Playing at Planning: Game Design Patterns from Disaster Response Practice

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ABSTRACT
We draw on years of ethnographic investigation into the disaster response practices of fire emergency response, urban search and rescue, and incident command to inform the design of games. Our objective is to support training disaster responders, yet our findings apply to general game design. We identify critical components of disaster response practice, from which we develop game design patterns: EMERGENT OBJECTIVES, DEVELOPING INTELLIGENCE, and COLLABORATIVE PLANNING. We expect that, in implementing these patterns, designers can engage players in disaster-response-style planning activities. To support the design patterns, we survey exemplar games, through case studies. The paper contributes a set of game design patterns that support designers in building games that engage players in planning activities.

ACM Classification Keywords
H.5.3. Group and Organization Interfaces: CSCW

Author Keywords
Game design; disaster response; ethnography; planning.

INTRODUCTION
A primary component of disaster response is *planning*, which is carried out by multiple individuals who each bring varied expertise and skills [14, 15, 30, 37, 38, 65, 69]. Plans, especially in large-scale disasters, must account for unseen changes and unknown variables, optimizing deployed resources. While existing games use planning as an activity, none feature disaster-response-style planning or use it as a core mechanic. Instead, fast-paced action, distributed emergent planning, and perfect information proliferate. We see an opportunity to develop games to help responders practice effective planning activities through games; thus the present research begins a new research agenda in this space.

The present research develops support for disaster response training games, building on our earlier work-in-progress [63]. Drawing on years of ethnographic observation of training practice of fire emergency responders (FERs), urban search and rescue (USAR) operatives, and incident command (IC) teams, we identify planning activities. We draw these fields together, collectively as disaster response, observing that they are characterized by emergent objectives, the development of intelligence, and collaborative planning, which we develop into game design patterns. We then connect the patterns to existing games, through brief case studies, identifying new areas to develop gameplay. The paper contributes new game design patterns, enabling designers to build games that engage players in planning activities, either to support disaster response training, or, simply, for fun.

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Scope
The present research is situated in the United States, and the findings are thus focused on practice in this region. Disaster response practice is different, but not wildly so, in other countries. Further reading on practice in other countries may be found in [8, 9, 14, 36–38].

Reporting Conventions
In the present research, we include a Ludography that, like the References section, reports on the games that we use as part of our case studies. Games from the Ludography are cited prefixed with a "G". Design patterns are identified by Alexander et al.'s [4] convention of SMALL CAPS.

Paper Outline
We next develop background that addresses collaboration, disasters, and games. We then describe our research activities and observation sites. As our main emphasis, we present and synthesize evidence from our observations to develop game design patterns. To illustrate the patterns and point to future opportunities, we present case studies of exemplar games that make use of planning, and close with discussion around the value of the developed patterns.

BACKGROUND
In this section we provide background on distributed cognition, collaborative sensemaking, disaster response, and games. Distributed cognition is our lens for understanding disaster response work practice. Our ultimate goal is to support training games to engage collaborative sensemaking. We briefly discuss game mechanics, gameworlds, and game design patterns.

Distributed Cognition

Distributed cognition theory describes cognitive processes as spread among individuals and artifacts as they mutually interact [25, 27, 28]. Information relevant to a task is represented in multiple forms, such as (shared) mental models, the physical environment, and information artifacts. Workers transform information to transition it between forms, enabling information seeking activities and sensemaking. Workable forms are communicated through physical and computational media, facilitating information transfer. Distributed cognition serves as a basis for understanding disaster response work practice.

Collaborative Sensemaking

A basic necessity in any incident is for responders to work in teams as part of a distributed cognition system to make sense of a situation and make decisions. Team coordination through shared mental models and situation awareness, sensemaking, and information seeking are key to success.

Team Coordination

Teams are a collection of actors, who have different assigned roles, and who collaborate and share information [49]. Teams organize their activities in order to avoid mutual interference and synchronize effort [1]. *Shared mental models* support teams in working together efficiently, enabling implicit and non-verbal communication through the use of artifacts, reference signs, and deep understanding of team activities [20, 26, 31, 40, 65].

Mental models enable individuals to predict future states of dynamic systems by mentally simulating processes and outcomes [17, 33]. *Shared* mental models occur when team members have compatible mental models that predict similar future states. This supports team coordination, reducing the costs of communication (i.e. *communication overhead* [40]) and aiding the team in achieving its objectives [41, 49, 59]. Shared mental models are fostered through careful communication among team members and contribute to effective team *situation awareness*.

Situation awareness is the ability to comprehend a complex situation and predict its future states [10–12]. A high level of situation awareness supports decision making, enabling an actor to identify one or more correct courses of action. Awareness is critical in distributed teams where team members must inform one another of personal status. In order to move from individual situation awareness to shared situation awareness, individuals need to take into consideration each teammate's understanding and perspective of the situation, and work collaboratively together to reach a shared mental model.

Sensemaking

Weick defines *sensemaking* as a social process performed in order to understand a situation and make decisions [74]; it is an ongoing collaborative process of understanding a situation through creating meaning, situation awareness, shared mental models, and mutual understanding of different individual perspectives [1, 73, 74]. The need for sensemaking arises in shifting environments, when new challenges, opportunities, and tasks are emergent [2, 48].

Sensemaking is often a social process [74]. Teams of different backgrounds, established or temporary, need to work together in order to make sense of critical situations. The outcome of sensemaking in teams can be affected by their team skills [29]. Each team member needs to have the knowledge and skills to work with other teammates in order to contribute productively [7]. This argues for a great need to investigate new ways and methods to contribute to the training of disaster response teams in order for them to be able to effectively work together.

A substantial body of research has studied the importance and methods of sensemaking in a number of contexts, including command and control [1–3, 29], collaborative information seeking [44, 45], education [47], organizational science [74], and team training [22]. Those studies together identify sensemaking as a process through which people collect, frame, and interpret information in order to understand a situation and make effective decisions.

Information Seeking

Information seeking is an essential part of the process of sensemaking [62, 74]. It involves collecting, filtering, processing, authenticating, and interpreting information in order to extract what is needed in order to understand a situation [1, 3]. The need to understand and make sense of the abundance of emergent information is central to making reliable decisions, therefore, the quality of information is measured by its completeness, correctness, currency, accuracy, and consistency [1]. The use of information visualization techniques (e.g., interactive maps) supports sensemaking [14, 52, 61], allowing teammates to easily share information.

Disaster Response

Disaster response comprises a large and complex set of activities to mitigate the effect of an incident. The term *incident* refers to "An occurrence, natural or manmade, that requires a response to protect life or property...." [69, p140]. Incident command (IC) is a set of activities that involve developing and executing plans in response to disasters and is the primary way that response is organized.

The National Incident Management System [69], accounts for how incident command structures form and disband for incidents of varying scale. For small-scale incidents (e.g., a single house fire), a lone Incident Commander makes all high-level decisions and provides direction. The same system specifies more complex hierarchies to manage large-scale incidents (e.g., multi-state wildfires), which may have a Unified Command at top and federated branches to handle aspects of response. As the need for incident response declines, the system specifies how the structure reduces its complexity.

According to the National Incident Management System, a complete IC team (e.g., one for the most complex incident) consists of the following branches: Operations, Planning, Logistics, and Finance / Administration. The branches (along with additional command staff that are not a part of any branch), report to either a singular Incident Commander or a Unified Command group. Commanders make high-level decisions with input from the branches and the command staff.

Operations converts the high-level decisions into specific objectives that can be accomplished by deploying, directing, and communicating with teams of responders. Planning gathers information and develops plan recommendations. Logistics manages supplies and equipment. Finance / Administration accounts for the costs of the response.

Crisis Informatics

Crisis informatics is an interdisciplinary area of study that focuses on how information and communication technology is used in emergency response [5, 57]. It is centered around the social, technical, and information aspects of a disaster [21]. In an incident, responders, volunteers, and non-government organizations closely collaborate together on-site and online in order to effectively coordinate humanitarian assistance to those affected [18, 56, 58].

Applying technology to crisis mapping through the use of mobile communication and social media empowers disaster responders [43, 54]. Digital volunteers are able to communicate helpful information to those who are on the ground [56]. The dissemination of geospatial information about affected areas through social media and disaster management systems helps responders, volunteers, and the general public gather data, yet sensemaking to get support to the right places at the right times remains a challenge [42, 52].

Disaster management systems enable information technology support. Such systems have been used to effect crowdsourced response to incidents. Disaster management systems are of interest in the present research primarily for their map-oriented designs. Ushahidi[1] [16] and Sahana[2] [53] are web-based applications that enable collecting and visualizing information. Social media reports can be used directly on map-based interfaces to enhance situation awareness [71] and disseminate information and direct citizen response [52].

Game Design Patterns: Game Mechanics & Gameworlds

Salen and Zimmerman characterize games as systems of *rules* and *play* [50]. Rules are the structures that constrain player action, rendering it meaningful. Play is the freedom to make decisions within the scope of the rules. A *game mechanic* is a moment at which a player makes a choice and observes the outcome [35, 50]. *Core mechanics* are the essence of a game, and are engaged with repeatedly. Game mechanics of digital games are fundamentally and deeply connected to user interfaces. The term *gameworlds* refers to game environments, constructed through rules, that players experience as a UI [34].

Game design patterns connect game mechanics and gameworlds in support of analyzing and designing games [6]. Design patterns support the creation of games and develop a vocabulary with which to analyze them. Each pattern consists of a name, a description, an explanation of using the pattern, consequences of using the pattern, and a set of relations to other patterns (e.g., "can implement", "may conflict with").

In the present research, we combine existing design patterns with our observations and our prior work [63] to develop new patterns. A deep discussion of the individual game design patterns (of which there are over 500, each with a multi-page description) is beyond the scope of this paper. For details on particular game design patterns we discuss, we direct the reader to Björk's wiki: http://protagonist.sics.chalmers.se:1337/mediawiki-1.22.0/index.php.

As in physical-world team coordination, communication is a key element of collaborative gameplay. Teammates communicate using voice, supporting fast-paced team action [60, 72]. At the same time, games offer direct support for coordination through *cooperative communication mechanics* that do not rely on voice or text chat [39, 64, 70]. By using cooperative communication mechanics, players can more easily identify elements of the gameworld and synchronize their actions.

Games / Simulations for Training

Prior simulations and/or games for training primarily address decision making, team coordination, and sensemaking. The Distributed Dynamic Decisionmaking simulation [55] is an open-source command-and-control training simulation where participants solve problems in ambiguous situations by collaboratively managing resources. The C3Fire simulation [19] is a training environment focuses on team decision-making and team situation awareness with a focus on managing resources on a map. The generated task environment allow participants to co-operate in order to complete a specific mission, such as extinguishing forest fire. The authors' *Team Coordination Game* [68] supports players in learning how to communicate and coordinate in a gameworld. While developed from our work on fire emergency response, characteristics of the real world are not captured, focusing learning on team skills. *Levee Patroller* [22, 23] is a single-player training game in which a player must find levee failures in a region and report them in a timely manner. This game is designed to target the Dutch water authorities in order to help them make sense of risks and develop decision-making skills.

Prior research primarily addresses non-disaster planning through urban and tactical planning. In urban planning simulation games (e.g., *SimCity* and *SCAPE*), players learn decision-making processes through engaging in city planning, risk assessment, and transport challenges [46]. Tactical planning assists players in dealing with uncertainty, intelligence, and decision-making [24].

DISASTER RESPONSE WORK PRACTICE

The present research is developed from years of observation by author Toups at the world-renowned disaster response training facilities operated by the Texas A&M Engineering Extension Service. Our focus is on IC, an activity that occurs in all disasters and at all scales. The complexity of IC activities vary, scaling with the scope of a disaster.

The present work synthesizes data from multiple observations of various disaster response practices. We use distributed cognition as an analytic lens to understand the information-centric activities and coordination that take place. We build on our prior work with FERs [63, 65–68], while adding new insights from a previously unreported extended observation of USAR and IC practice. While we focus on IC, we bring

[1] https://www.ushahidi.com/

[2] http://sahanafoundation.org/

in other "boots-on-the-ground" perspectives from operatives practicing in the field. Observed activities include firefighter live-fire training and classes, elite USAR teams practicing full-scale exercises, and a multi-day simulation of IC.

Here, we describe the observation sites, research activities, and observed practice for each disaster response domain. Collected evidence is presented in a synthesized form in the next section.

Fire Emergency Response Burn Training

Our initial (and previously reported [65–68]) observation concerned fire emergency response (2007–2010), including participant observation of classroom time with FER recruits, inside and outside live-fire burn training simulations, and discussions with expert emergency responders. Student responders undertook high-fidelity simulations of fire response, including use of apparatus[3] and radio. The objective of this project was to understand the communication practices of FERs, to drive game-based training.

Observation Site

The observation site includes the world's largest (as of 2010) collection of live-fueled training props: Brayton Fire Training Field[4] [51] in College Station, Texas. The burn training sessions were undertaken in and around props that simulated residential, commercial, and industrial buildings, as well as vehicle fires. These environments are developed to mimic physical-world locations and are constructed of fire-proof materials. Facility personnel use specially formulated fuel, as well as dry hay, to create conditions that simulate building fires. Victims are simulated using weighted dummies (for unconscious victims) or instructors in turnout gear (for conscious victims). Students effect response against real fires with real firefighting equipment, including apparatus, turnout gear and air packs, hoses, and hydrants.

Research Activities

Data presented here are derived from five burn training sessions[5] that were observed from outside the building, and three from inside, over the course of the observation period. For the outside sessions, the researcher primarily observed the Incident Commander, but was free to move and observe from multiple angles. Outside sessions were video recorded.

For the inside sessions, the investigator was equipped with turnout gear and guided by an experienced firefighter. No recordings were taken in the inside environment, which, according to the guide, would reach 1,200°F, and so was inhospitable to recording equipment. The investigator recorded observations after the experience.

Observed Practice

In the observations, students took on all FER roles: firefighter (i.e., an FER that searches a burning building, puts out fires, etc.), driver/engineer (i.e., an FER that maintains the apparatus, manages equipment, and otherwise provides outside

[3]"Apparatus" refers to the vehicles used in fire emergency response, such as fire engines and ladder trucks.

[4]https://teex.org/Pages/about-us/teex-brayton-fire-training-field.aspx

[5]Our previous work reports only on the first three observed burn training sessions.

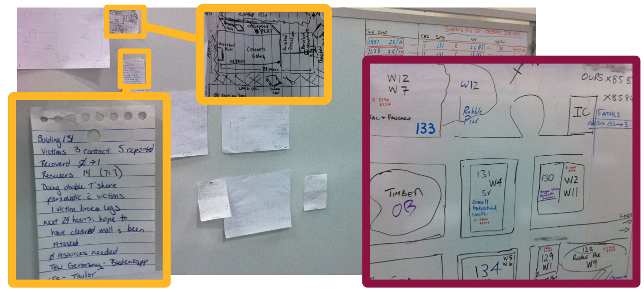

Figure 1. Planning artifacts at Multi-National USAR Exercise (October 2011). Background shows whiteboard with planning sheets and a resource-tracking chart. Left insets are taped to board: a diagram of a building (top) and plan notes (bottom). Rightmost inset is from another whiteboard, showing a drawing of the entire operation area; each rectangle is a large building and notes describe details of the area.

support), and Incident Commander. Students in the Incident Commander roles directed fellow classmates on how to fight the fire and how to search for and rescue victims. The Incident Commander was responsible for allocating resources at the scene. Upon completion of the response effort, the commander and expert instructors would run a *hotwash*, reviewing what went wrong and what went right, supporting learning. Such practice is common even outside of training.

Urban Search and Rescue Full-Scale Exercises

A second set of observations concerned USAR and took place during 2010–2012 at Disaster City[6] in College Station, Texas. In these observations, author Toups was embedded at a USAR training facility and undertook day-to-day interactions with the staff, many of whom were part of Texas Task Force 1, a combination state / US federal-level elite USAR team [15]. In addition, author Hamilton observed one of the described exercises. The purpose of this work was to understand the future role of information technology in disaster response and develop interventions for its use.

Observation Site

Disaster City is a USAR training facility that features highly realistic props; it consists of three main areas for simulations. This excludes a range of classrooms, as well as facilities used for actual operations that may be temporarily used for simulations.

One space is the Technical Skills Training Area, which provides individual props designed to hone specific skills, such as shoring and breaching walls. This area is not normally used as part of a full simulation, but for practice.

A large-scale specialized simulation environment mimics a combination of offices, homes, and commercial properties and the buildings are designed to appear as physical-world collapsed structures of an appropriate scale (including a three-story office complex with parking garage). Each building features slots for *breach plates*, interchangeable steel and concrete blocks, on which operatives practice using concrete saws and jackhammers to access inner spaces. The operational area is approximately four city blocks.

[6]https://teex.org/Pages/about-us/disaster-city.aspx

Finally, an Emergency Operations Training Center offers a location that serves as the base of operations in a simulated response. It provides a meeting space with information technology to support incident command.

Research Activities
During the observed practices, the researchers split time evenly between the simulation area and the simulated base of operations. They moved throughout the simulation area, taking notes and photographs and discussing activities with idle responders. As many activities take extended periods of time to complete, the observers circulated among the parallel activities, checking on progress.

Observed Practice
The investigators observed two multi-day USAR training exercises in the simulation environment. The first exercise involved an international assortment of teams from the USA, England, Germany, Belgium, and others, collaborating in the Multi-National USAR Exercise (October 2011). In the other, Texas Task Force 1 met for its annual training exercise (April 2012). Both simulations represented a large-scale disaster over four city blocks of indeterminate cause undertaken in a high-fidelity environment.

USAR operatives were tasked with gathering intelligence, shoring walls, and breaching buildings to rescue victims played by local volunteers (Figure 2).

Figure 2. USAR operatives breaching a rubble pile during the full-scale exercise (April 2012). After analyzing the structure for the safest entry point, the team has begun jackhammering concrete to access the interior.

Incident Command Simulation
Author Toups participated in an Enhanced Incident Management System simulation (June 2011). He took on the role of a student, and worked in different IC branches during the simulation.

Observation Site
The observation site for this component consisted of a large room set up to run the simulation in the Disaster City Emergency Operations Training Center. Groups of desks, each with a computer and phone, were set up for each of the IC branches. The Plans and Operations sections had access to large whiteboards. Three projected displays showed information on the status of a computer-simulated incident, unfolding in real time, showing the locations of deployed resources and problem areas. Finally, a side room was used for meetings with the heads of each branch.

The simulation was composed of special software and human operators and actors. The software managed the map and disaster simulation (e.g., realistically moving resources to specified locations, tracking the spread of damage). Human operators control the simulation, specifying how it changes over time in response to the players. Actors, expert responders with decades of experience, played remote boots-on-the-ground responders (and other humans with which the Incident Command Post would have contact, such as local officials), providing simulated reports from the field and accepting directions from the command post staff.

Research Activities
The investigator was a participant observer in the IC simulation. During the scenarios, he took on assigned roles in different sections, including Plans, Operations, and Logistics. The researcher took notes on experiences and observations, primarily in the downtime between simulations. In addition, he took notes on the instructors' lectures. No photographs were collected.

Observed Practice
The IC simulation educated responders and officials from across the USA and across disciplines and work roles. The IC team, the students, were 40-strong and assigned roles in the Incident Command Post.

Each simulation scenario represented an extreme incident that had happened some hours prior. The scenarios are designed to be challenging for a coordination center with about 40 members. The first three scenarios were half-day events, while the last scenario was played over a full day. The scenarios were as follows:

1. **Train Wreck**: A train carrying hazardous materials has derailed and collided with an oncoming passenger train; the resulting toxic cloud is blowing toward the local state fair.

2. **Stadium Attack**: During a major sporting event, a terrorist crashed an aircraft into the stands; the aircraft contained radioactive material.

3. **Tornado Strike**: A heavily populated town has been struck by a tornado.

4. **Airport Bombing**: At a major international airport, two bombs have been detonated on passenger planes waiting to take off; the state of the airport is presently unknown.

GAME DESIGN PATTERNS FOR PLAYING AT PLANNING
In this section, we present our data and synthesize it, developing design patterns. Based on our data from disaster response training practice, we observe that planning is characterized by DEVELOPING INTELLIGENCE, EMERGENT OBJECTIVES, and COLLABORATIVE PLANNING.

Each subsection includes a design pattern description that follows Björk et al's [6] conventions of a description, using the pattern, consequences, and relations. The relations components are not exhaustive.

Sensemaking by Developing Intelligence
IC develops the concepts of information and intelligence (I&I), a concept that also materialized in the USAR component of

this work. *Information* can be collected from any number of sources, but may be false. *Intelligence* is information that has been vetted and confirmed. Thus, intelligence is more reliable and actionable.

The role of I&I is to drive sensemaking and provide intelligence to Command, Plans, and Operations. Activities include information seeking to gather details and ensure accuracy, triangulating unknowns, and/or finding prior ground truths. I&I work is a distributed cognition environment, in which information is translated into usable forms, synthesized from multiple sources in multiple forms. Sensemaking in I&I work forms the basis of the DEVELOPING INTELLIGENCE design pattern.

Evidence

In USAR, I&I work was heavily connected to search, where teams of operatives need to report back findings to the base of operations. Returned data is transferred to paper maps and resource-tracking cards, in a distributed cognition process. Much information in the USAR simulations began as locations with speculation as to what might be found (e.g. chemical weapons, expected victim locations), which drove searches.

In conversations with USAR experts, we learned that there are challenges with redundancy in collecting information. As reports come in, they may be from multiple sources, but describe the same problem. The result was the unnecessary expenditure of resources to check the same victims multiple times.

A key component of I&I is the *red slice* of the pie chart of information. Information in disaster response consists of three categories: known, known unknown, and unknown unknown. This last category, the red slice, is the most dangerous. Discovering the contents of the red slice requires that IC staff constantly gather data by talking to one another, collecting remote data, investigating reference material, and otherwise undertaking research during the incident.

Information management in IC uses the intelligence cycle (which is further documented in the US military's *Joint Intelligence* [32]) involves the following five steps:

1. **Identify** essential elements of information (EEI), focusing attention;
2. **Collect** and centralize information as guided by EEI;
3. **Process** information to systematically document it;
4. **Analyze** information collected, convert it into usable intelligence to drive development of objectives and operations;
5. **Disseminate** actionable intelligence.

In all of the IC simulations, there were at least two people assigned to I&I. As questions about information from the field came in, these students would find relevant members of the IC team and hunt down documents that pertained to the question. At one point, during the Airport Bombing exercise, I&I was needed to assess the locations of various populations on a map of the airport and verify locations of suspected bombs. In multiple instances in all the simulations, I&I was called upon to determine clear routes for resources into the incident site.

Design Pattern Description

In order to engage players in DEVELOPING INTELLIGENCE, players should make informed decisions about how to collect information in a gameworld, and need to make judgements of its authenticity and value. They should engage in filtering processes to identify EEI. This pattern makes sensemaking, information seeking, and authentication key elements of play.

Using the Pattern: To design for DEVELOPING INTELLIGENCE, a game needs to supply information the player collects. This information need not be accurate, yet sources of accurate information must be discoverable. Players should be able to act without first engaging with DEVELOPING INTELLIGENCE (i.e., it should not be an OBSTACLE that impedes progress), but, without intelligence, it will be challenging for a player to succeed.

Consequences: A concern for DEVELOPING INTELLIGENCE game mechanics is the need for intelligence that **cannot** be reused across play sessions. If intelligence can be reused, it poses a risk to REPLAYABILITY, even in the short term (e.g., when one might sacrifice a unit to gain intelligence, then restart and use that intelligence without making the same sacrifice).

Imperfect information should be discovered ecologically through the gameworld; players need to make active decisions about what is valid and what is not. This argues against corrective game rules that mark information as verified and/or discard false information automatically.

Relations: DEVELOPING INTELLIGENCE can be instantiated by RANDOMNESS or other forms of unpredictability (e.g., SOLUTION UNCERTAINTY, UNCERTAINTY OF INFORMATION, PERFORMANCE UNCERTAINTY, PLAYER UNCERTAINTY, UNPREDICTABLE BEHAVIOR). Involving other players (e.g., MULTIPLAYER GAMES) is a straightforward instantiation. Further, RECONFIGURABLE GAME WORLDS, which can be changed between plays, offer a meaningful way to create the uncertainty that drives the need to DEVELOP INTELLIGENCE.

DEVELOPING INTELLIGENCE modulates UNCERTAINTY OF OUTCOME by reducing that uncertainty.

It can partially instantiate GAME WORLD EXPLORATION.

It potentially conflicts with MEMORIZING.

Emergent Objectives

Our data in all three domains indicates that objectives are emergent and their priority depends on level of danger. While some objectives materialize as the incident progresses, most already exist, but are undiscovered until the environment is investigated by operatives and/or with sensors. These observations lead to the EMERGENT OBJECTIVES design pattern.

Evidence

FERs work in environments that change rapidly, which shifts objectives. For example, objectives may involve rescuing victims and putting out the fire, but, the latter may shift to containment, preventing damage beyond the burning structure. A key part of decision making between putting out a fire and containing it, we learned from informants, depended upon the structure in question: many structures are not designed to withstand even short fires, which means it is safer for FERs to stay outside. Another informant explained that losing a single structure is often acceptable if all victims have been rescued, but only if the loss is limited to that structure.

USAR environments feature clear general objectives (e.g., rescue all civilians in the region). However, our USAR contacts explained that intelligence must drive the development of more detailed objectives and activities. Reports for the activity may come from multiple people, but those reports may be inaccurate or the problem may have already been solved. Thus, a solution must be considered in light of the problem being unclear, unsolvable, or already solved. Additionally, plans may need to change in real-time to respond to new intelligence.

Much of USAR practice is devoted to search, where operatives move through the environment, looking for damaged areas where people might be in need of rescue. Sensing tools and search dogs support this activity [15]. USAR work involves shoring walls [13], a process of in-the-field on-the-fly situated engineering, to prevent further collapse and opening up spaces using lifting equipment and cutting tools to further search for victims. Through the laborious process of searching, USAR operatives discover where to direct effort.

IC works with emergent objectives at various levels: Plans identifies long-term objectives, while Operations works with a smaller scope. In the observed Stadium Attack simulation, Operations learned that the crashed airplane was loaded with radioactive material. Mitigating exposure to the material, supporting exposed responders and victims, and bringing specialized teams to remove the material became new objectives. This caused Plans to respond by requesting details on the material to drive intelligence on the appropriate response.

An emphasis in the IC simulation involved training command staff in how to develop objectives for an incident. We learned that Command does not dictate what Operations is doing, but provides guiding objectives. A key part of ensuring that objectives are attainable and realistic involves developing objectives that can be completed using the currently available resources.

Design Pattern Description

As players progress through a game, EMERGENT OBJECTIVES may be discovered, developed, and/or lost as a scenario plays out. EMERGENT OBJECTIVES arise through engaging with DEVELOPING INTELLIGENCE. Such play could appear at either end of the process: players may identify new objectives through developed intelligence or computer-controlled agents could gather information to trigger new objectives for players.

Using the Pattern: EMERGENT OBJECTIVES likely require that a game feature multiple paths to victory [50], where the player can accomplish some, but not all, objectives and still succeed. Players may find that some EMERGENT OBJECTIVES become cut off, or new ones open, as implemented through the EPHEMERAL GOALS pattern. Alternative objectives might be substituted for one another.

Consequences: EMERGENT OBJECTIVES suggests that **not** all objectives should be achievable, which may frustrate players. Such designs mean that not all players experience all events in a game.

Relations: EMERGENT OBJECTIVES can be implemented through DEVELOPING INTELLIGENCE, EPHEMERAL GOALS, SECRET GOALS, and FOG OF WAR.

Spatio-Temporal Collaborative Planning

Iterative, careful planning activities characterize USAR and IC, domains, where events typically emerge more slowly than FER practice. Planning activities are undertaken by multiple people, enacting distributed cognition, to make sense of an incident and effect change. We expect such activities to be interesting sources of play for the COLLABORATIVE PLANNING implication, creating situations in which players collaboratively coordinate activity in advance.

Evidence

We observed collaborative planning in the USAR and IC domains, with similar activities occurring in both. FER practice is fast-paced; while we expect that larger incidents require collaborative planning, the size of the ones we observed resulted in single Incident Commanders doing most of the work.

In observed USAR activities, a remote coordination center and local base of operations collaboratively developed plans to execute a response, following the National Incident Management System [69]. These command structures developed plans, a sample of which appear in Figure 1, that spanned 12-hour periods; tracked and requested resources; and followed progress using a collection of printed and hand-drawn paper maps and other information artifacts.

In the IC simulation, we observed groups gathered around whiteboards, drawing maps, and positioning resources. Plans were developed in the long-term by the Plans section, while the Operations section tended to gather together, develop a small plan of attack, then execute it.

In long-term incidents, objectives are connected to physical spaces where activity takes place. Objectives must be laid out such that they account for expected progress of deployed operatives, with contingencies to account for changes in the incident and/or the success or failure of deployed teams.

Design Pattern Description

A key component of COLLABORATIVE PLANNING involves the development of mechanics and interfaces that support time and space synchronization, as well as limited programming that can respond to successes and failures of events. This enables players to consider converging and diverging lines of activity that happen in the field. Players should learn how to plan for contingencies when activities enter exceptional states, such as failure modes, faster-than-expected completion, or slower-than-expected completion. Various failure modes are further buoyed by the design of EMERGENT OBJECTIVES that enable the player to recover and succeed, even after failures.

Using the Pattern: Players should interact with space, typically on maps, to specify future activities that will be undertaken by players or agents. COLLABORATIVE PLANNING should involve accounting for emergent changes in state.

Figure 3. Planning interfaces in *Due Process* (left), *Rainbow Six* (middle), and *Transistor* (right), all of which feature a map on which the player draws paths and specifies activities spatiotemporally. The planning phase in *Due Process* (left) gives each team the ability to plan breach/defensive positions, here they have identified locations for activities and paths to follow in the action phase (screenshot from the developer's press kit). In *Rainbow Six* (middle) and *Breach & Clear* (not pictured), the player specifies what actions game units will take when play begins (screenshot taken 🅭🅯 author Toups). In *Transistor* (right), the player may stop time to specify a set of actions the avatar can take (screenshot taken 🅭🅯 author Toups).

Consequences: Players need to communicate to succeed at COLLABORATIVE PLANNING. Voice and chat communication enable players to coordinate with language [72], but cooperative communication mechanics [64, 70] offer a means of coordinating with the game interface directly. Implementing the COLLABORATIVE PLANNING pattern likely requires some level of artificial intelligence or other reasoning, to enable computer agents to be involved in the collaborative component or to execute developed plans.

Relations: COLLABORATIVE PLANNING can be implemented by STIMULATED PLANNING, STRATEGIC PLANNING, and TACTICAL PLANNING (though these relate heavily to the structure of the game rules and do not address collaboration). Further patterns for implementation are those relating to location (e.g., STRATEGIC LOCATIONS, SNIPER LOCATIONS, RESOURCE LOCATIONS) and time (e.g., REAL-TIME GAMES, TIME PRESSURE, TIME LIMITS, DEVELOPMENT TIME). COOPERATION is also an essential pattern, and SYMBIOTIC PLAYER RELATIONS, MUTUAL GOALS, and opposing teams (e.g., having one or more GAME SYSTEM PLAYERS and/or working on TEAMS in MULTIPLAYER GAMES) motivate players to cooperate.

GAME PLANNING INTERFACE CASE STUDIES

A number of existing games feature planning interfaces and mechanics; the authors identified these based on experiences playing and on game reviews. To connect to our deep investigation of planning practices in disaster response and accompanying design patterns, we develop case studies of games that offer implementations of the patterns, using them as analytic lens. We highlight a breadth of exemplars in this section, as brief case studies of their planning interfaces.

Transistor

Transistor [G9] is an isometric-perspective action game in which combat is played through a combination of a real-time mode and a planning-oriented strategy mode, `Turn()` (Figure 3, right). In `Turn()` mode, the player may move the avatar and select a set of actions, each of which consume time. During `Turn()` mode, enemies are frozen, and the game supplies a simulated expected outcome for each action. Movement paths and actions can be undone during the `Turn()`, usually without consequence. Later enemies can interfere with `Turn()` mode, altering the game mechanic and engaging players in careful meta-planning when engaging such enemies. While executing, `Turn()`s cannot be interrupted.

Transistor enables the player to try out strategies, think critically, and plan ahead, but sometimes penalizes the player while using `Turn()` mode. Simulated outcomes inform players' plans, but may provide unreliable results; players have little means to DEVELOP INTELLIGENCE except through trial and error. While players can engage in planning tasks, there is no TIME PRESSURE or need for COLLABORATIVE PLANNING.

Due Process

Due Process [G5] is a multiplayer first-person shooter (FPS) focused on COOPERATION, STRATEGIC PLANNING, and TACTICAL PLANNING; it does a good job of implementing spatiotemporal COLLABORATIVE PLANNING. At the beginning of a game, two opposing teams are given a planning phase to collaboratively establish strategy. During this phase, each team is given a top-down view of the map detailing walls and doors (Figure 3, left). The offensive team identifies means of ingress and progression through the environment, while the defensive team can specify defensive positions and responsive strategies.

During the planning phase, team members may draw plans on the map. The drawing system serves as a novel cooperative communication mechanic, allowing players to point out which walls/doors will be breached, or which walls/doors the defenders suspect the attacking team might use. Teams are also able to show where they will be defending from and draw out the best defensive positions to take, to cover points of entry.

The planning phase map drawing is made visible on the ground during the execution phase, enabling use during action gameplay. This gives the players the ability to know exactly where to place themselves to breach/take cover. Players may communicate via voice during the planning and action phases to discuss strategy (at first) and tactics (during the action phase).

Due Process's innovative map-drawing mechanic makes COLLABORATIVE PLANNING usable in action play. The superimposed map drawings enable the players to establish a shared mental model of gameworld and execute the developed plan.

Figure 4. The smart ping menu in *League of Legends* provides players with four types of map pings, which they can use to warn teammates about threats or to communicate map-based information. Neutral monsters, like Baron Nashor (seen here), serve as EMERGENT OBJECTIVES for opposing teams to contest. Screenshot taken ⓒⓘ author Alharthi.

As the game progresses, players are subject to EMERGENT OBJECTIVES as information about the opposing team is revealed through play (defense / attack points and maneuvers). DEVELOPING INTELLIGENCE and sharing of emergent information is supported through a voice communication channel.

Breach & Clear

Breach & Clear [G6] is a tactical strategy SWAT-team simulation game developed in consultation with special forces members, an exemplar of the genre. The game is a single-player isometric-view turn-based strategy game. Each turn includes a planning phase where the player issues directions to individual units; once planning is finished, the player waits for all units to complete their actions. This next phase is only reached when every member of a squad has either reached a designated position or died. While not COLLABORATIVE PLANNING, players engage in contingency planning, responding to EMERGENT OBJECTIVES as play progresses.

Like many strategy games, *Breach & Clear* uses the FOG OF WAR pattern to hide information. While the position of enemies is hidden until a unit obtains line of sight, players know the layout of the gameworld. A design to address DEVELOPING INTELLIGENCE might incorporate false information, requiring that the player engage in information seeking.

League of Legends

League of Legends (*LoL*) is a popular multiplayer online battle arena [G8]; a highly successful exemplar of the genre. During a match, five-player teams battle to control territory. To succeed, players coordinate and engage in COLLABORATIVE PLANNING; *LoL* also provides some support for EMERGENT OBJECTIVES and DEVELOPING INTELLIGENCE.

LoL is designed so that not all objectives can be achieved immediately, even though they are known in advance. Teams must prioritize objectives. While the main objective in the game is to destroy the opposing team's base, the game features EMERGENT OBJECTIVES discovered as the match progresses. For example, Baron Nashor, a neutral monster (Figure 4), is an EMERGENT OBJECTIVE; by killing it, the team gains an increase in strength, helping them achieve the main objective. The Baron only appears 15 minutes into the game, and respawns seven minutes after being killed by a team. The team must complete this objective while fending off the enemy, who will mostly likely try to contest the objective.

The *LoL* mini-map (Figure 4, lower right) provides a UI for DEVELOPING INTELLIGENCE through concise information access. It provides a summary of the gameworld, detailing the position and condition of defenses, allies, and enemies. *LoL* uses FOG OF WAR to only show activity near a team's avatars or defenses. Additionally, players can engage mechanics that provide vision on the gameworld, temporarily granting extra intelligence. Gaining vision at strategic locations (e.g., Baron Nashor's lair), helps the team engage in DEVELOPING INTELLIGENCE about the enemy team's behavior.

To support COLLABORATIVE PLANNING, *LoL* provides cooperative communication mechanics in the form of pings. Pings allow players to focus one another's attention, warning about a threat or to pass on a message during the game [39, 64]. *LoL* provides two regular pings and four smart pings, each of which represents a different message (Figure 4). Pings enable lightweight spatio-temporally referenced communication, supporting COLLABORATIVE PLANNING.

Tom Clancy's Rainbow Six

The original *Rainbow Six* [G7] is an FPS that focuses on the development and execution of tactical plans. Play occurs over missions, each consisting of planning and execution stages. During the planning stage, the player is presented with various information sources including a biography on opposition forces and a map of the mission (Figure 3, middle). The map shows obstacles, objectives, and probable enemy locations. This information is presented as intelligence, and the player must create a detailed plan for four assault teams. The player makes plans by defining a spatio-temporal path for each team and specifying actions (e.g., breach a door, use a flash-bang grenade). We note that the provided planning information is not comprehensive or perfect, which leads to EMERGENT OBJECTIVES during play, but that, since all intelligence is true, the game does not implement DEVELOPING INTELLIGENCE.

During the mission, the player may directly control one team at a time, switching between teams, while the other teams are computer-controlled. Missions typically progress slowly and methodically, while encounters with enemy forces are usually won or lost in short, rapid exchanges. During play, the only way for the player to deviate from the plan to handle EMERGENT OBJECTIVES is to directly control a team. During planning, teams can be ordered to wait for specific commands at waypoints enabling a limited degree of contingency response and management of spatio-temporal synchronization.

The fast-paced nature of exchanges, difficulty in deviating from plans, and limited control over each team during the mission makes it difficult to respond to EMERGENT OBJECTIVES. While there are mechanics in *Rainbow Six* for assembling and executing plans, there is no need to engage in COLLABORATIVE PLANNING through communication with others. There

Figure 5. ***Siege*** **players engage in DEVELOPING INTELLIGENCE by piloting drones to gather and share information (e.g., objective locations). Screenshot taken 🅭🅯 author Hamilton.**

are also limited means for players to engage in DEVELOPING INTELLIGENCE beyond what is provided.

Tom Clancy's Rainbow Six Siege

Tom Clancy's Rainbow Six Siege (*Siege*) is another tactical FPS [G10]. In contrast with the original *Rainbow Six*, *Siege* emphasizes competitive, team-based play. In *Siege*, teams of five players play against each other over a series of rounds in alternating offensive and defensive conditions. The offensive team tries to secure or eliminate an objective the defensive team is protecting (e.g., a hostage or bomb). Players communicate through built-in text or voice chat.

Siege incorporates several novel mechanics that support exercising planning activities. For example, at the beginning of each round, a short fortification/scouting period allows the offensive team to use remote-controlled drones to scout the gameworld and gather information (e.g., enemy and objective locations; see Figure 5). This encourages team members to engage in DEVELOPING INTELLIGENCE by sharing their individually discovered information with one another.

Objective locations change from round to round and provide constrained but guided objectives for players to defend or attack. During the fortification period, and throughout the round, defensive players can modify the gameworld to block approaches. Conversely, throughout each round, both teams can destroy parts of the gameworld to open up new approaches. The dynamic nature of the gameworld forces both teams must identify and address EMERGENT OBJECTIVES.

Additionally, the defensive and offensive team maintain access to security cameras and drone feeds. After a player is killed by the opposing team, they can still participate in COLLABORATIVE PLANNING and DEVELOPING INTELLIGENCE with the remaining teammates through information seeking.

Together, these mechanics and information sources create an environment in which players must engage in COLLABORATIVE PLANNING, DEVELOPING INTELLIGENCE, and addressing EMERGENT OBJECTIVES in order to succeed.

DISCUSSION

Existing games minimally support our design patterns. To educate responders, we argue for games incorporating DEVELOPING INTELLIGENCE, EMERGENT OBJECTIVES, and COLLABORATIVE PLANNING. While we anticipate that systems to support disaster response training will benefit most from incorporating these design implications, we expect them to be a fun source of play. Future research will investigate the effectiveness of designs based on these patterns.

Games typically supply true information to players, limiting opportunities to DEVELOP INTELLIGENCE. Further, gathered intelligence rarely changes in games, which limits replayability. While players expect games to be truthful about game state, we expect that, as long as games are truthful about the presence of false information, DEVELOPING INTELLIGENCE can make compelling play. *Papers, Please* [G1], for example, makes information seeking and the detection of consistency in information a core mechanic.

We rarely observe EMERGENT OBJECTIVES in play. Many games use the FOG OF WAR pattern (e.g., *XCOM: Enemy Unknown* [G4], the *StarCraft* series [G2, G3]) to obscure objectives on a map. While compelling, we argue for a deeper engagement with EMERGENT OBJECTIVES, dealing with objective timing and even being able to fail at some objectives. Mutually exclusive objectives, where only one of a set of objectives *can* be completed, are an interesting implementation.

COLLABORATIVE PLANNING relies on multiple players working together, but not all players need to be human. While we have observed many examples of COLLABORATIVE PLANNING, few are the kind of iterative, careful activity found in USAR or have the focus on planning that characterizes IC. Some games do offer the ability to direct other players or identify a single waypoint, but none offer longer-term planning.

CONCLUSION

We developed an understanding of distributed cognition in multiple disaster response domains, using it to drive game design patterns to support disaster response learning through game play: DEVELOPING INTELLIGENCE, EMERGENT OBJECTIVES, and COLLABORATIVE PLANNING. Our primary guiding principle is a need for better long-term planning game mechanics, with the objective of developing new games for disaster response education. Interfaces that make clear a series of planned events and contingencies for the success or failure of those activities are a useful space for future design. We believe these essential disaster response activities and characteristics need to be made available for play, and future games will serve to validate the value of these design patterns.

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