps, weather and road conditions to determine where to put the incident command center.

The Narrative

Using the information derived in interviews, we designed the scenario narratives. Each narrative is a story that presents a logical and consistent picture of past and future events. In order to immerse the learner into to the scenario, it is important that the ILS design have real-world relevance to the user. This real-world relevance comes from three dimensions of immersion:

- ➢ *Spatial Immersion* (Response to Setting): this is the "hook" that relates to the learner's past memories to help develop an intimate relationship to the setting.
- ➢ *Temporal Immersion* (Response to Plot): past events cast shadows on the future and restrict the range of what can happen next. This is how we experience suspense. Suspense increases as the range of possibilities decreases and this is when the learner can reach a state of complete temporal immersion.
- ➢ *Emotional Immersion* (Response to Character): this response occurs fundamentally as the learner begins to form attachment with the characters within the simulation.

To immerse learners, scenarios must tell a captivating story with action that grips participants and engages them in the learning process. Scenarios should begin by presenting general characteristics of the event and environment. As situations progress, information and events reveal more detail about the event, enabling learners to construct a story about the situation. Actual emergencies place severe time-pressure on decision makers, and so should simulated events. There should be enough time pressure so that a "sit and wait" response is *not* an acceptable course of action. Adding chaos or information overflow can increase the feeling of time pressure. However, too much time pressure exists if learners can only make knee-jerk reactions that prevent them from assessing situations and thinking out responses.

Similar to time-pressure, a certain amount of uncertainty is necessary to create a scenario that

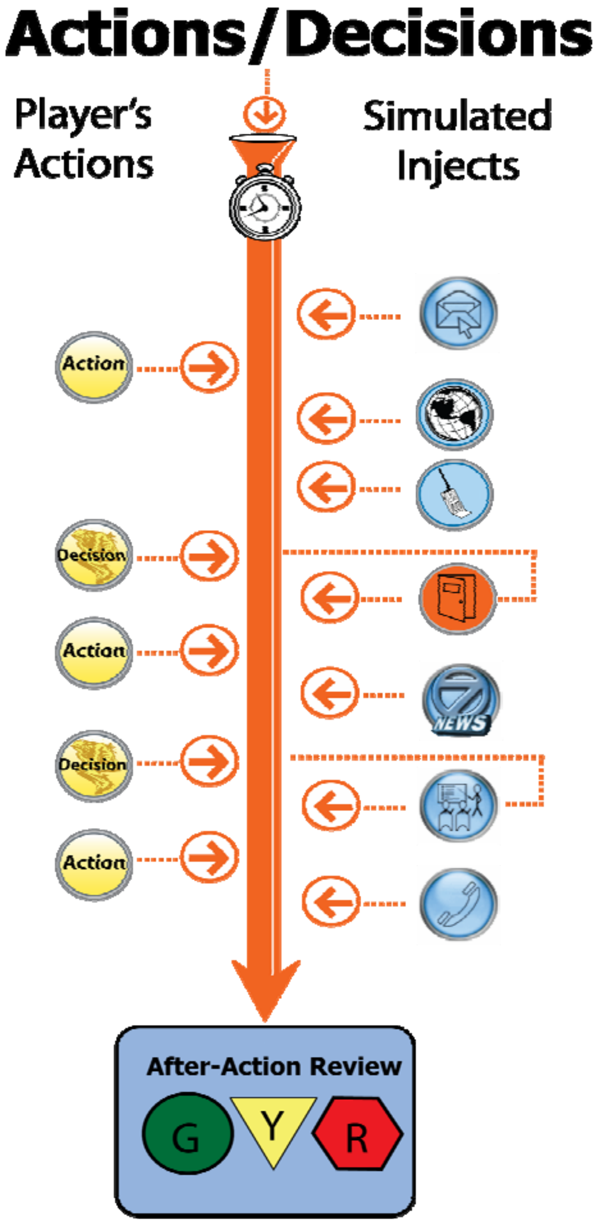

Figure 4. Interplay of Injects, Actions, &Decisions.

mimics real-world emergencies where much is unknown. If learners know everything about the event, such as current and future weather conditions, all responder reactions, the location of all victims, all potential secondary hazards, etc., it creates an unrealistic and simplistic scenario with little opportunity for learning. A reasonable amount of uncertainty enhances scenarios and allows for multiple interpretations of the situation, and variation in action choices. It is vital that scenarios contain multiple acceptable courses of action. Rarely in real situations is only one course of action acceptable. Rather, many actions will suffice to resolve the situation in a satisfactory manner (Simon, 1990). At the end of scenarios, learners should feel like they have been sitting in "the hot seat" where they must react even though they do not have a clear idea how to react. A good scenario forces learners to make tough decisions throughout the incident, rather than one incident ending decision (Harris-Thompson, et al., 2004).

Timeline Formation

Once the scenario narrative is complete, a high-level scenario timeline is developed. Timelines provide brief descriptions of major events and segments that take place in the scenario. They provide a guide for scenario developers to organize detailed injects within the scenario. Each major event poses an opportunity for players to encounter new challenges and take action(s) that will affect exercise outcomes.

For example, in our sabotage scenario involving a disgruntled, recently terminated airport fuel tank driver, the employee's termination causes him to become extremely angry and storming out the office making threats. The high-level timeline lays out these cues, which prompt players to take actions such as filling out an incident report or alerting security to have a heightened awareness of high-risk targets.

Within each high-level event, injects prompt the tasks and present corresponding conditions and expected actions. This forms the basis for assessments reported in the after action reviews (AAR). The AAR indicates player's responses based on a multi-colored assessment scale. The color green indicates that the player met the assessment criteria and expected standards for completing the task. Yellow indicates the player met the assessment criteria and expected standards with prompting from simulated entities. Finally, red indicates the player failed to meet the assessment criteria at the expected standard.

Inject Development

Injects are the driving components of simulations, allowing learners to perform tasks. Once scenario developers establish learning objectives, narrative, and a general timeline, they begin to create injects that adhere to the narrative and timeline. Several elements are important to consider when developing injects:

- *Time*: inject occurrence on the timeline
- *Type*: inject form (email, phone call, fax, live conversation, video, etc.)

- *Content*: body of information conveyed to the learner
- *Responders*: participants the information is conveyed to and from
- *Feedback*: standardized responses to the injects/stimuli
- *Consequence*: positive and negative actions of responding to an inject

It is critical to develop well written, authentic injects that compel learners to make decisions and take actions during the simulation. For instance, if the learner is presented with an email inject and content of the email body is too ambiguous or does not use proper domain verbiage, the learner may or may not respond to the stimuli, thus compromising the original intent of the inject. Linking negative or positive consequences to injects is also important. For example, if the learner does not perform a task and there are no repercussions (e.g. follow-up email notification from a superior) then the learner will fail to recognize the necessity of the task and will not complete the task objective.

Injects, along with their associated tasks, should allow learners to gradually gain insight into the nature of the scenario (Davis & Kahn, 2007). Injects should provide learners with the opportunity to expand their experience base and ability to structure information as it is collected. In addition, well developed injects allow learners to focus and comprehend the situation and enables them to assess events and reflect on actions.

Several questions to consider when developing well designed injects include:

- Does the inject provide multiple representations of reality and avoid oversimplification of instruction by representing the natural complexity of the world?
- Does the inject present an authentic, contextualized picture that mimics day-to-day operations?
- Does the inject provide real world, case-based learning, rather than pre-determined instructional sequences?
- Does the inject support collaborative construction of knowledge through social negotiation, not competition among learners?

CONCLUSION

This paper describes a systematic process for transferring the experience-based knowledge of emergency responders into a realistic computer-based training simulation. Transitioning actual experiences to simulated events is a challenge for scenario developers, but our procedure provides a systematic process that takes into account both the cognitive aspects of an event along with the key instructional design components that insure learning occurs during training.

In our AEROS project, we created a training simulation, to train management level responders. The cognitive challenges faced at this level differ from those faced by on-the-ground tactical responders, thus the simulated environment must be different. Information is present on the scene of an emergency that is not immediately available to emergency managers. By representing this challenge accurately in a scenario, emergency managers receive training to enhance the skills they need during real-world emergencies. Similarly, creating scenarios that take into account the interactions between multiple agencies, allows diverse sets of responders to train together, determine where collaboration is necessary, and learn what the needs and requests of other agencies will likely be during emergencies.

This process is applicable across many domains, such as military and business domains, where mid- and upper-managers must make time-pressured decisions. Seasoned decision makers in these domains bring experience-based knowledge to their fields and it is possible to capture and embed these experiences into training. However, training will only be effective if developers incorporate the components that foster learning into the training. Simulations will only promote learning if scenarios contain realistic environmental and cognitive components, and present engaging stories that present real decision challenges and tasks. This process brings a level of realism based in solid learning design that provides learners with experiences they can take with them as they confront real world emergency events.

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