CREATING A GAME-BASED LEARNING TOOL FOR OPTIMIZING INTRA-HOSPITAL DISASTER RESPONSE

by
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ABSTRACT

Preparing for Disasters such as Mass Casualty Incidents (MCIs), whether of natural or human origin, are of increasing concern. When these incidents occur, hospitals are overrun with an influx of new patients and day-to-day operations are interrupted. Concurrently, increased demand for intensive care resources can outpace the ability of hospital staff to organize appropriately. In such events, efficient management of space (emergency rooms, operating rooms), medical staff, and supplies (blood, hospital beds) is imperative for reducing injury, illness and saving lives.

The Johns Hopkins Bloomberg School of Public Health recently identified key disaster categories for which United States hospitals need to be prepared: Large-scale natural disasters, complex MCIs, and catastrophic health events. Each category poses its own set of challenges for effective management of operations and resources.

During a complex MCI, demand for space, staff, and supplies quickly expand beyond the bounds of Emergency Departments (ED). Although many training tools exist for both the field and ED, surprisingly few exist for hospital-wide disaster response. Programs that do exist come in the form of infrequent, costly, and time-intensive large-scale simulations. A game-based instructional modality was developed to practice the medical knowledge, teamwork, and complex decision making required by multidisciplinary teams. As part of this research, a physical board game was developed using an iterative design approach. Additionally, a wireframe prototype of a complimentary digital version was developed using the Waterfall design approach. Both these options were chosen to reduce training costs, and increase training frequency and efficacy compared to large-scale MCI simulations.

The purpose of this project is to create an accessible and cost-effective game-based disaster readiness training tool specifically for intra-hospital personnel. The desired outcome is to increase efficiency and effectiveness of intra-hospital disaster response for MCI. For this project, a mass-shooting scenario has been selected as the focus of gameplay.

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INTRODUCTION

Preparing for Mass Casualty Incidents (MCIs), whether of natural or human origin, are of increasing concern. When these incidents occur, hospitals are over-run with an influx of new patients and day-to-day operations are interrupted. Concurrently, increased demand for intensive care resources can outpace the ability of hospital staff to organize appropriately. In such events, efficient management of space (emergency rooms, operating rooms), medical staff, and supplies (blood, hospital beds) is imperative for reducing injury and illness as well as saving lives (TeriVerdi et al, 2018). The purpose of this project is to create an accessible and cost-effective disaster readiness training tool specifically for hospital personnel outside of the Emergency Department (ED). The desired outcome for this research is to increase the level of knowledge that participants have of intra-hospital disaster response for MCI.

Guidelines for Mass Casualty Incident Preparedness

In September of 2006, the World Health Organization (WHO) held a Global Consultation on Mass Casualty Management at its Geneva Headquarters. The next year, the WHO published a series of strategies and guidelines designed to help health sector personnel at all levels overcome gaps in health system preparedness for mass casualty incidents. In this document, a ***mass casualty incident (MCI)*** is defined as "an event which generates more patients at one time than locally available resources can manage using routine procedures" and "results in a number of victims large enough to disrupt the normal course of emergency and health care services" (World Health Organization, 2007).

Since the publication of the WHO's MCI preparedness strategies and guidelines, much work to improve health sector preparedness has been completed. Hospitals in the United States of all capacities and provider classifications have pushed to generate and/or improve their Disaster Preparedness Plans. Still, breakdown in communication remains the most commonly noted problem in disaster management and results in the loss or delay of vital information that impedes or prevents the sort of necessary decision making needed for emergency activities (EL Khaled, 2019). Thus, the tenets for MCI preparedness training first proposed in 2007 by the WHO still ring true. These training tenets include, but are not limited to:

- "Training and education should be planned and budgeted as a **continuous and scaled process**, and scheduled to reinforce and update skills on a regular basis."
- "Knowledge should be periodically tested through exercises **including "tabletop" exercises (involving writing and discussion rather than physical action)**, sectoral drills, and comprehensive Emergency Management System field exercises involving all sectors."
- Education should be continuously "**monitored and evaluated** to ensure that training and education is effective."
- Preparedness systems and procedures should be standardized, interoperable, well-practiced, and "**fully understood by all who will use them."** (World Health Organization, 2007).

In 2018, The Johns Hopkins Bloomberg School of Public Health further defined MCI by identifying key disaster categories for which United States hospitals need to be prepared: relatively small-scale mass injury/illness events, large-scale natural disasters, complex MCIs, and catastrophic health. Each category poses its own set of challenges for effective management of operations and resources (Toner et al., 2018). *Table 1 provides a listing of the different disaster categories.*

EVENT TYPE:	EXAMPLES:	BURDEN ON SYSTEM:
Small-scale Mass Injury/ Illness Events	-Bus crash -Tornado -Multiple shooting -Small mass shooting (<10) -Local infectious disease outbreak/epidemic	-Transient surge -Typically limited to hospitals
Large-scale Natural Disasters	-Hurricanes -Moderate earthquakes -Large-scale flooding	-Many parts of system degraded over a long period of time -Transient surge in ED patient volume -Prolonged surge in remainder of healthcare system
Complex Mass Casualty Incidents	-Large-scale shooting -Bombing with many victims -Mass casualty burn event -Large scale decontamination of patients -Chemical, radiological, or limited scale biological terrorism	-High trauma burden in multiple hospitals -Transient and prolonged surge may overwhelm capacity at individual facilities -Local/Regional capacity becomes insufficient
Catastrophic Health Events	-Nuclear weapon detonation -Large-scale bioterrorism -Severe pandemic -Massive earthquake	-Severe increased burden on local/regional healthcare facilities -May overwhelm capacity even if infrastructure is intact -National coordination likely required for response

Table 1. Disaster Type Overview (adapted from Toner et al, 2018)

Current Training Methods

During a Mass Casualty Incident, demand for space, staff, and supplies quickly expand beyond the bounds of emergency departments and necessitate accommodation by the remainder of the Hospital (Mahoney et al, 2005) With this in mind, it is surprising that although many MCI training tools currently exist for both the field and Emergency Departments, surprisingly few exist for hospital-wide disaster preparedness. Programs that do exist come in two forms:

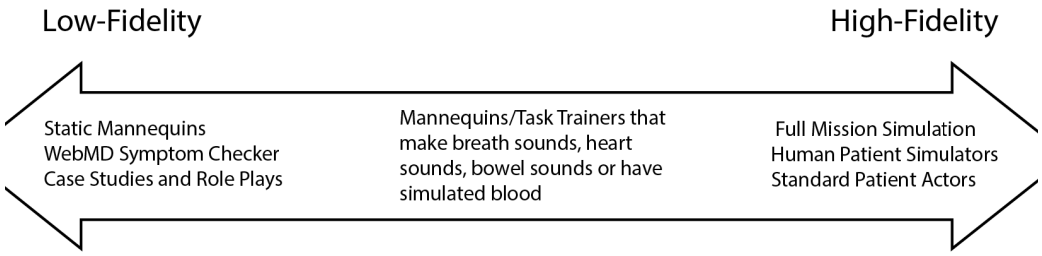
- **Digital training modules on MCI National and Hospital protocol:** Johns Hopkins Medicine Office of Emergency Management (JHMOEM) requires that departmental emergency management coordinators, deputy emergency management coordinators and incident command team members take three online courses offered by the Federal Emergency Management Agency

(FEMA): 1) “Introduction to the Incident Command System”, 2) “Basic Incident Command System for Initial Response”, and “3) An Introduction to the National Incident Management System”. (https://training.fema.gov/is/courseoverview.aspx?code=IS-100.c) These one-time training courses are comprised of a series of online videos and presentations with educational content and case studies that are clicked through by the user in relative isolation. These introductory courses are then supplemented with monthly training sessions, drills and exercises hosted by JHMOEM. Case studies such as these are considered to be a low-fidelity form of simulation training (definition of low-fidelity simulation is provided below). The low relative cost and higher frequency of these types of training improve knowledge retention. However, these training sessions are limited to a small, select group of individuals within the hospital and are frequently missing core elements of MCI training – coordinated hospital-wide collaboration, communication, and teamwork.

- **Large scale, hospital-wide simulations**: These relatively high-fidelity simulations serve to highlight systemic gaps in preparedness within the hospital and have the benefit of including a much larger sampling of hospital employees and stakeholders in hospital preparedness training. However, limitations include a lack of training frequency, high monetary and resource expense, and their time-intensive nature. Learning and skill retention are also negatively impacted by the lack of training frequency.

Simulation

Simulation is defined as a technique for practice and learning that attempts to recreate real world characteristics in a controlled environment. Using this definition, many healthcare training tools fall under the broad category of simulation training. In health care, this environment allows for the practice of procedures, decision making, and critical thinking necessary for patient care without the risk of patient injury. Health care simulation is achieved through combined use of both devices that represent a patient or part of a patient and activities that mimic the clinical environment (Durham, 2008). The degree to which simulations replicate reality is commonly referred to as ***fidelity (Figure 1)***. It is common in the literature surrounding simulation to label a simulator either low- or high-fidelity depending on how closely it imitates reality.



High-Fidelity Simulations

The goal in these environments is to mimic real life as closely as possible - acting as a stand in for hands-on training that would either be too risky to execute, or too costly to practice in real life or rare enough that most practitioners would have little opportunity for other educational exposure. Examples of this type of simulation are Full Mission Simulators, Human Patient Simulators, and Standard Patient Actors.

Low-Fidelity Simulations

These closely mirror the actions or scenarios that need to be practiced, but exclude certain factors that might be experienced in real life. Symptom checkers like the one hosted on WebMD are examples of low-fidelity simulations. They mirror the actions performed in a doctor's office: stating a region of symptoms and then progressively narrowing the list of possible ailments through a series of targeted questions.

The classification of simulations existing along a scale between high- and low-fidelity is helpful for the engineers who design and build simulations. However, this unidimensional approach to describing simulation becomes much less helpful to instructional designers as they consider what learning and environmental elements should be included in team training programs such as those required for Mass Casualty Incident training.

Multidimensional Simulation Fidelity

In 1995 Rehmann et al proposed a new method (*as seen in Figure 2)* of classifying simulation trainers through the instructional designer perspective. He and his colleagues described a multidimensional Venn

diagram consisting of three overlapping dimensions of fidelity that should be considered while designing a training program. These categories include: 1) Environmental fidelity, 2) Equipment fidelity, and 3) Psychological fidelity (Rehmann et al, 1995).

Equipment fidelity is the degree to which a simulator duplicates the look and feel of reality. In virtual reality surgical simulation equipment fidelity would be the visual realism of the 3D patient models, surgical equipment, and the virtual operating room. ***Environment fidelity*** constitutes the extent to which the simulator emulates the other sensory information of the training scenario. This category encompasses the degree of haptic feedback, motion cues, and auditory stimuli present in the simulation environment. ***Psychological fidelity*** refers to the degree to which the trainee suspends disbelief and perceives the simulation to be a bel).

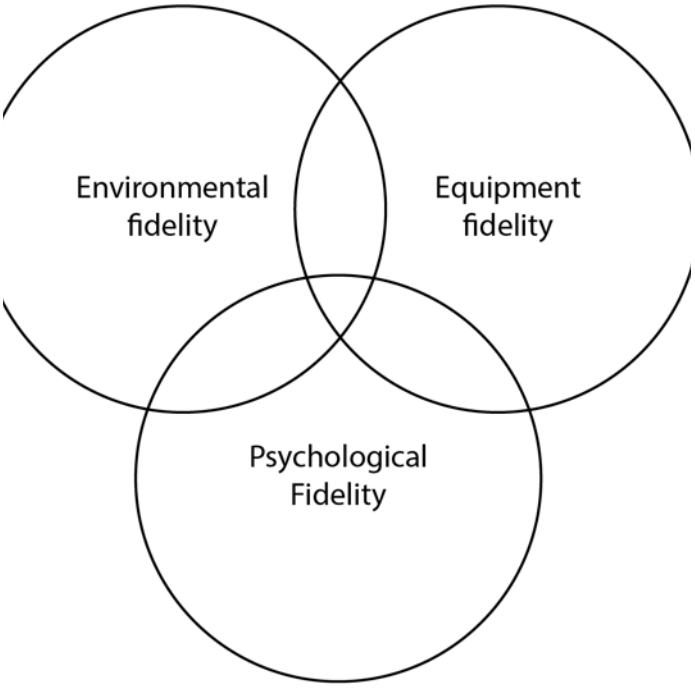


Figure 1. Simulation Fidelity Typology (Baubien, 2004 as adapted from Rehmann et al, 1995)

Consideration of the various dimensions of simulation and their practical application to learning objectives is critical to the success of the visual and instructional design of the training program. For example, if the learning objective for a Mass Casualty Incident training program is to maximize teamwork and

collaboration, it would be important to design a training simulator that is primarily high in psychological fidelity and low in environmental fidelity. This choice would maximize the engagement of all participants in the completion of the designated tasks while reducing unnecessary and potentially distracting environmental factors. Conversely, if the primary learning objective is to transfer trained procedures from the MCI training scenario to a real-world event it would be more important to include the environmental conditions of that event in the development of the training program (Rehman et al, 1995).

Guidelines for Simulation Effectiveness

In addition to the manipulation of these three fidelity dimensions to achieve learning objectives in simulation training programs, there are some practical guidelines that should be considered when attempting to maximize simulation effectiveness in healthcare team training. These concepts were summarized quite eloquently in Beaubien and Baker's 2004 journal article, "*The use of simulation for training teamwork skills in health care: how low can you go?"* and are as follows:

- **"Ensure that training needs, goals, content, and evaluation measures reinforce one another.**" Make sure to regularly audit the training program as it is designed to ensure that needs, goals, content, and evaluation measures continue to stay linked to one another and remain readily apparent to learners.
- **"Use case studies and role players to train teamwork related knowledge and attitudes."** To work successfully as a team, individual learners must progress through several stages of learning. These stages include the acquisition of factual knowledge about a task, acquisition of practical knowledge of how to perform tasks, acquisition of knowledge of when to perform the task, and the acquisition of the ability to self-evaluate the success of one's performance. Parsing out these stages of learning into separate, successive training events provides the opportunity to both emphasize the importance of teamwork and build on knowledge and execution of teamwork concepts.
- **"Use part-task trainers to train teamwork related skills to the point of over-learning."** Where possible, segment complex tasks into main components. In MCI training, this concept is particularly relevant. Large scale, hospital-wide simulations are necessary, however the

learning limitations discussed earlier can be greatly reduced, if not altogether eliminated by clustering educational goals. Part-task training components such as hospital procedure, role distribution, and teamwork can be taught independent of a hospital-wide simulation.

- "**Use full mission simulators to hone teamwork related skills under conditions of ambiguity, time pressure, and stress."** Once core learning elements have been achieved and a standard baseline for team function have been established, it is important to move on to more ambiguous, time sensitive, and stressful tests of teamwork. Overtraining team performance can prevent the team from becoming overwhelmed during real life implementation of trained tasks.
- **"Use post-simulation debriefings to reinforce the lessons learned during training."** While practice may make key behaviors more or less permanent and repeatable, practice with feedback is necessary for team members to learn from mistakes and establish methods for improving upon previous performances.
- "**Training is not a one-time event, so plan accordingly."** Create your training/simulation regimen in such a way that it can be implemented iteratively. The "use it or lose it" concept applies as much to team training as it does to any other learning. Finesse training resources so that they include the ideal balance of awareness training, skills practice, and recurrent skills maintenance (Beaubien, 2004).

Learning and Serious Games

Serious games are defined as "games that are designed to entertain players as they educate, train, or change behavior." There are several benefits associated with serious games such as: entering into a "stealth mode" of learning as the educational goal melds with the entertainment (Ricciardi et al, 2014). Some compelling reasons for gamification of learning are as follows:

- **Entertainment:** It has been demonstrated that playful learning experiences (such as gaming) stimulate regions of the brain associated with reward, memory, cognitive flexibility, and stress regulation. Experiencing joy and success in gaming may induce increased levels of dopamine in the brains reward system. Spikes in dopamine levels has been associated with enhanced memory, attention, creativity, and motivation in learning. (Liu et al, 2017)

- **Cognitive flow:** Serious games engage learners in a number of novel challenging tasks and force them to use a high degree of skill to navigate through the learning environment. This process of working unfamiliar stimuli into existing mental frameworks under (tolerable quantities of) pressure recruits neural networks that are associated with memory, transfer, and awareness of one's own thought processes – all necessary regions of engagement for tackling team-based learning. (Liu et al, 2017) Additionally, the level of deep concentration, absorption, and immersion required for serious gaming facilitates a level of engagement that may bolster learning outcomes. (Csikszentmihalyi, 1990)
- **Safe practice environment:** Games (and simulations) are good training methods because of their inherent safety. Skills can be practiced without risk of harming themselves or others. This freedom from physical repercussions allows space for creative problem solving and active learning. (Horachek, 2014)

Healthcare professionals have many demands on their time and are subjected to a high volume of traditional learning methods (seminars, on-line learning, presentations, etc.). Approaching MCI training through the lens of a serious game may improve not only learner engagement and learning outcomes, but also enjoyment of the process.

Scaffolding in Educational Gaming

Training for Intra-hospital MCI response must accommodate for the introduction of an array of novel, complex concepts. In gameplay, this complexity could easily overwhelm trainees and negatively impact not only the learning environment but also learner outcomes. ***Scaffolding*** in educational gaming is defined as "the process that enables a novice to solve a problem, carry out a task or achieve a goal beyond unassisted efforts." (Wood, 1976) Effective scaffolding systems often incorporate the concept of ***fading*** – a process through which learning is facilitated by an individual who has mastered the material. In the early stages of learning/gameplay, the facilitator is heavily involved in coaching the participants towards the target skill. Over time, the facilitator gradually reduces participation (or fades) providing limited hints, refinements,

and feedback while the learner simultaneously increases the smoothness with which they can execute the skill. (Loparev, 2015)

Iterative (Game) Design

Iterative design methodology (*refer to figure 3)* relies on a cyclical process of prototyping, testing, analyzing and refining a product or process. In this process each iterative round of product testing yields new information upon which changes and refinements are made. The spiral model of iterative design is an evolutionary process of game development in which a project progresses from initial concept generation through several stages of design, prototyping, testing, and design modification. This design methodology relies on several stages of prototyping and product testing to refine concepts until an operational prototype is achieved. Use of this method is advantageous when developing a novel game that has high-risk, real world implications such as training for intra-hospital mass casualty response.

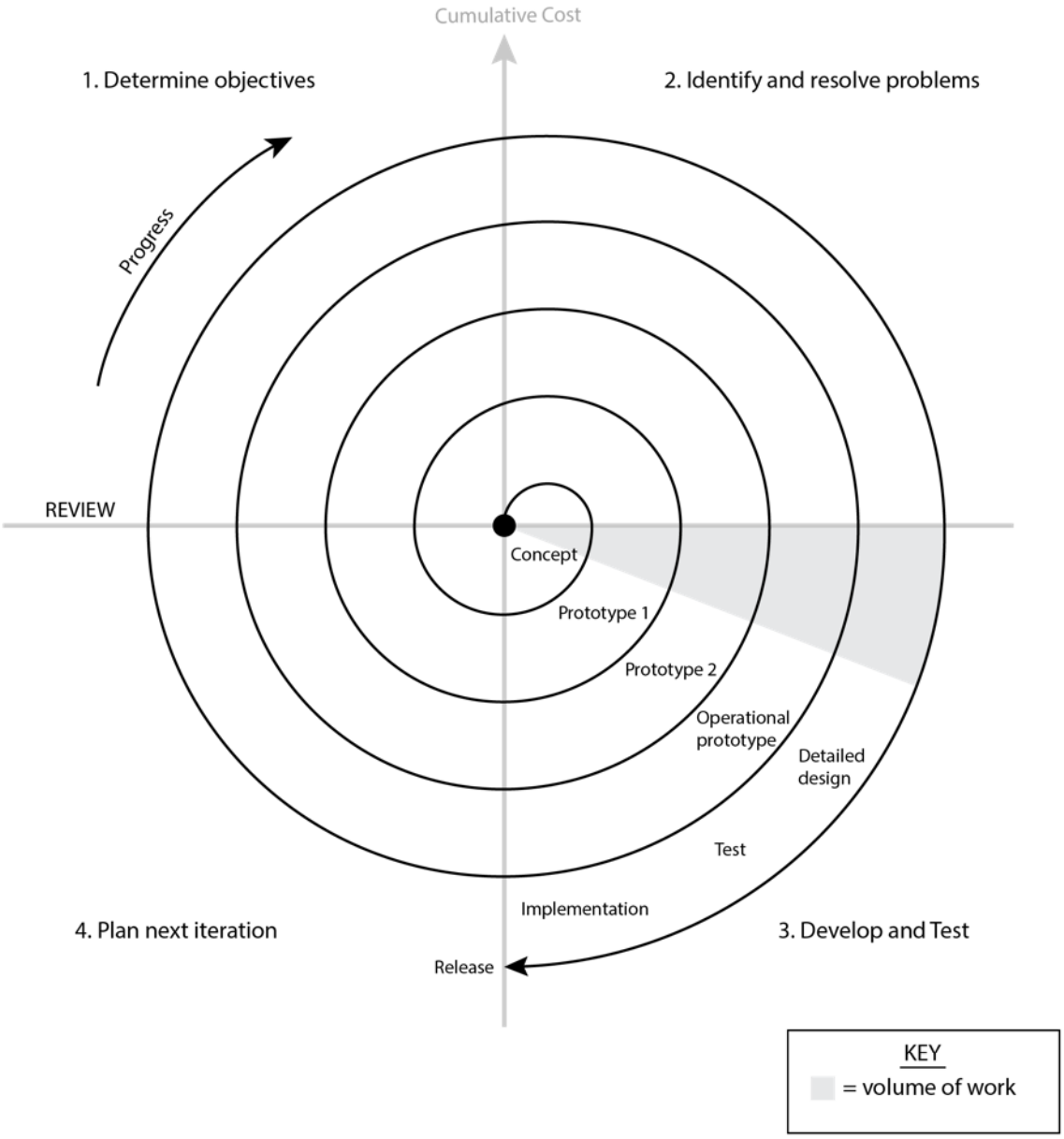


Figure 2. A Spiral Model of Iterative Design. (as adapted from Boehm, 1986)

Waterfall Development Model: Digital Design

The ***Waterfall Development Model*** represents a different design approach. It is based on a methodical, phased progression of development activities. Using this model, the development team breaks the project into discrete, understandable segments. The team then proceeds through the development process in a linear phased approach. Progressing to the next phase only when the prior phase has been completed and

approved. This approach is useful when a project is well-defined and relatively predictable. It's focus on prior documentation and extensive planning differs extensively from the agile yet unpredictable Iterative Design Method. The Waterfall Development Model minimizes resource waste, maximizes budget predictability, and the ability of new developers to be brought into the process.

Research Objectives

Specific goals for this research included the following:

1. Increase the level of knowledge that participants have of intra-hospital disaster response for MCI.
2. Construct a board game, with an associated interactive digital application, for learning hospital MCI interdisciplinary communication, and emergency response policy.
3. Create a framework upon which to build digital MCI preparedness training modules, possibly through an internet-based delivery platform.

Audience

The primary audience for this training tool is intra-hospital nurses, technicians, doctors, administrators, and public liaisons. The training tool developed as part of this research should enable hospital staff to learn about their hospital specific emergency preparedness plan and associated policies. It will also promote practicing communication and teamwork as they implement those policies throughout repeated gameplay.

Scope of the Research Problem

Limitations of current training methods for MCI online learning and large-scale simulation contrast sharply with the needs for such a training tool posited by the World Health Organization and Johns Hopkins Center for Health Security. This disparity between current instructional methodologies and desired learning outcomes constitutes the focus of the research problem.

The purpose of this project is to create an accessible and cost-effective disaster readiness training tool specifically designed for hospital personnel outside of the ED. The desired outcome is to increase efficiency and effectiveness of intra-hospital disaster response for MCI.

The use of serious gaming as a training methodology has the potential to simultaneously fulfill many needs of MCI training as outlined by the Johns Hopkins Center for Health Security. A single, staged board game may be able to function as a full mission simulator (to hone teamwork skills under conditions of ambiguity, time pressure, and stress) as well as include role playing and case studies to train teamwork related knowledge and behaviors. At the conclusion of gameplay, lessons learned can be reinforced by a post-game debriefing. It is hypothesized that such a board game with built-in degrees of simulation may not only enhance learning, but also embed necessary skills, and improve the application of learned materials to real world situations.

This type of training tool can be developed by implementing a hybrid of the iterative design method and waterfall development models. Modifications can be made to the game elements and mechanics of play during the game development cycle so that it can be used in multiple configurations. Two possible modules are envisioned, a standalone board game, and a digitally-facilitated game. The initial board game can be developed using the iterative development method - meaning that regular intervals of user feedback during the development process will form natural breaks. These breaks will allow for periodic high-level testing and evaluation of game effectiveness. During these evaluative periods, developers can also ensure that training needs, goals, content, and associated evaluation measures continue to reinforce one another throughout the game. Once the core elements and principles of the game have been iteratively developed, the digital version can be developed using the more predictable and methodical waterfall development method.

This research seeks to answer the following question: Can the creation of a serious game achieve the broad learning objectives of introducing MCI protocol by strengthening interdisciplinary communication, promoting engagement with material through discussion, and practicing team-based problem solving? Can it serve as a training platform that allows for continuous repeatability, scaled learning, monitoring, and evaluation, that is fully understandable by all users?

MATERIALS AND METHODS

The creation of this MCI training game followed the Spiral Iterative and Modified Waterfall design methods. The process originated with the development of the initial concept and then progressed through repeated cycles of planning, prototyping, testing and design modification. Four rounds of increasingly refined prototyping and functionality testing with stakeholders were completed. When the game-mechanics and visual design for the board game were fully functional, an operational prototype was generated and tested with the target audience. Feedback received from the operational prototype was implemented for the final iteration of the board game as well the initial development of a digital version of the game. The following is a narrative description of the various cycles of development undertaken through this research.

PHASE 1: BOARD GAME

CONCEPT DEVELOPMENT

To initiate research, the development team played several collaborative games such as Pandemic *(Z-Man Games, Mahopac, New York)* and Dungeons and Dragons *(Wizards of the Coast, Renton, Washington)*. The team included: Deborah Schwengel, MD (Pediatric Anesthesiology, Johns Hopkins University), Robert Greenberg, MD (Pediatric Anesthesiology, Johns Hopkins University), Greg Walsh, PhD (Information Arts and Technologies, University of Baltimore), Mira King, MHA (Administration, Anesthesiology and Critical Care Medicine, Johns Hopkins University) and Serkan Toy, M.Ed., PhD (Anesthesiology and Critical Care Medicine, Johns Hopkins University). These initial gameplay experiences informed the concept for a board game to teach Intra-Hospital Mass Casualty Disaster Response Policy as well as interdisciplinary communication and teamwork. This initial concept served as the foundation for iterative development of game assets and gameplay mechanics. At this early stage, versions of gaming elements were created from cut paper with hand-written concepts on them. Gameplay was attempted by the development team several times in this condition with the intent of expanding the possibilities of gameplay mechanics and ensuring that all team members understood core elements of the game concept.

At the end of this phase, the board game concept included the following elements:

- An opening statement that set the scene for gameplay: “It is 2pm on a Thursday. There is an active shooter at a Food Truck Rally at Patterson Park (a local park in Baltimore).”
- A poster board with a handwritten list of hospital rooms on it
- Notecards with five player roles and brief “scope of practice” descriptions including:
    1. Nurse
    2. Administrator
    3. Liaison
    4. Tech
    5. Doctor
- A 5-minute sand timer
- Seven rounds of gameplay:
    1. Partial Hospital Mobilization
    2. Declare Hospital-wide Emergency; Prepare for Surge
    3. Triage
    4. Media Management
    5. Advanced Triage - Prep for Definitive Treatment
    6. Prep for Return to Normal Operations
    7. Debrief

Once the development team established core concepts for the game, I was tasked with coordinating the various stages of iterative game development. To do this, I collaborated closely with game designers Daniel Datu and Greg Walsh, PhD from the University of Baltimore. While we developed these elements the remainder of the team developed more specific learning goals and the metrics with which to test them. Development team meetings were held on a monthly basis to discuss the results of usability tests, review changes, and discuss new ideas for game-mechanics and visuals.

PROTOTYPE ONE

To start the process of creating the first testable prototype, I formulated a speculative list of assets needed for the training of Mass Casualty Incidents. This list was based on discussions with the development team.

The items on this list fell into one of two large categories of information: conceptual and physical. The conceptual elements were derived from the desired learning outcomes for the game. The physical elements were intended to visually support conceptual elements by cueing player collaboration and problem solving. The goal in this phase of prototyping was to take a broad-strokes pass at creating physical game-assets that supported the conceptual learning elements so that game-mechanics could start to be tested.

The following is an outline of elements included in the first prototype:

Conceptual Elements:

- Interdisciplinary Communication
- Team-based Problem Solving
- Introduction of MCI Protocol

Physical Elements:

- Introductory Scenario Statement
- Johns Hopkins Patient Influx: Disaster Plan (PDF)
    - Player Role Sheets
        - Doctor
        - Nurse
        - Tech
        - Liaison
        - Administrator
- Representation of Intra-Hospital Rooms
    - ED 1
    - ED 2
    - Security
    - Main Entrance
    - Morgue
    - ICU 1
    - ICU 2
    - Conference Room
    - OR 1
    - OR 2
    - Supply Closet
    - Incident Command Center
    - Floor
    - Corridor
    - Cafe
    - Pharmacy

- Designation of Hospital being converted from regular operations to Code Yellow ED Emergency Department vs. Code Yellow Hospital
- Representation of Patients (including casualties)
- Guidelines for Each Round

Production of visual elements during the first prototype was limited to Room Cards, Player Role Sheets, Patient Information Cards, and a Facilitator Guideline for gameplay. These cards were very primitive in nature and consisted of a number of note-cards with hand-written information on them.

Room Cards

Cards representing various rooms within a hospital (*Figure 4)* were also made and given two sides: one white and one red. Both sides of the card had the room title. The white side of the card represented normal hospital operations. The red side represented the declaration of Code Yellow. Participants were asked to flip room cards from normal to code yellow as needed to handle the mass casualty incident.

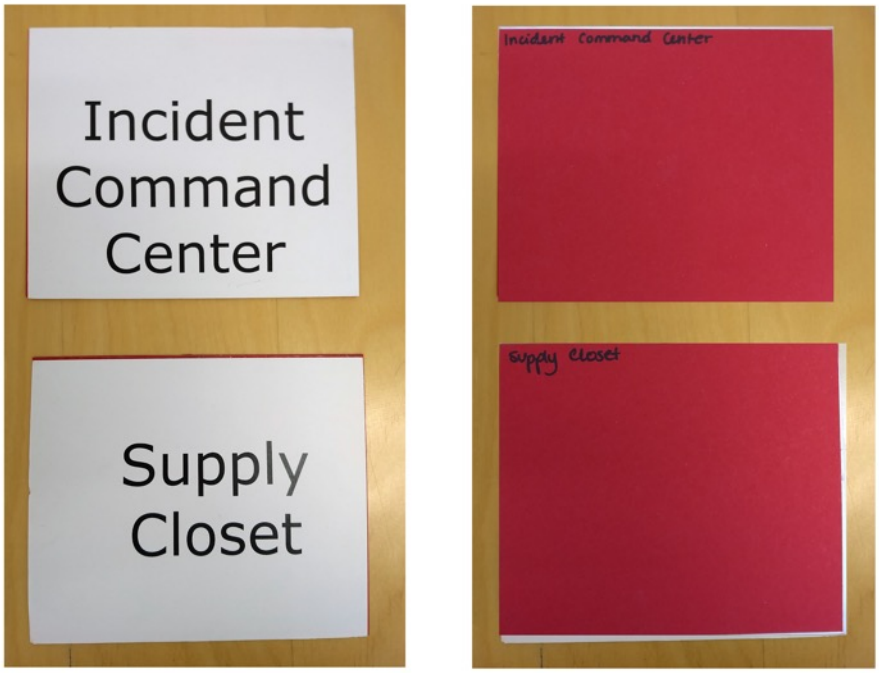


Figure 3. Room Cards, Prototype One
(Shown for layout purposes; text not intended to be read. Final version available in Results section).

Player Role Sheets

The player role sheet (*Figure 5)* included a description of possible actions that could be taken by each role, an illustration pertaining to the role, a meter for participants to measure fatigue (based on how many actions were performed), a list of fatigue modifiers, an inventory of supplies, and a space for tokens (used to motivate players to perform actions).

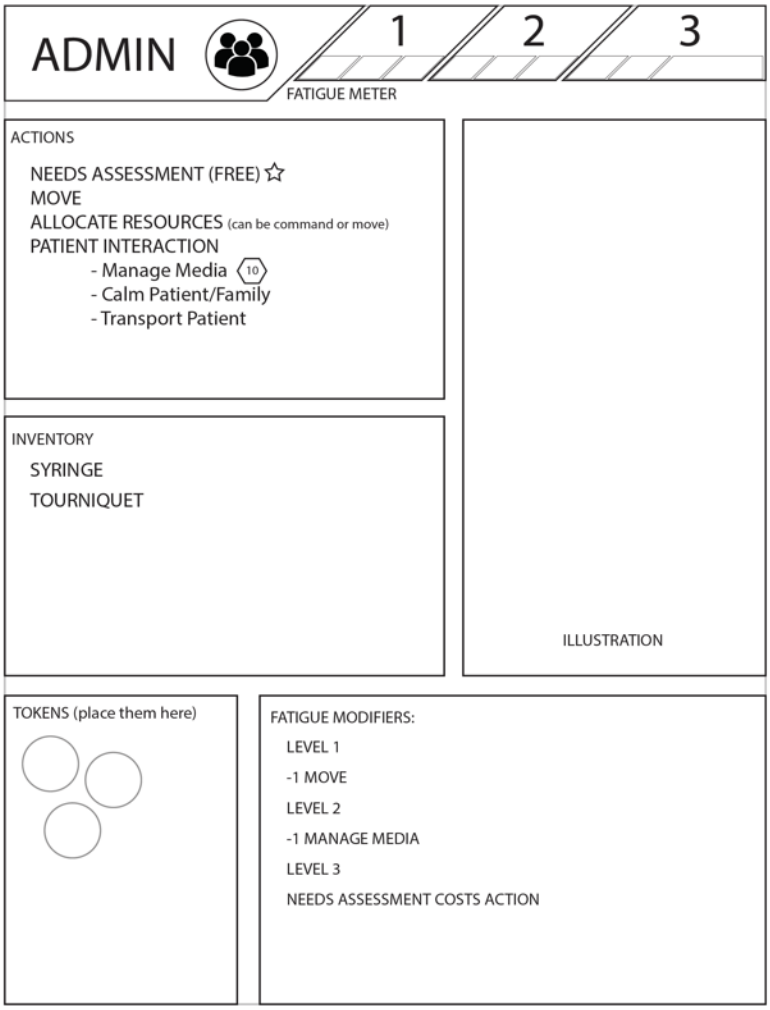


Figure 4. Player Role Sheet, Prototype One
(Shown for layout purposes; text not intended to be read. Final version available in Results section).

Patient Triage Cards

Patient Triage Cards (*Figure 6)* were produced to include demographic and medical information of representative mass casualty patients. Information on the front of the card included: Age, Gender, Race, Weight, Heart Rate (HR), Respiratory Rate (RR), Blood Pressure (BP), Temperature (Temp), Oxygen saturation (O^2 Sat), Chief Complaint (CC), History of Present Illness (HPI), Allergies, Medication (Meds), and results of a Physical Exam (PE). The cards served as physical elements that supported the larger goal of team decision making. Participants were asked to assign triage priority and appropriate medical intervention as a team based upon the demographic information on the front of the card. Once triage

priority was assigned, participants would flip the card to determine the accuracy of their decision. A total of 10 patient triage cards were developed for this round of prototyping.

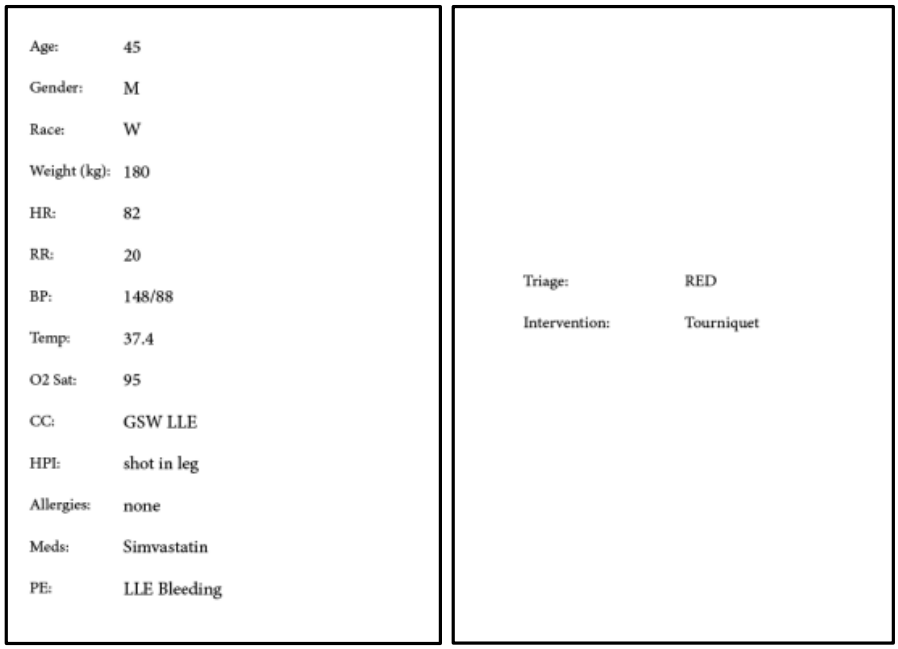


Figure 5. Patient Triage Card, Prototype One
(Shown for layout purposes; text not intended to be read. Final version available in Results section).

Functionality Test #1

In the first round of prototype testing, the goal was to determine the success of the visual assets and game mechanics during the participant on-boarding process. For this reason, game setup and the first round of gameplay were isolated for testing. Three graduate students participated in this round of testing.

Gameplay was initiated by the Game Facilitator by reading the following ***Objectives Statement:***

"Your mission today is to collaborate to solve a problem. As the game progresses, please use teammates and the resources available to find solutions to the problems you encounter."

Participants were then asked to layout board-game pieces in such a way that made sense to them. The intent here was to ease players into collaboration with a relatively easy and low-stakes task.

Next, participants were asked to select one of five Role Cards at random from a pile. Participants were asked to read over their cards and ask questions if they were confused. Two of the five roles were

absent during this round of gameplay. Participants were not notified what roles were missing. To begin play participants were read the following ***Scenario Statement*:**

"*It is 2pm on a beautiful Thursday in Patterson Park. A Food Truck Rally is the scene of an active shooter. Multiple people have been shot and police are on the scene. EMRC identifies your hospital as the closest hospital. Code Yellow: ED is declared by the ED. Attending and Trauma teams have been activated for Adults and Pediatrics. Patients are on their way. We will now begin round one of the game. The end-goal for this round is to prepare the hospital for the influx of patients.*"

Participants were then handed the Johns Hopkins Hospital: Business Continuity and Emergency Preparedness Plans and Policies for Emergency Preparedness (Patient Influx: Disaster Plan) as an accessory material.

Next, participants were asked to decide on their tasks for the round and make a formal statement as to which tasks would be performer by which player roles. Additionally, participants were asked to record fatigue modifiers as they performed tasks. Fatigue was not clearly defined at this stage of development, however we decided to include this as a game element.

When players self-determined they had finished discussing and making decisions concerning all of the necessary tasks for the round, gameplay stopped. At the conclusion of this first round of gameplay the Facilitator read a list of pre-determined objectives out loud and noted which were met by the players and which were not.

Notes were taken on the challenges experienced during gameplay mechanics and participant errors. Additionally, upon concluding the first round of gameplay, participants were asked a series of questions: What did they learn? What did they find engaging? What did they have difficulty understanding? User feedback was evaluated and corresponding modifications to game-visuals and in-game mechanics were made.

PROTOTYPE TWO

The goal in this round of prototyping was to build upon previously generated and tested visual assets. Visual elements that were successful in supporting learning objectives in the first round were developed further. Elements that did not function as intended were revised; elements missing were created and testing

was repeated. Improving game mechanics and the facilitator role was the main focus of this round of prototyping. The facilitator guides participants through early stages and then gradually lessens the amount of instruction given as the game progresses (thereby implementing the concept of scaffolding). Visual elements remained relatively undeveloped - serving only to communicate the basic elements of the game (i.e. Room Cards).

Facilitator Guide

A Facilitator Guide was developed to improve scaffolding and consistency between periods of gameplay. This guide provided a description of the various player roles, the objective of gameplay, a "rough" version of rules for playing the game, an introduction, and the opening scenario statement. In addition, the Facilitator Guide provided a bulleted list for each round that included: the time allotted for the round, the number of injured patients, and the goals for each round. An attempt was made to further clarify the concepts of role fatigue, and supplies. A concept for surprise events was also generated during this round of prototyping.

Player Role Sheets

The number of elements contained in the Player Role Sheets (*Figure 7*) was reduced to decrease player cognitive load. This reduction was accomplished by removing the player inventory, illustration, and tokens. The list of possible player, fatigue meter, and list of fatigue modifiers remained.

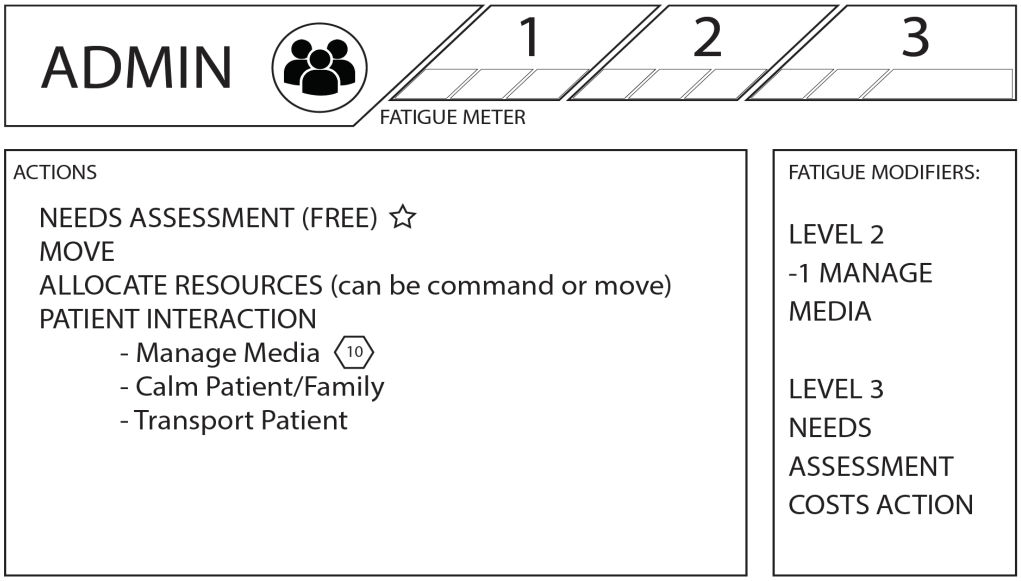


Figure 6. Player Role Sheet, Prototype Two
(Shown for layout purposes; text not intended to be read. Final version available in Results section).

Patient Triage Cards

While the layout of Patient Triage Cards remained the same in this round of prototyping, the number of cards included during gameplay increased. A total of 20 Patient Triage Cards were developed for this round of prototyping.

Functionality Test #2

In this functionality test, the game was played through the third round. In round one of play, changes made to the on-boarding process and game-scaffolding were tested. The introduction of rounds two and three of gameplay tested game-mechanics, participant patient triage capacity, and application of hospital mass casualty incident response protocol. There were four participants for this round of functionality testing.

Gameplay began in much the same way as it had before. Players were asked to collaborate to arrange hospital Room Cards in a way they saw fit, the facilitator read the objectives for each round, players randomly picked their role cards, and the scenario statement was read. This time missing Role Cards were shown to participants and rules of the game were reviewed in more detail before gameplay commenced.

Once again, participants were asked to comment on the necessary tasks that needed to be accomplished for each round and make a formal statement as to which roles were going to perform which tasks. Additionally, participants were asked to record fatigue on the provided scale as they completed tasks.

When players felt that they had discussed and completed the necessary tasks for the round, gameplay stopped. The facilitator announced which goals were met and unmet within each round of gameplay. Round three of gameplay was the only round of triage in the game at this time.

Notes were taken of any in-game challenges and participant errors that occurred. At the conclusion of play, participants were asked a series of questions: What did they learn? What did they find engaging? What did they have difficulty understanding? Participant user feedback was evaluated and appropriate modifications to game visuals and elements were made.

PROTOTYPE THREE

Major revisions occurred between prototype two and prototype three. Gameplay scaffolding was revised so that patients came in waves during each round, reflecting the quantity and injury distribution that might occur during an MCI scenario. Scripts were written for prompts that would be read to begin each round of play. At the conclusion of this round of prototyping, most of the necessary visual and game elements had been generated and gameplay was able to progress through all rounds. The Facilitator Guide was reformatted and developed further, Room and Role Cards saw major revisions, and Patient Triage Cards were reformatted. A Game Board, a Player Mat, Supply Cards, and Action Cards were created to enhance game function. Adobe CC 2020: Illustrator, InDesign, and Photoshop (Adobe Inc., San Jose, CA) were used to create all of visual game elements.

Learning Goals

At this stage of development, a series of multiple-choice questions had been developed to test participant understanding of MCI policy. Game mechanics and visuals were re-organized to incorporate some of the major concepts included in this series of questions. ***Refer to Appendix A for the list of questions*:**

Changes to gameplay included:

- Patient Triage Card delivery was changed from being limited to round three to being delivered in waves throughout the game.

- The color-based triage system was included as a visual on the Patient Triage Cards (and later on the Role Mat).
- The story-line now included the passing of time. Fifty-percent of patients arrived within the first 60-minutes of the story.
- The concept of scarcity was introduced to game-mechanics to drive home the exhaustion of resources associated with MCI

Facilitator Guide

In this prototype, the content within the Facilitator Guide became more comprehensive. It included a section for game-setup, as well as sections for each round of gameplay. Each round included time-limits, scripted facilitator prompts to begin each round, a list of goals, and a chart for the facilitator to record actions performed by players

Game Board

A Game Board (*Figure 8)* was designed to help organize team-work and decision making during gameplay. At the beginning of gameplay all Room Cards were placed with the blue side up indicating that the hospital was in normal operations. As the hospital broke from normal operations, the Room Cards were to be flipped from blue to yellow, indicating code yellow hospital. The Game Board also served to represent the location of patients. As triage decisions were made, triaged Patient Cards were to be placed above the appropriate Room Card. Research was done to determine what the printing size options were for custom board game printing companies. As a result, the Game Board was set at 29 x 19in. (the largest possible printable board size).

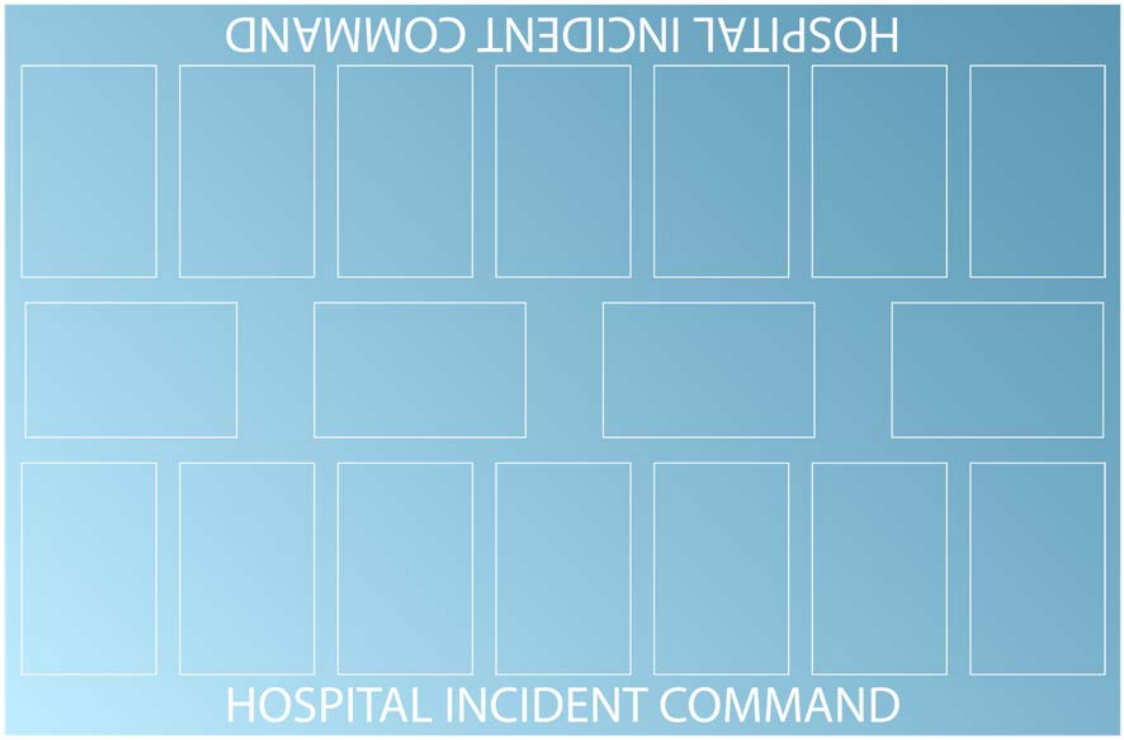


Figure 7. Hospital Incident Command Game-Board, Prototype Three
(Shown for layout purposes; text not intended to be read. Final version available in Results section).

Room Cards

Room Cards (*Figure 9)* were redesigned to correspond with the Game Board and relevant hospital color codes. Normal hospital operations were represented by a blue color that matched the coloration of the game board. The reverse side of the card was colored yellow to represent both the Emergency Department and Hospital "Code Yellow." The cards were sized at 5.5 x 3.5 in. (the largest possible printable card size). This size was necessary so that cards would be large enough to stack the triaged Patient Cards on them and still allow the room name to be visible. A grid-like pattern was created to add visual interest to the cards and differentiate them from the Game Board.

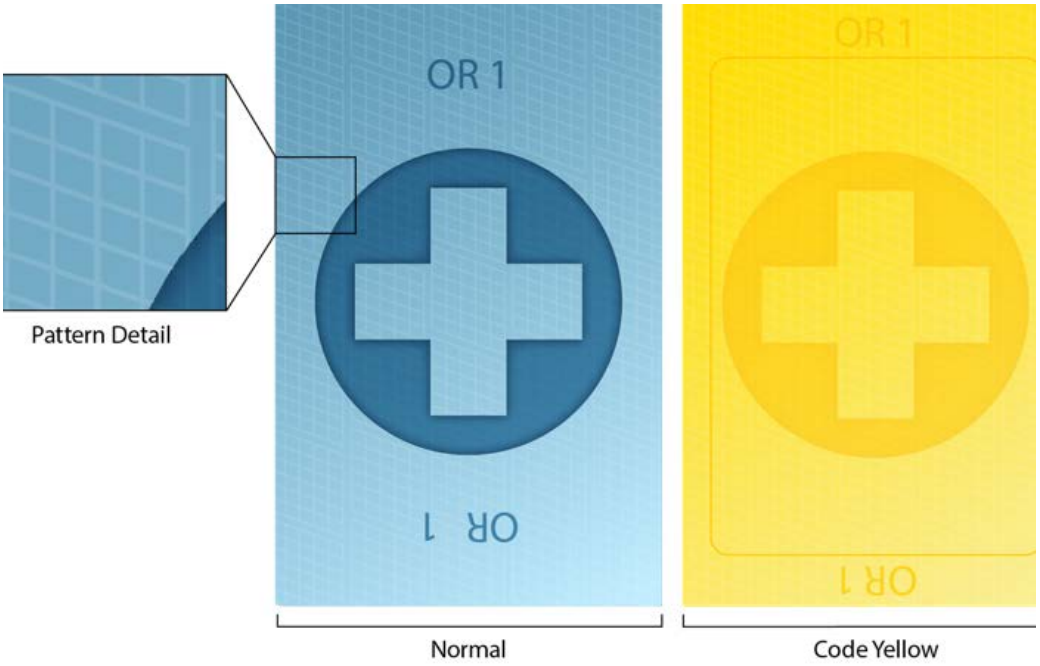
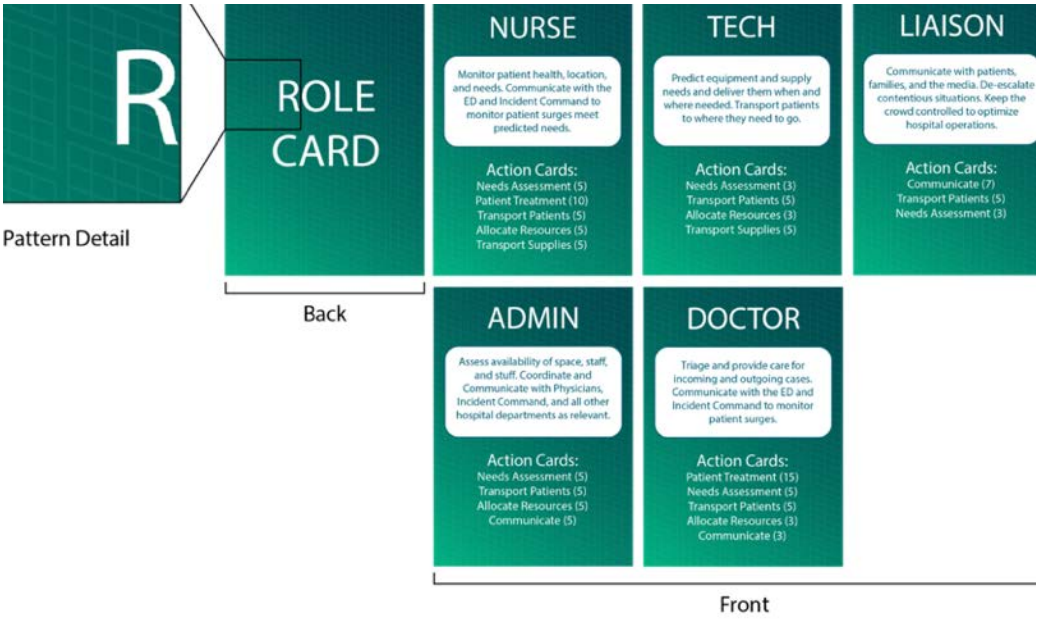


Figure 8. Room Cards with inset for Pattern Detail, Prototype Three
Shown for layout purposes; text not intended to be read. Final version available in Results sectio

Role Cards

Player Role Cards (*Figure 10)* were redesigned as Role Cards. Text elements included both job duties during normal operations and duties required during an MCI, as defined by the Johns Hopkins Hospital Patient Influx: Disaster Plan. Contents of this card included, role title, role description, and a list of Action Cards (including the number of cards to be drawn at the beginning of play). Role Cards were designed with the same patterning and font as the Game Board and Room Cards. Green was chosen to differentiate these cards from other card types and to work cohesively with the blue and yellow color scheme of Game Board and Room Cards. These cards were set at 2. 5 x 3.5 in. in dimension.



Player Mat

A Player Mat (*Figure 11)* was created for each game participant to place their Role Card. An area was provided to place played Action Cards during each round of gameplay. At the end of each round of play, participants would be asked to clear Action Cards to the Used box.

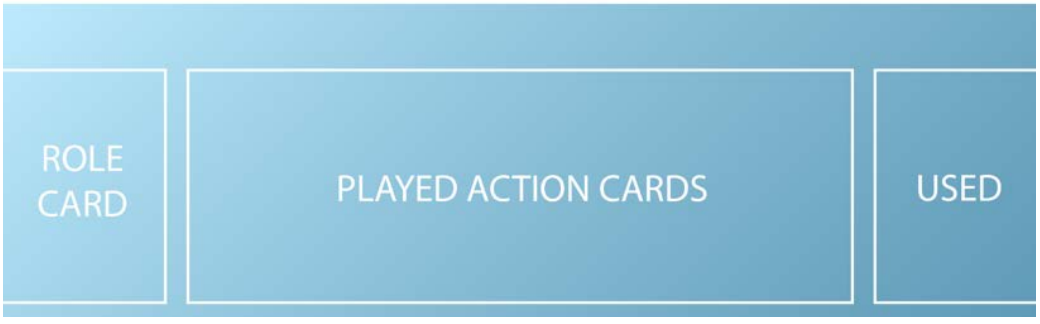


Figure 11. Player Mat, Prototype Three
(Shown for layout purposes; text not intended to be read. Final version available in Results section).

Action Cards

Action Cards (*Figure 12)* were created to serve three purposes: concretely define differences between player roles, visualize individual player contributions, and represent player fatigue. As actions are played during a game round, they would be placed in the "Played Action Cards" box on their player mat. At the conclusion of the round, played Action Cards would be cleared into the "Used" box on the Player Mat. The use of a grid pattern on the Action Card is consistent with the patterning used on the Room and Role Cards. An orange and yellow gradient was chosen to emulate the "active" use of the card and its application within a "Code Yellow Hospital/ED" scenario. Contents of the card include the action category, a brief set of instructions and a list of possible examples of card use.

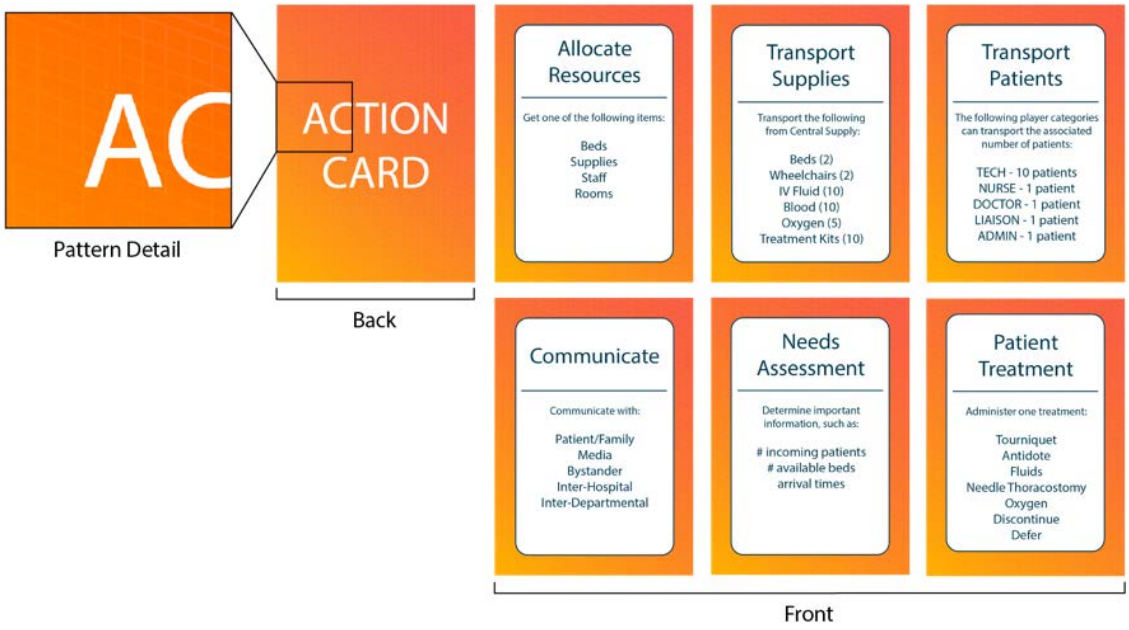


Figure 10. Action Cards and inset for Pattern Detail, Prototype Three
(Shown for layout purposes; text not intended to be read. Final version available in Results section).

Patient Triage Cards

Patient Triage Cards (*Figure 13)* were designed to mimic the design of a triage card that might be used in the field by Emergency Medical Services during MCI. Contents include a patient number (for the facilitator to track game progress), a figure where the patient's specific region of injury would be documented, a box for recording types of injury, a box with patient demographic details (male/female, age, weight, etc.), a box where patient vitals could be recorded, (heart-rate, blood-pressure, oxygen saturation, etc.), and a box

where game participants could record the triage priority level assigned to the patient. Design consistent with that of other game elements was used. A blue color background was once again chosen to harmonize with the Game Board and Room Cards. The delivery of Patient Triage Cards was redistributed to be delivered in distinct stages. The first stage of Patient Triage Card delivery was just one patient who self-transported to the hospital and was the first to notify hospital staff of the MCI. The second stage, included a small cluster of ambulatory or on-looker delivered patients with injuries that were not immediately threatening. The third stage of patients was the largest and included more threatening injuries delivered to the hospital by EMS. The fourth stage of patients included media and family. In the fifth round, previously triaged patients were re-evaluated and definitive treatments were determined.

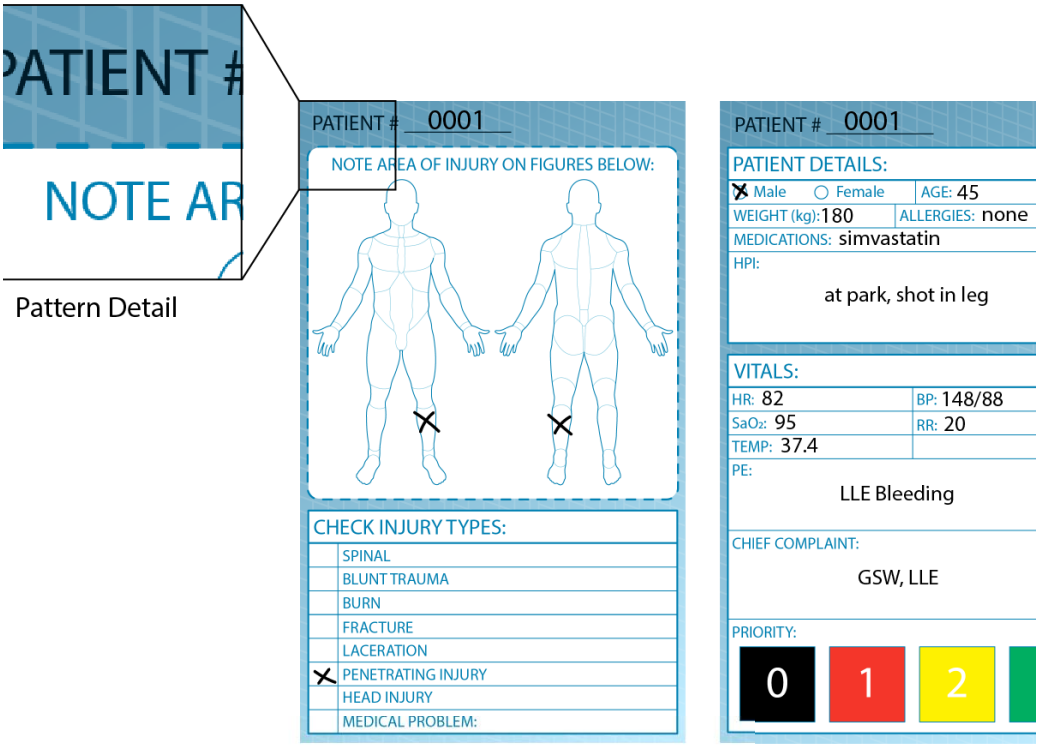


Figure 11. Patient Triage Cards and inset with Pattern Detail, Prototype Three
Shown for layout purposes; text not intended to be read. Final version available in Results sectio

Supply Cards

Supply Cards (*Figure 14)* were created to represent the finite quantity of supplies available during MCI and to visually represent patient interventions being performed during gameplay. These cards were used in conjunction with the "Patient Treatment" Action Card as well as Patient Triage Cards. A gradient background consistent with all other game elements was used. A blue gradient was modified to differentiate "Supply Kit" Cards from other game cards. Illustrations were created to represent various supplies that would be used in an emergency patient intervention. These illustrations represent a tourniquet, a thoracostomy needle, pharmaceuticals, fluids, and oxygen.

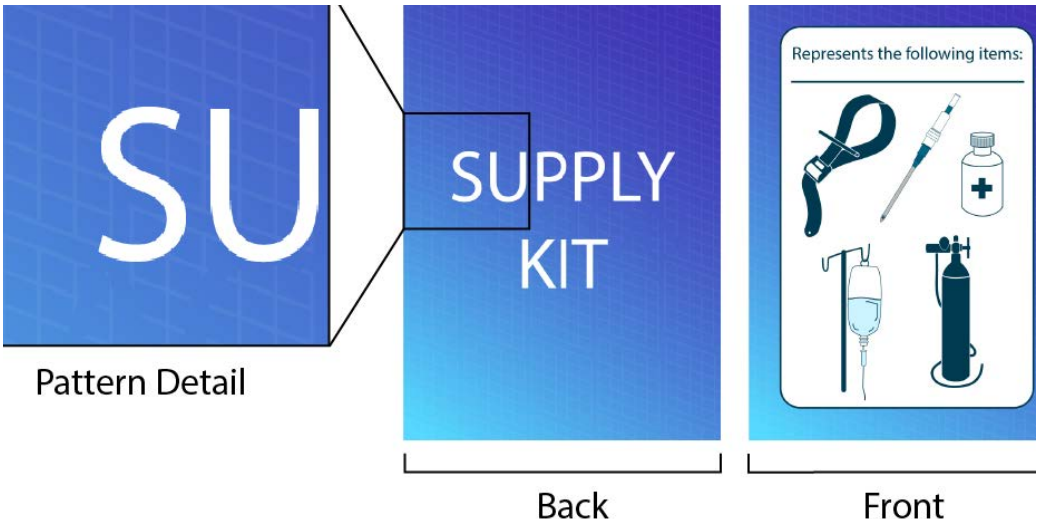


Figure 12. Supply Card and Pattern Detail Inset, Prototype Three
Shown for layout purposes; text not intended to be read. Final version available in Results section

Functionality Test #3

Three participants were included during this round of game-functionality testing. Increased scaffolding of learning provided by the facilitator script was bolstered by more robust visual game elements. In previous rounds of play the game cards contained too much information, were not clearly defined, and lacked color to differentiate and support conceptual goals of gameplay. With updates to these elements, players were able to progress through all seven rounds for the first time (though not within the preferred time limit of 60 minutes).

Gameplay began in much the same way as it had before. Players were once again asked to collaborate to arrange hospital Room Cards in a way they saw fit, the objectives statement was read, rules were reviewed in detail, players randomly picked Role Cards, the Scenario Statement was read, and the missing Role Cards were shown to participants.

Players were then asked to collect the quantity of Action Cards specified on their Role Card. Once this was accomplished, participants were asked to decide on the necessary tasks to be performed for each round and make a formal statement as to which roles were performing which tasks. This time however, once a task had been decided upon and delegated to a particular role, participants were asked to place the played Action Card in the "Played Action Cards" box on their Player Mat to represent a formal action. The finite quantity of Action Cards held by each player served as fatigue. If a player ran out of Action Cards, the whole team would be penalized. At this point in game development, however, what format this penalty would take was not fully defined.

Each round of gameplay now had a designated amount of time. Based on the round of play, the facilitator would either hand out the next round of triage cards or read the scripted prompt to begin the next round. The Facilitator would once again announce which goals were met and unmet within the last round of gameplay before starting the next round of play.

Notes were taken on gameplay challenges and participant errors that occurred during play. At the conclusion of play, participants were asked a series of questions: What did they learn? What did they find engaging? What did they have difficulty understanding? User feedback was evaluated and modifications to game visuals and elements were made.

PROTOTYPE FOUR

By this round of prototyping all of the necessary visual components for the game had been generated. The Facilitation Guide and Rules had been refined further, and all of the Triage Cards had been created. Players were able to progress through all rounds of play with relative success and within the intended 60-minute time limit. Visual elements were refined further to support the story and decrease cognitive load. The game was tested again, this time with new players to refine the play time and catch major errors before production of an operational prototype.

Facilitator Guide

In this prototype, content within the Facilitator Guide became even more comprehensive. The guide was re-written in a script format so that the facilitator could read it methodically from start to finish as gameplay progressed. This revision reduced cognitive load on the facilitator and improved consistency within the game structure. The guide still included a section for game-setup, as well as instructions for each round of gameplay. Time-limits were adjusted for each round. Scripted prompts were provided to begin each round, some rounds ended with a period of triaging patients. The list of goals for each round was represented as a Goal Progress Chart. The chart previously used by the facilitator to record player actions was removed to further reduce facilitator cognitive load.

Game Board

Functionally, the game board remained the same for this prototype. So this was not revised.

Room Cards

A Social Work/Mental Health Services Room was added to the deck of room cards. This was done to provide a space to which family members could be triaged as well as a location for hospital workers to recover from fatigue.

Role Mat

To reduce the bulk of the game, Role Cards (*Figure 15)* were glued to the Player Mat for this round of prototyping. Thus, we redefined this game element as a Role Mat.

Figure 13. Role Mat, Prototype Four.
(Shown for layout purposes; text not intended to be read. Final version available in Results section).

Action Cards

In Functionality Test #3, having Action Cards (*Figure 16)* visually represent played actions and player fatigue worked well. An additional "Interaction" card was created to represent hospital staff communication with media, family, and the general public. Different colors were added behind action titles to increase the speed with which players could visually differentiate between various types of action cards.

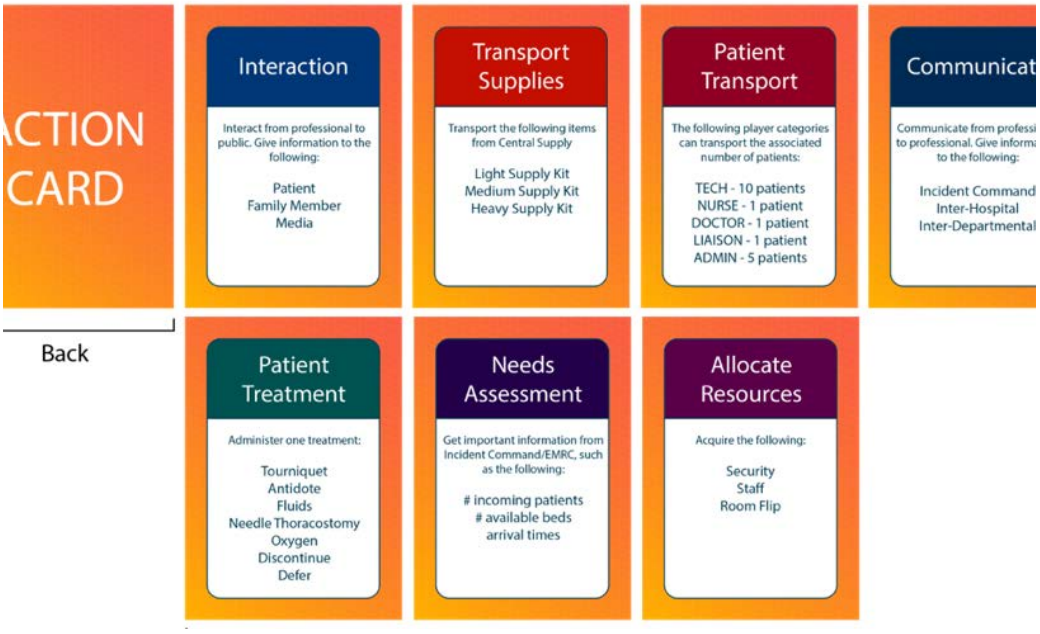


Figure 14. Action Cards, Prototype Four.
Shown for layout purposes; text not intended to be read. Final version available in Results sectio

Triage Cards

Triage cards retained the same function and visual attributes for this round of prototyping, and thus the design was not revised. Additional Triage Cards were created that described family members and media.

Supply Cards

The role of supply cards in gameplay was expanded into three different categories to clarify their use. The color palette was kept consistent with that of the previously designed supply cards, but three different values of color gradient were used to differentiate between the different supply categories (*Figure 17)*.

Goal Progress Chart and Goals List

The creation of a Goal Progress Chart and associated Goals List (*refer to Appendix A*) serves two purposes: to hint at the number of goals players needed to meet, and to provide a small reward system for having satisfied the goals. As successive goals were achieved for each round, a token is placed over the corresponding number of goals reached.

Functionality Test #4

Four participants were included in this test of game functionality. The speed of play was improved with the increased clarity provided by added facilitator scripts and other game revisions made since the previous rounds of testing.

This time the board was set up by the facilitator, reducing set-up time. Players were once again asked to collaborate to arrange hospital Room Cards in a way they saw fit. The Objectives Statement was read, and Game Rules were reviewed in detail by the facilitator. Players then randomly picked roles (by

selecting Player Mats with affixed Role Cards), the Scenario Statement was read, and the missing roles were shown to participants. As in the previous round, players were asked to collect the quantity of Action Cards listed on their Role Card. As previously done, at the beginning of each round participants were asked to decide amongst themselves what the necessary tasks for the round were and make a formal statement as to which roles were performing the necessary tasks. As performed in Functionality Test #3, once an action task had been decided upon and delegated to a particular role, that player was asked to place the corresponding Action Card in the "Played Action Cards" box on their Player Mat in order to represent the played action.

The finite quantity of Action Cards held by each player once again served to provide a measure of fatigue. However, this time if the player ran out of cards, the player had to report to the newly added room "Social Work/Mental Health Services" for a period of two minutes. This served as a penalty to the player and the team for not considering the needs of their teammates and their own limitations. After the two-minute penalty period, the player could regain their full suite of action cards and rejoin play. As goals were met by the team of players, the facilitator moved a token forward on the Goals Sheet and announced which goal had been satisfied.

In this functionality test, adjustments were made to the allotted time for each round. At the conclusion of this time, either the next set of Patient Triage Cards were handed out, or the scripted audio prompt was read aloud to begin the next round.

Notes were taken on gameplay challenges and participant errors that occurred during play. At the conclusion of playing, participants were asked a series of questions: What did they learn? What did they find engaging? What did they have difficulty understanding?

After this round of functionality testing, the development team decided that game-mechanics and visuals were concrete enough to perform a usability test with the target audience. User feedback was evaluated once-more and the last round of major changes were made to game-visuals and elements.

OPERATIONAL PROTOTYPE & QUALITY ASSURANCE TEST

At this stage, all of the necessary visual components had been generated and tested for core-functionality. With core-functionality determined, the graphic design of the game was elaborated upon to enhance the

gaming experience. Fonts were changed from Myriad Pro to AgencyFB for titles and Omnium Wide Bold for main text. In order to enhance the stimulatory experience of the game, scripted prompts that began each round of gameplay were recorded as audio files with background hospital sound effects (sirens, background voices, etc.). A separate instructions document (termed the Rule Set) was created containing game rules and diagrams of game-setup. All sixty Patient Triage Cards were generated. The time designated for each round was refined to fit exactly within the 60-minute time limit. The game was tested again this time with the intended target audience, intra-hospital staff.

Hospital Capacity Command Board

Titles of rooms were added to the Game Board (*Figure 18)* so that Room Cards could be consistently arranged by the Facilitator. The title of the board was changed from Hospital Incident Command to Hospital Capacity Command. The new title more accurately corresponds with the intended board use for the visualization of patient placement, patient movement, and changes in room status between normal operations to code yellow.

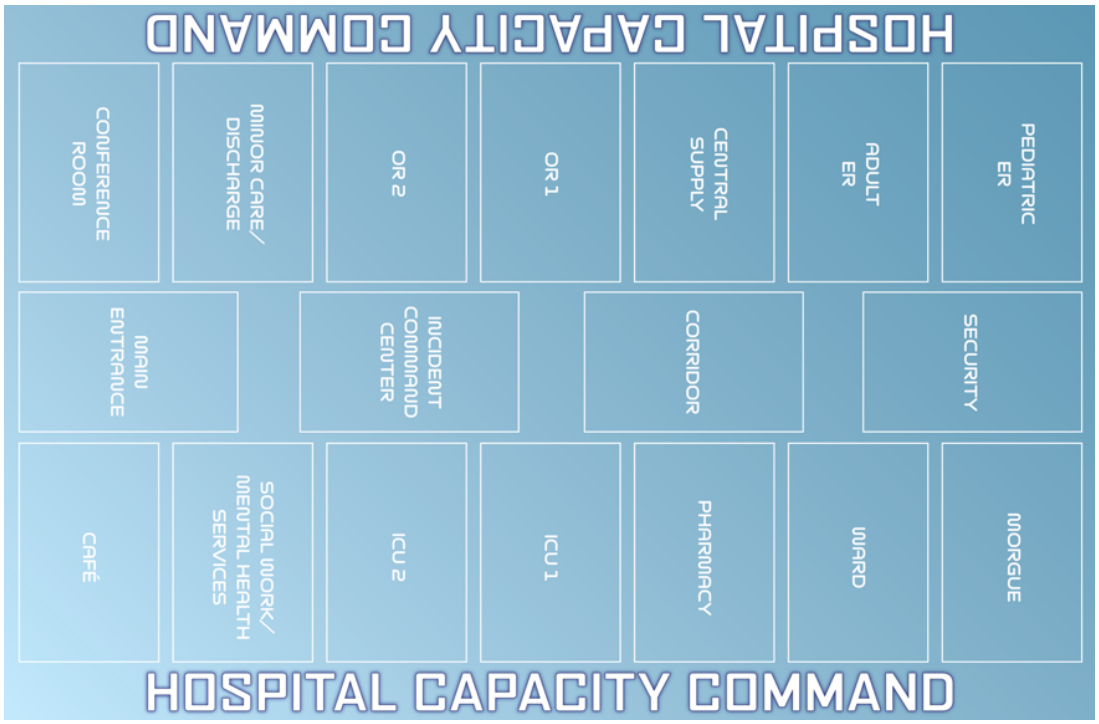
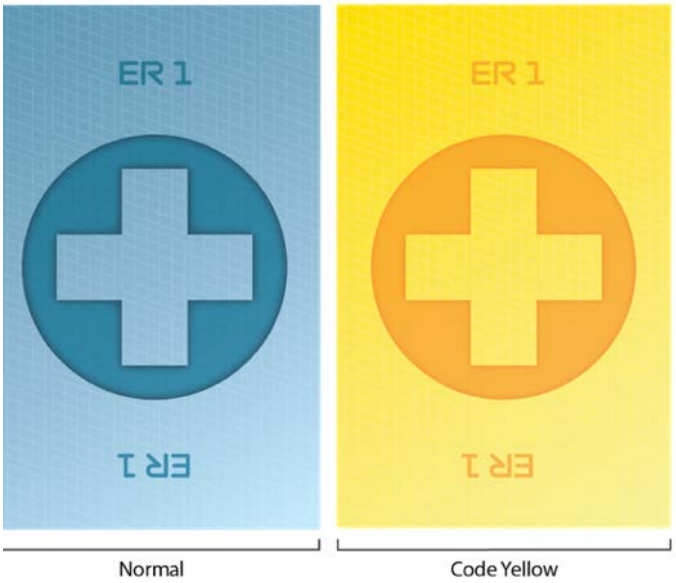


Figure 16. Hospital Capacity Command Board, Operational Prototype
(Shown for layout purposes; text not intended to be read. Final version available in Results section).

Room Cards

Room Cards (*Figure 19)* generally remained consistent with previous rounds with the exception of the typeface, which was switched from Myriad Pro to Omnium Wide to correspond with the remainder of the game. The text and in :asing their legibility.



Role Mats

Role cards were formally united with the Role Mat (*Figure 20)*. Fonts were changed to be in line with look of the remainder of the game. A quick reference guide to hospital patient influx codes and triage priority levels was added along the bottom of the mat. The job description was shortened and quantity of Action Cards associated with each player were tweaked to bolster the concept of resource scarcity and better serve as a mechanism for fatigue measurement.

Figure 18. Role Mat, Operational Prototype
(Shown for layout purposes; text not intended to be read. Final version available in Results section).

Action Cards

The back of Action Cards (*Figure 21)* was redesigned to be more dynamic with the addition of a white star pattern behind the "action" title and drop shadows on the text. The type face was changed to correspond with the remainder of the game. The grid-like background patterning was increased in opacity so that it woul

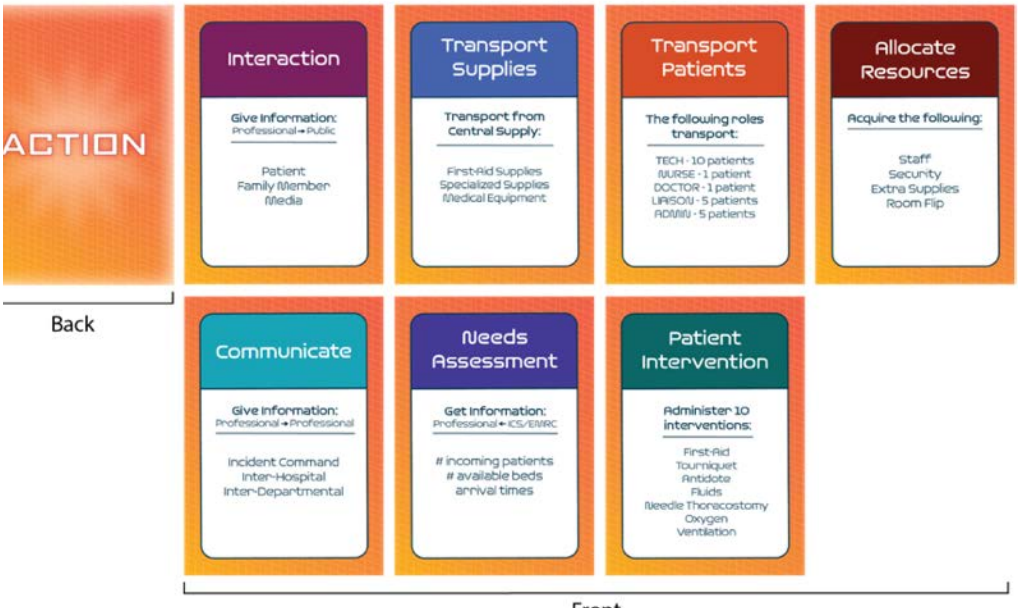


Figure 19. Action Cards, Operational Prototype
(Shown for layout purposes; text not intended to be read. Final version available in Results section).

Supply Cards

Supply Card (*Figure 22)* category titles were modified to increase clarity. Light, Medium, and Heavy Supply Kits were changed to First-Aid, Specialty Medical, and Medical Equipment kits respectively. The type face was once again changed to correspond with the remainder of the game elements. A ventilator was added to the Medical Equipment Kit. The grid-like background patterning was increased in opacity so that it would be more evident.

Figure 20. Supply Cards, Operational Prototype
(Shown for layout purposes; text not intended to be read. Final version available in Results section).

Patient Triage Cards

While the design of the Patient Triage Cards did not change drastically, by this point the full suite of 60 profiles was completed, including: 51 patients, 7 onlookers, and 2 media members. Triage patients came in 4 waves during gameplay. The first wave of patients contained one introductory patient, the second contained twelve mostly minor priority patients, the third had 30 patients with a higher quantity of seriously wounded patients, and the fourth had a mix of all priority levels as well as onlookers and media. This phased introduction of patients was intended to reflect the average distribution of injury severity over time within an MCI event.

Rule Set

The Rule Set was developed as a separate document from the Facilitator Script to support testing of the games scaffolding in this round of usability. *(For full text, refer to Appendix B)*

Setup Guide

A diagrammatic Set-Up Guide was generated to aid Facilitators in preparing for game set up and facilitation. It contained labeled images of the Action Cards, Supply Cards, Patient Triage Cards, Player Mats, Room Cards, and Game Board. It also contained a diagram of how the Player Mat should be used, and image of the initial Game Board setup, as well as the Game Board during partial hospital mobilization (mid-game). *(For full text, refer to Results)*

Facilitator Script

The Facilitator Script included written description of game set-up, and refined time-limits for each round of play. Audio recordings were now partnered with scripted prompts and played at designated times throughout gameplay. Rounds 2, 3, and 4 ended with a period of triaging patients, Round 5 included the re-evaluation of triaged patients for definitive treatment. The list of goals for each round is provided to the facilitator as a Goal Checklist, corresponding in number to the Goal Progress Chart. *(For full text, refer to Appendix C)*

Audio Recordings

Scripted audio was recorded to enhance the immersive feeling of the board-game. Play of the audio-files at the beginning of each round of gameplay helped push participants forward into the story-line. The audio also provided hints as to what sort of actions participants should take during the round. *(For full script, refer to Appendix D)*

Quality Assurance Test #1: Operational Prototype

Whereas previous iterations of the game prototype had been tested to assess core mechanics of the game (through Functionality Tests), the purpose of this round of testing was assess playability of the game based on the amount of scaffolding provided to the player teams by each facilitator.

This first quality assurance test was performed with three groups *(labeled A, B, and C in Table 2)* each composed of four people from the target audience of intra-hospital personnel (doctors, nurses, technicians, and administrators). Each group received a different degree of facilitator instruction

(scaffolding). Group A received the most scaffolding as the facilitator read the full Facilitation Script and provided the Game Rules, Hospital Preparedness Plan, Goals Checklist, Goal Progress Chart along with all other game components. Group B received the next scaffolding level as the facilitator read the full Facilitation Script, provided the Goals Checklist, and Goal Progress Chart along with all other game components. Group B was not provided with the Game Rules, or Hospital Preparedness Plan. Group C received the least facilitator scaffolding as they were only provided with the Rule Set and Audio Prompts for the beginning of each round.

Included Scaffolding	**Group A**	**Group B**	**Group C**
Facilitation Script	X	X	
Audio Prompts	X	X	X
Rule Set	X		X
Hospital Preparedness Plan	X		
Goals Checklist	X	X	
Goal Progress Chart	X		X
Game Components	X	X	

Table 2. Level of Scaffolding, Quality Assurance Testing.

Prior to gameplay, Greg Walsh, PhD collected data to establish a baseline for MCI protocol knowledge in hospital personnel during a final quality assurance test. Data was collected in the following manner: through a pre/post-test knowledge questionnaire, a post-test participant satisfaction questionnaire, and the collection of observational data during gameplay. After participants completed the post-test they were once again asked a series of qualitative questions: What did you think of the story? Did this game remind you of any other games you've played before? What was your favorite part of the game? What was your least favorite part of the game? What challenges did you and your team have? What changes would you make to the game?

Refinements were made to the Operational Prototype based upon the information acquired during this round of Quality Assurance testing.

PHASE 2: DIGITAL APPLICATION

By Prototype Three, the core game elements of the board game had been determined and tested and thus concurrent development of the digital application began. Although an iterative design methodology was useful during the development of the board game, now that the core elements had been identified it would have been time consuming and cumbersome to apply to the development of the digital application. For this reason, digital game-development progressed using a different approach, the waterfall design methodology. This approach was useful in that the waterfall design method focuses more heavily on the documentation of design information. Due to the time-constraints of this research, only the initial phases of design were completed.

The digital version is different from the physical board game in the following ways:

- Variation in game facilitation could be reduced.
- An animation could preface gameplay that could highlight core-learning concepts of mass casualty incident response.
- Facilitation could begin with a standardized video that introduces core elements of gameplay (for example: how Action Cards should be used, how Supply Cards should be used, etc.)
- Audio and video clips can be delivered automatically at specific timed intervals to progress players through rounds and increase environmental simulation-fidelity
- Triage decisions can be more fluidly recorded and evaluated for accuracy.
- The condition of triaged patients can change over time to closer reflect reality.

User Experience Design

Step 1: Requirements

Adobe XD v.24.0.22 (Adobe Systems, San Jose, CA) was chosen as the platform with which to design the screens, elements and flow (together referred to as a "wireframe") for the digital application. This software was chosen due to its easily understandable interface, extensive library of existing components (buttons, icons, etc.) and the ability to animate and test the functionality of wireframes within the software. Unity v.2019.3.1 (Unity Technologies, San Francisco, CA) was chosen as the preferred development software due to its accessibility for beginner software developers and cross-platform delivery capabilities.

Accessibility features include: the existence of a thorough online manual, numerous video tutorials, and free sample projects. Cross-platform delivery capabilities include: iOS, Mac, Android, and PC, as well as cell phones, tablets, and computers.

To initiate creation of the digital game facilitator, a list was compiled that included necessary elements and features for the digital application. The following elements would serve as building blocks upon which to build the application:

- **Login/Game Set-Up:**
  - Hospital Name
  - Hospital Location
  - Hospital Capacity
  - Trauma Center Level
- **Facilitator Script:** information that progresses players through the game
- **Round associated Count-down Timer:** gives players a countdown clock for each round of play, motivating them to solve problems in a timely manner.
- **Help button:** includes definitions of key terminology.
- **Rules button:** provides information on how the game is to be played.
- **Rounds 1-7**
- **Triage Speed Rounds**
- **Triage Code Buttons**
- **Patient Information Display**
- **Patient Image:** possibly includes either AR, video, photo or illustration elements
- **Goals Tally**
- **MCI concepts animation**
- **Video explaining game rules and mechanics**

Step 2: User Interface Design

A ***flowchart*** (*refer to appendix E)* was created to represent player progression through the Digital Facilitator. ***Wireframes*** *(refer to appendix F)* were then created to represent each screen of the application. Each screen was assigned a function within which to place various categories of information. This step served as a rough visual guideline for further application development and also provided a platform through which the first round of quality assurance testing would occur. Finally, a ***style guide*** (*refer to appendix G*) was created for the game (both physical and digital) as a template for further development. Due to the time-constraints of this research, development of the digital game stopped at the creation of style guide.

RESULTS

Mock-Ups

The "mock-ups" of the game board represented in this section provide an opportunity to review how the final design (referred to as the "Final Prototype") will work in the world it will inhabit once printed. Printable dimensions constrained both the graphic design and dictated the layout of all game elements throughout the development of the physical board game. Mockups shown of the Final Prototype are intended to facilitate a final visual and content review as well as an assessment of functional cohesion of all game elements before committing to the expense of professional printing.

Rationale for Graphic Design and Color Choices

The Action Cards were the most understandable element of the Operational Prototype. The color saturation of the blue background on the game board, room cards, and role mat was increased to create more visual contrast in the final version of the physical game. The increase in color saturation and subsequent contrast widened the range of colors among other game elements and allowed for more dynamic and visually engaging storytelling throughout the game. This change also served to provide a sense of urgency throughout gameplay as well as unify the look of the game.

Supply Card Changes

In the Final Prototype of the Supply Cards (*shown in Figures 23-24*), titles were changed from First-Aid, Specialty Medical, and Medical Equipment Kits to First-Aid & PPE, Specialty Medical, and Medical Equipment Supplies. These changes were made to better reflect the content in each category and to suggest that the cards represented individual items instead of groups of items. Additionally, Medical Supply card illustrations were re-done to match the illustrative style of the Patient Triage Cards and Role Mats.

Patient Triage Card Changes

Patient Triage Cards (*shown in Figures 25-26*) changed drastically between the Operational Prototype and the final version. In the final, patient visualizations shifted from a universal line drawing, where injury sites were represented with an "x," to detailed illustrations of the patient as they come into the hospital. In these

new illustrations, the patient is distinguished from environmental elements by being rendered in highly saturated colors and by being surrounded in a white glowing highlight. Patient injuries are now also rendered in detail. The text within Patient Details, Vitals, and Symptoms on the reverse side of the card was reduced to include only the most necessary information required for triage. The background color of the cards was changed to green to differentiate Patient Triage Cards from other game elements. The green color helps to maintain visual continuity between the related functions of the "Patient Intervention" Action Card (which is also green) and the Patient Triage Card.

Action Cards

Action Cards (*shown in Figures 27-28*) worked as intended in the Operational Prototype and thus were not changed for the final design of the game board.

Role Mat

The Role Mat (*refer to Figures 29-30*) changed significantly between the Operational Prototype and the final version. First, the size of the Role Mat was increased to 18 x 8.5 inches in order to accommodate the illustrations and the action cards at the top. The "job description" on the mat was modified to be include possible actions. Corresponding illustrations were created that visualizes possible actions for each role. The list of Action Cards to be collected by each role was integrated with what was formerly known as the "Play Action box." Now, all corresponding Action Cards are placed on the Role Mat facedown at beginning of play. As Action Cards are played throughout a round, they are flipped over before being cleared to the "Used" box at the end of each round. To increase visual "empty" space on the mat, Patient Influx Codes were moved to the main Game Board. Triage Priority Levels were revised to follow similar layout formatting to the Patient Influx Codes. Each priority level now includes the same three categories in the same order: representative symptoms, priority level in words, and subsequent required actions.

Rule Set

The Rule Set was converted from a text document (*shown in Appendix B*) to an illustrated booklet (*refer to Figures 31-32*) in order to increase clarity of the instructions and follow a similar graphic style to other game elements.

Game Board Mock-up

As previously mentioned, Game Board and Room Card color saturation was increased. The "Influx" game logo was added onto the board in place of the board title. The "Central Supply" Room Card was removed and in its place, the Central Supply box on the game board was expanded to provide a location for placement of Supply Cards during gameplay. During gameplay, additional cards such as the Room Card, Patient Triage Cards, and Supply Cards are placed on the box in the Game Board for the corresponding room to which patients are triaged. (*refer to Figures 33-36*).

Digital Facilitator

Future versions of the game will include a Digital Facilitator (*refer to Figure 37*). The Digital Facilitator will serve both to facilitate gameplay and aid in the psychological and environmental fidelity of the game in several ways. A series of auditory clips and instructional videos can be integrated into gameplay through this application. Additionally, the digital application can integrate with the physical game by scanning illustrations on the front of the Patient Triage Cards so that patient vitals can change throughout the game. Scripted audio files can also be linked to a timer so that they que at specific intervals, further engaging users and accelerating gameplay. These functions can also increase facilitation consistency across training sessions, thus possibly decreasing variation in the delivery of educational content. Finally, the digital facilitator function can be used to track player and team progression throughout the game and report data on participant performance.

Figure 23. Supply Card Mock-up, Final Version.

Figure 24. Supply Card Detail, Final Version.

Figure 21. Patient Triage Card Mock-up, Final Version.
(Shown for layout purposes; text not intended to be read)

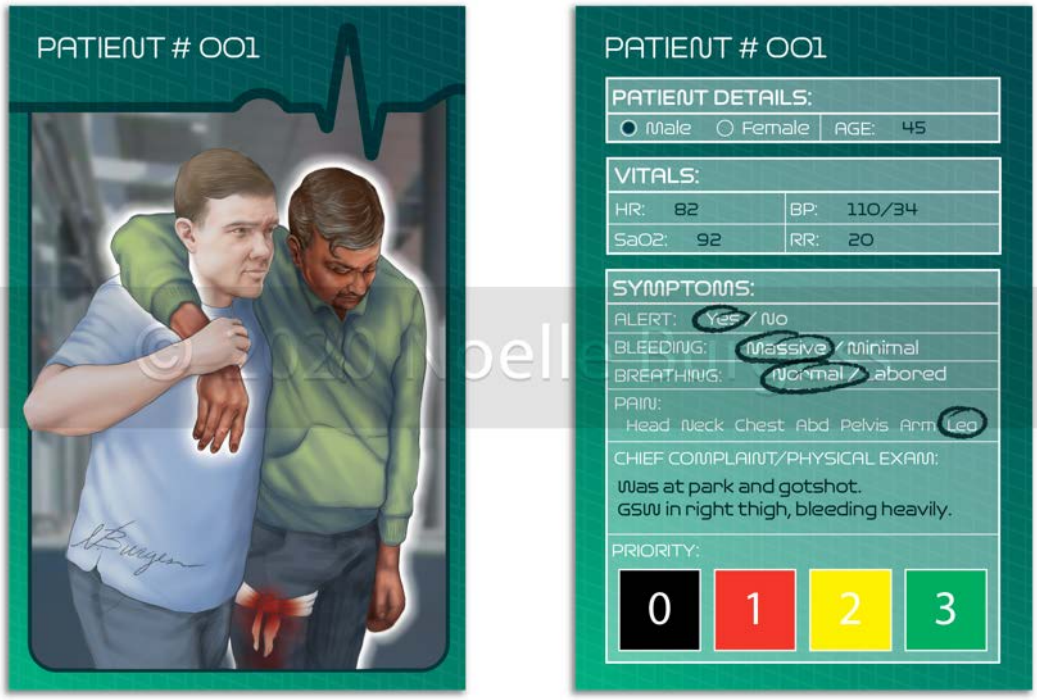


Figure 22. Patient Triage Card Detail, Final Version.

Figure 23. Action Card Mock-up, Final Version

Figure 24. Action Card Detail, Final Version
(Shown for layout purposes; text not intended to be read)

Figure 29. Role Mat Detail, Final Version.
(Shown for layout purposes; text not intended to be read)

Figure 30. Role Mat Mid-Game, Final Version.
(Shown for layout purposes; text not intended to be read)

Figure 31. Rule Set Mock-up, Final Version.
(Shown for layout purposes; text not intended to be read)

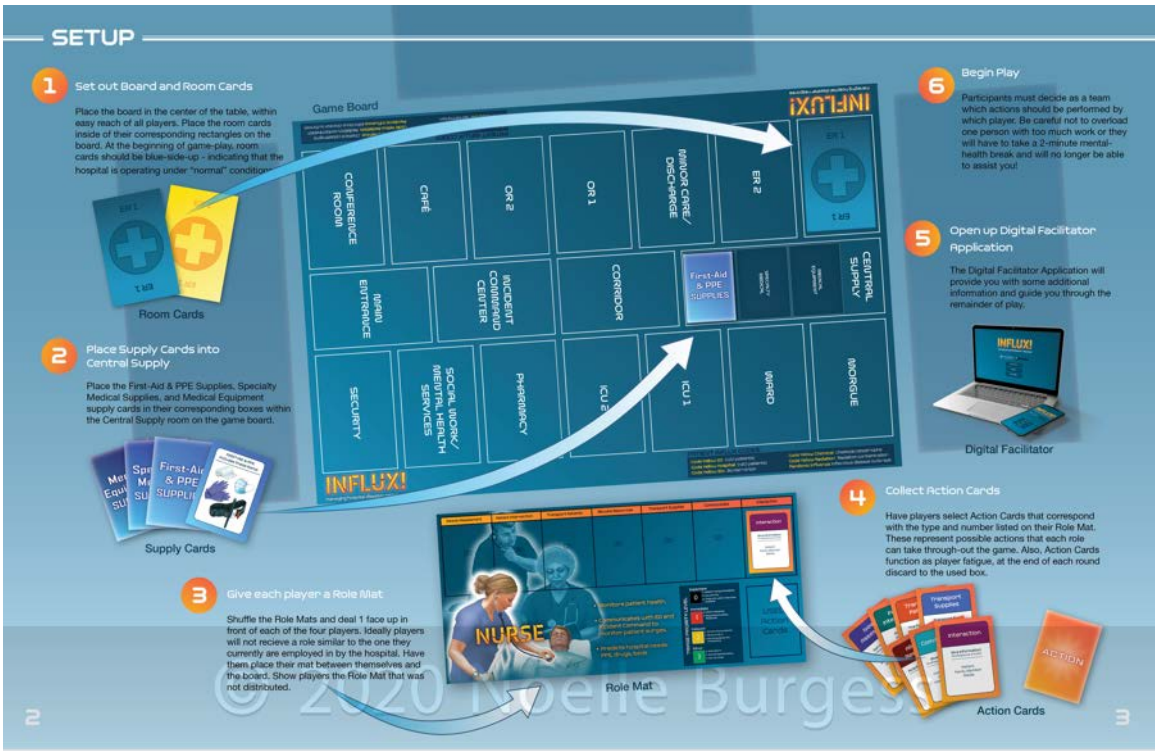


Figure 32. Rule Set Detail of Setup Spread, Final Version
(Shown for layout purposes; text not intended to be read)

Figure 25 Game Board Mockup Mid-Game, Final Version
(Shown for layout purposes; text not intended to be read)

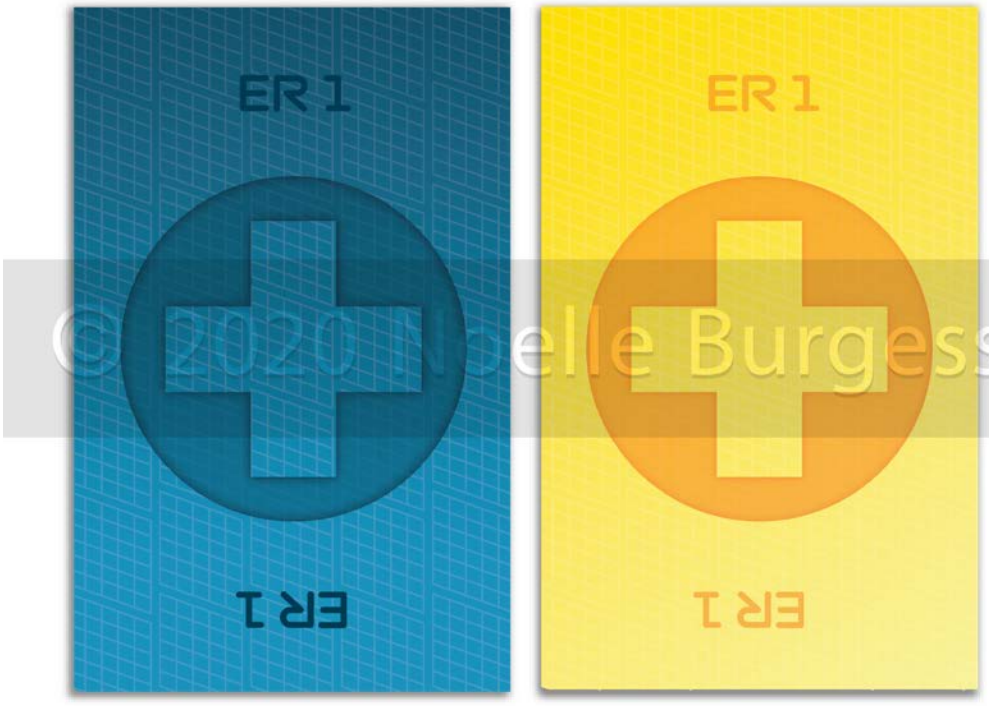


Figure 34. Room Card Detail, Final Version

Figure 26. Game Board Detail, Final Version.
(Shown for layout purposes; text not intended to be read)

Figure 27. Game Board Mid-Game, Final Version.
(Shown for layout purposes; text not intended to be read)

Figure 37. Digital Design Mock-up
(Shown for layout purposes; text not intended to be read)

Access to Assets Resulting From This Thesis

Images resulting from this thesis will be partially found at www.burgessbiovis.com. Access to other files can be granted by contacting the author at burgess.biovis@gmail.com or through the website of the Department of Art as Applied to Medicine at Johns Hopkins University School of Medicine: http://medicalart.johnshopkins.edu/.

DISCUSSION

Testing of Project Goals

The primary goals of this research project were to create a training tool that increases knowledge of MCI protocol, strengthens inter-professional communication, and improves team-based problem solving among intra-hospital staff. With these primary goals and the target audience in mind, repeated episodes of functionality testing and game modification occurred throughout game development culminating with the testing of the resulting board game using the target user audience. The information collected during testing through the pre/post knowledge test, game playability and satisfaction survey, and observational data was shared with the author in a generalized format to inform decisions made during this period of research and for and future game development.

Pre/Post-Test Knowledge Questionnaire

The main focus of iterative game development up to the point of the pre/post tests and surveys had been on establishing facilitator scaffolding and general game-mechanics necessary to engage in collaboration and team-based decision making. During this process, some consideration was given to incorporate specific game elements meant to reinforce knowledge of disaster response. Examples of this include Patient Triage Cards with data of vital signs used for triaging and using the typical arc of MCI patient influx throughout the timeline of game rounds.

As of now, there is not a significant increase in participant knowledge based on the pre and post-tests. This result is not surprising given that additional instructional content has yet to be developed and specifically taught as part of the pre-game experience, in order to meet the stated research project goal of increasing knowledge of MCI protocol.

Post-Test Satisfaction Survey

Knowledge gain is one goal of the project and the other is to provide an enjoyable, collaborative learning experience to practice intra-hospital disaster response that could be recommended to

others. The storyline was found among users to be realistic and there was an overall sentiment that knowledge of MCI subject matter had been bolstered through the gaming experience. This suggests that the game was successful in generating enough psychological and environmental fidelity to engage participants in the scenario. During gameplay, it was observed that participants engaged in discussion about the material with enthusiasm. The game was successful in facilitating a team-based approach to decision making between individuals who perform different roles within the hospital. It also peaked participant interest in further learning MCI protocol.

Considerations

Cognitive Load

The visual and mechanical elements of this board game expanded and contracted organically as development progressed through the iterative design process. The generation of new game elements, particularly in Prototype Three, resulted in an overwhelming demand on participant working memory capacity. As game interactivity increased, the volume of content could no longer be simultaneously processed by multiple participants. Thus, steps had to be taken to reduce the quantity of visuals in the game and streamline gameplay mechanics where possible through the next two rounds of prototyping and testing.

The degree to which participants (both player and facilitator) experienced cognitive load during gameplay had a significant impact on the design of the game. ***Cognitive load*** is defined as "the total amount of mental effort used for learning." (Paas, 2003) There are three categories of cognitive load: intrinsic, extraneous, and effective.

Intrinsic cognitive load is driven by material interactivity. The more interactive learning material is, the more simultaneous processing of information must occur, and the greater the demand on an individual's working memory capacity. Board games have a high degree of inherent interactivity. This means that the intrinsic cognitive load a participant is being subjected to needs to be consistently managed and considered throughout every stage of development. Additionally, intrinsic load increases with the novelty of the concept being taught. When material is new, an additional load is placed on working memory which has limited capacity.

Extraneous cognitive load is additive in nature, and refers to the level in which instructional design interferes with the ability of a student to understand content. If students must search for the information necessary to solve a problem, the level of working memory capacity dedicated to the task is also increased. When the intrinsic cognitive load of a task is already high (as it is in board games) and participants must also search for necessary information, they may become overwhelmed and struggle to absorb instructional content. In this case, it is best to streamline the process of information gathering for students. For example, in early designs of the board game, there were many different cards, each with a high volume of text. Participants found the extraneous cognitive load imposed by the instructional design to be overwhelming. In subsequent iterations of the game, number of cards were reduced, text was edited down, reformatted, and replaced with images where possible. For example, the Role Cards and Player Mat were once separate game elements. The insights provided by functionality testing prompted unifying these two elements into one, the Role Mat. In addition, the Role Mat was reformatted for the final game version after the first Quality Assurance test was held. Information provided on Supply Cards was provided via images instead of text. The increased efficiency with which participants could process information decreased overall cognitive load.

Effective (Germane) Cognitive Load refers to the manner in which the instructional design enhances the ability of students to process educational materials and translate it into long-term knowledge. The addition of Action Cards is prime example of game design that enhanced the ability of students to process educational materials. Action Cards allowed participants to associate a physical item with an abstract concept. This provided the foundation upon which to practice team-based problem solving and engage with the material through multiplayer task-based interaction. This process translates previously learned knowledge into practicable actions, and then subsequently into long-term memory. (Paas, 2003)

Iterative Approach to Design

The use of an iterative game design process throughout game-development was useful in that it helped to gradually refine instructional material. Since the concept of teaching and practicing hospital preparedness protocol through gaming is novel in nature, it was important to use a development methodology such as iterative development, that was agile and user-driven in its approach. In addition, individual game-mechanics could be developed simultaneously throughout the iterative process. However, since the iterative design process is cyclical, it is a time consuming and frequently redundant process. The labor intensive nature of developing the board game left little time for developing digital elements that could enhance the psychological and environmental fidelity of the game. Therefore, these elements may be approached using a different development methodology in future development.

Educating through a Serious Gaming Format

A person intending to replicate parts of this project or adapt it for different applications should consider the limitations and difficulties associated with teaching highly complex information (such as MCI preparedness policy) via a board game format. In this instance, the instructional goals of building communication, team-work, and team-based decision making skills were well served by a game-based approach to instruction. In its current design, the game was found to be fun and engaging. The way that the storyline progressed round by round regardless of whether participants accomplished their goals was found to be realistic and kept participants on their toes. Subplots associated with the Patient Triage Cards that were found to be fun. Examples of these storylines include a patient with a weapon who needed to be triaged to be managed security, a distressed mother who had lost her child, a distressed child who had been separated from her mother, a falafel truck owner with a shish kebab impaled in his shoulder. For each new element of the larger story and its associated subplots, participants had to collaborate, make decisions and communicate to delegate necessary actions – fulfilling two of three major objectives for the game. These skills are realistic, representing real hospital disaster response requirements.

It is important to note that generating an instructional game is more time and resource heavy than creating an online learning module. When considering game methodology as a delivery method for instructional materials, it is important to evaluate the ratio of cost to educational benefit. The use of serious gaming to enhance learner engagement and provide a platform through which to practice MCI response warrants the cost of this development process. In addition, the use of a table-top delivery method such as a board-game allows for face-to-face interaction with other participants. This face-to-face contact is an important element of real "in-the-trenches" team-based problem solving and multi-disciplinary collaboration.

Future Suggestions to Increase Learning

In future iterations of this learning tool, it will be necessary to expand upon the depth and breadth of certain instructional elements of the game. In its current state, the game primarily functions to practice intra-departmental communication and teambuilding in the context of MCI. While some information is being taught during gameplay, it is clear that more comprehensive instructional content is needed to achieve the goal of instruction. Future development of this project will include additional learning content provided through the integration of knowledge content, questions, expanded learning outcome-oriented subplots, and in-game repetition of the most challenging and important learning outcomes. The following section of discussion addresses areas for further investigation in pursuit of achieving primary desired learning outcomes.

Extended Time for Training Delivery

Participants noted on the post-test satisfaction survey that they found the storyline convincing and the provided information useful, but that the time dedicated to instruction felt rushed. During the iterative process undertaken to develop the game, instructional content had to be reduced significantly in order to meet the 60-minute game-time limit and decrease cognitive load. At this current "pared down" state, the game primarily functions as a platform for engaging in and practicing elements of MCI protocol – not as a primary method for teaching knowledge of MCI protocol. If training occurred over a longer period of time (90 to 120-minutes) the incorporation

of pre-game or integrated knowledge modules could effectively provide the learning material necessary for acquisition of knowledge.

Modifying Patient Triage Cards

During the first Quality Assurance Test, it was discovered that gameplay was largely overwhelmed by time spent on the triage element of the game. Learning and practicing core concepts of triaging patients, while among the goals of the game, was not the only desired educational outcome. Future revisions of the game will include tactics to simplify triaging such as the reduction of written information on triage cards. If each patient triage card is treated by developers as an opportunity to present additional desired instructional content, it is possible that greater instructional value can be woven into the process of triaging. This can be done by building interlinking storylines for triage patients that reinforce learning content. For example, initial notification of an MCI may come from casualties who self-transport to the hospital. Having the first notification of the MCI in-game come from an ambulatory casualty who walks in off the street places desired instructional content into context and provides space for game-participants to revisit previously learned material and apply the sort of team-based decision making necessary for MCI response. These changes could make better use of game-time.

Developing a Digital Facilitator

Development of a Digital Facilitator will decrease variation in game instruction delivery and may increase immersion of participants in the game. Currently, facilitators are in charge of delivering introductory information, setting time-limits on rounds of play, distributing triage patient cards, tracking achievement of goals, and reading/playing audio prompts that provide hints on how the game should progress. Integrating this content into an automated delivery system with a pre-programmed game time limit will prevent improvisation done by human facilitators and may improve predictability of learning outcomes.

Additionally, increasing environmental and psychological fidelity of the game may increase participant immersion. For example, pertinent data contained in Patient Triage Cards

could be programmed to change over time. In-game incorrect priority classifications by participants can be linked to worsening patient conditions as gameplay progresses.

Integration and Implications for Medical Education

Simulation is highly used in medical education. Surgical trainers, manikin-based training, exam room simulation, standardized patient programs and serious games are examples. The use of a serious game format to practice team-work for large-scale, highly dynamic situations in mass casualty response offers the opportunity to engage more hospital workers in rehearsal than by other simulation techniques. This research indicates there is great potential to improve inter-disciplinary communication, team-based learning and participant engagement during in-hospital training for MCI scenarios.

APPENDICES

Appendix A: Team Goals *(by Round of Gameplay)*

ROUND 1 GOALS:

1. Understand the base concepts of Triage
2. Localized incident command set up with administration
3. Notify clinical departments: ED, trauma for Peds & Adults, radiology & shift coordinators
4. Ask for needs assessment of incoming patients and time-line
5. Ask for needs assessment for ED capacity
6. Partial mobilization of incident command
7. Partial mobilization of staff: ED trauma nurses, radiology, public affairs
8. Partial mobilization of security
9. Acquire/Prepare additional supplies
10. understand base concepts of code yellow ED vs. code yellow Hospital
11. Declare code yellow ED
12. Make public affairs aware of incident

ROUND 2 GOALS:

1. Activate Hospital Incident Command
2. Call code yellow hospital & page overhead
3. Conduct Needs Assessment for hospital
4. Discharge people from their units where possible
5. Stop elective OR & radiology
6. Notify staff & call-in essential staff
7. Deploy clinical teams to Clinical OR, Main Adult ED, Peds ED
8. Establish contact with other hospitals
9. Go on ED diversion
10. Contact materials management for more PPE & Supplies

ROUND 3 GOALS:

1. Triage + Treat Patients
2. Move Patients Around
3. Expand available space to accommodate more patients
4. Secure perimeter/crowd control
5. Attempt to Resupply

ROUND 4 GOALS:

1. Maintain contact with other hospitals
2. Needs assessment: open ICU/OR beds check
3. Borrow supplies
4. Re-supply
5. Media/crowd management
6. Triage

ROUND 5 GOALS:

1. Staff management – getting more fatigue mitigation; food
2. Family management
3. Advanced triage
4. Definitive Treatment - ICU, OR, Home, Psych Liaison, Morgue
5. Ongoing security

ROUND 6 GOALS:

1. Send excess staff home
2. Begin elective procedures again
3. Bring in new staff
4. De-escalate security
5. Restock supplies
6. Laundry/Room Flips

Appendix B: Rule Set (*Operational Prototype*)

INTRODUCTION

It is a sunny Thursday afternoon in April. People are out enjoying public events in the city when suddenly, tragedy strikes! A mass shooting has occurred, and your hospital is the closest to the vicinity of the incident. As a group of professionals in the medical field, you must work together to manage a hospital through the *Mass Casualty Incident Protocol* - set in place for incidents such as these – to maximize your hospital's capacity to accommodate patients, saving as many lives as possible.

This card game is designed to train professionals in the medical field for MCI Protocol by simulating a high influx of patient traffic entering your hospital. By progressing through the game, players will be familiarized with responsibilities of different hospital staff, stages in activating Incident Command, crowd control practices, as well as opportunities to practice communication, collaboration, and at times, delegation.

PRE-GAME (SET UP)

Each game has a facilitator and 4 players. The *Hospital Board* must be set up with the **blue** side of the room cards facing up. These room cards will be flipped to the **yellow** side during the game, if the corresponding room is activated. With each player's deck of cards placed beside the Player Mat, briefly discuss each active role: their primary jobs, advantages and disadvantages. This will be important during play!

The Game Facilitator should shuffle the mats and place them on the table face down, participants should select roles at random from the pile. Once the 4 Player mats have been distributed to participants, there will be a role that is not active.

Ideally, players should receive a role that they are not familiar with (e.g. a Medical Technician should play as any of the roles that are not 'Tech', since that matches their job description the most) in order to familiarize themselves with responsibilities of other staff during MCI.

ROLES

Each player must read the *Job Description* in their player mat. Players must select the appropriate amount of different *Action Cards* in hand, which vary according to their role.

Admin

Assess availability of space, staff and stuff. Coordinates and Communicates with Physicians, Incident Command, and all other hospital departments as relevant. Receives *Available Beds per Room List* at the beginning of the game *ACTION CARDS: Needs Assessment (5), Transport Patients (1), Allocate Resources (5), Communicate (5), Interaction (5)*

Doctor

Triage and provide care for incoming and outgoing cases. Communicate with ED and Incident Command to monitor patient surges. *ACTION CARDS: Patient Treatment (3), Needs Assessment (5), Transport Patients (5), Allocate Resources (3), Communicate (3), Interaction (3)*

Liaison

Communicate with patients, families, and the media. De-escalate contentious situations. Keep the crowd controlled to optimize hospital operations. *ACTION CARDS: Communicate (7), Transport Patients (1), Needs Assessment (3), Interaction (5)*

Nurse

Monitor patient health, location, and needs. Communicate with the ED and Incident Command to monitor patient surges meet predicted needs. *ACTION CARDS: Needs Assessment (5), Patient Treatment (2), Transport Patients (1), Allocate Resources (5), Transport Supplies (5), Communicate (3), Interaction (3)*

Tech

Predict equipment and supply needs and deliver them when and where needed. Transport patients. *ACTION CARDS: Needs Assessment (2), Transport Patients (5), Allocate Resources (3), Transport Supplies (5), Interaction (3)*

THE FACILITATOR

Similar to the esteemed Dungeon Master in *Dungeons and Dragons* campaigns, The Facilitator's role is to advance the story as the rounds progress, track goals specific to the round, and relay information to the players when requested (as an in-game action). They must read from the *Facilitator Script* provided with the game, which outlines a Mass Casualty scenario.

As is the case of all Mass Casualty Incidents, information is not readily accessible while the incident develops. As such, the facilitator must *withhold* certain information from players until they have taken the appropriate actions in-game (e.g. a player using the Needs Assessment action card to ask about the number of incoming patients). Additionally, round-specific goals must also be withheld from the players. The goals are meant to track players' knowledge of the protocol, as the Facilitator can inform them of what they did right or wrong when a round concludes. The Facilitator will have a script to read from and a list of goals to check for each round. For reference during gameplay, a copy of the MCI Protocol document is also available at all times during the game. For more information on facilitating, please consult the *Facilitator Script*.

ACTION CARDS

Action Cards are the representation of explicit actions taken in a round of *Incident Command Game*. As mentioned, each role has a specific number of each action card. When playing an action card, each player must place it on the area of the Player Mat that says *Played Action Cards*.

Once a player has finished their actions for that round, they must place their used cards on the *Used Cards* space in the Player Mat. In any round, a player can use as many Action Cards as desired, *at the expense of losing those cards for the rest of the game*. If a player uses all of their Action Cards, they must report to the *Mental Health* room for 2 minutes during which they cannot participate in gameplay. Afterwards, they regain all their cards.

TRIAGE PATIENT CARDS

During gameplay, the Facilitator will hand a stack of *Patient Cards* on rounds that have incoming patients. Representing patients affected by the Mass Casualty Incident, these Patient Cards must be triaged (Green, Yellow, Red, Black), placed in the correct *Room Card* of the hospital board, and given the proper *Supply*

Kit card. As the game progresses, triaged patients must be moved to other areas of the hospital depending on the treatment needed.

Each Patient Card has a visual representation of area of impact in the front, a list of vitals in the back, and chief complaints, and so on. Based on the information provided, players must decide how to triage these patients.

PLAYING A ROUND

Each round has a list of goals to be met. Designed to match the MCI Protocol Document, these goals are seen only by the facilitator. Players must work together to meet these unknown goals, whether by consulting the document while playing or by other means, while also accommodating and treating incoming patients.

Every round begins with an information update from the Facilitator. After the Facilitator reads the script, play begins. Players can plan amongst themselves, use Action Cards in anticipation of potential needs or to meet a goal, or consult the Facilitator for more information using the *Needs Assessment* action card. It is recommended that players strategize about how to distribute the workload, or risk a player sitting out for two minutes if too much work is placed upon them.

On rounds that require Triage, the Facilitator will hand out a deck of *Patient Cards*. Players must work together to correctly triage these patients and place them in the correct areas of the hospital. As these areas are utilized, players must flip them from blue to yellow, indicating that the area in question is *activated*.

As Round Goals are accomplished, the Facilitator will move the goals token to indicate player progress and *read out the goal that was just accomplished*. When the time is up for each round, the Facilitator should read out the goals that were not accomplished in the allotted time (if any).

DEBRIEF

As the game concludes, have players self-assess their ability to progress through the game, some of the gaps in knowledge, and difficulties that players dealt with throughout the game. Discuss decision-making errors made throughout the game and penalties/repercussions associated with those decisions, as manifested both in-game and what hypothetical real-life repercussions.

Appendix C: Facilitator Script *(Operational Prototype)*

GAME SETUP:

<<<<< 5 min. time limit >>>>>>

Board Set-Up (to be done before players show up):

Place Game Board in center of table in a location where everyone can see and reach it. Each room card should be placed within appropriate box on incident command board.

Room Cards:

As rooms are being diverted from day-to-day operations and incorporated into the disaster plan - cards must be flipped from blue (Normal) to yellow (Code Yellow Hospital).

Role (Player Mat) Distribution:

The Game Facilitator should shuffle Player Mats and place them on the table face down. Participants should select roles at random from the pile. Once the 4 Role Mats have been distributed to participants, make sure to **point out the role that is missing**. Listed on each Role Mat is a short "job description" with a list of actions that each role can perform and number of times it can be performed (e.g. "move patient (3)")

Action Cards:

Ask players to select action cards from the stack in quantities corresponding to the number in parenthesis on their Role Mat (for this example, the player selects 3 "move patient" cards). Un-played Action cards should be placed directly on the table. There are 7 possible Action card categories: Allocate Resources, Patient Intervention, Patient Transport, Communicate, Needs Assessment, Interaction, and Transport Supplies.

Participants must decide as a group which actions need to be performed by each player. When coordinated decisions have been made about how to proceed, appropriate Action cards should be played by individual participants. At this time, they should also formally state which action is being performed to the facilitator.

As each card is played during the game - it should be moved into the "Play Action" box on the Player Mat. At the end of each round, participants should clear the cards in the "Play Action" to the "Used" box on the Role Mat.

Fatigue Points:

Action cards also function as player fatigue points. Each Role gets a finite amount of action cards for the entirety of the game. If a player runs out of action cards, they will have to report to "Mental Health Services" for 2-minutes. During this time the player cannot contribute any action cards to gameplay and the remaining participants must compensate for their absence. After the 2-minute penalty period is complete, the participant may bring all of the action cards in the "Used" box on the Player Mat back into gameplay.

Hospital Beds:

The player in the Administrator role will get a list of rooms with available beds. The Administrator is in charge of determining available bed space and coordinating reverse triage with players in the Nurse or Doctor role categories. If no one plays as an Administrator, then the Nurse gets the chart and is in charge of coordinating patient placement and reverse triage.

Goals

As successive Goals for each round are accomplished, the Facilitator moves the token on the Goals Board to indicate player progress and announces which goals were accomplished . When time for each round ends, the Facilitator announces goals not accomplished in the allotted time (if any).

<<<<< GAME SETUP COMPLETE @ 5 minutes>>>>>>

ROUND 1:

Starting Play / Partial Hospital Mobilization

<<<<< 10 min. time limit >>>>>>

INTRODUCTION:

Read the following statement:

Your mission today is to collaborate to solve problems. As the game progresses, make full use of your teammates and resources provided to find solutions to problems. I will be guiding the first round of gameplay in order to introduce all the game elements. After that, you will be on your own to make decisions and take actions.

Okay, let's begin play!

Here's the scenario:

It is 2pm on a beautiful Thursday afternoon in April. People are out enjoying the unseasonably warm weather in droves. There are a number of public events occurring around the city: a concert at the amphitheater downtown, a craft show at the local Farmers Market & Bazaar, and a Food Truck Rally in a nearby park.

In spite of the beautiful weather outside – emergency admissions are normal and your day has been running pretty smoothly so far.

You're taking a quick coffee break with some coworkers at the cafe near the main entrance of the hospital. Suddenly, you hear a commotion and turn around. Stumbling through the doors are two men - blood is everywhere.

One of the men yells out:

"Help! My friend has been shot - there was a shooter at the Food Truck Rally! People were dropping all around us - more are running this way!"

ACTIVATION OF PLAY:

Hand the player in Doctor or Nurse role the Orange Triage Card - this is the first patient.

This is your first patient - you will need to triage, apply an intervention (if necessary), and transport them to the appropriate location.

1. **Triage:** This is an assignment of priority to wounds/illnesses needed to manage treating a large number of casualties.

a. **What priority level would you assign this patient?**

b. **Black (0), Red (1), Yellow (2), or Green (3)?** *(have participants refer to triage chart if necessary)*

c. **Who amongst you is responsible for making this decision?**

2. **Intervention:** Now that you have triaged your patient, you will need to apply an immediate intervention. Examples of intervention include packing the wound and applying a tourniquet to stop/slow the blood loss. To perform this action, one person will need to play a **Patient Intervention** card. As you play Action Cards, make sure to place them in the Play Action box on your Player Mat. At the conclusion of each round - clear your cards to the "Used" box on your player mat.

a. **Which one of you should play the Patient Intervention card?**

In addition to playing the **Patient Intervention** card, you will also need to use a **Supply Kit** card. This card represents the resources that must be used in order to treat each patient.

b. **Take a look at the 3 types of Supply Kits available – what kind of Supply Kit will you use?**

You will use the "first-aid supply kit" which contains items that any hospital staff with basic first-aid training will be able to apply.

3. **Transport:** Now that the intervention has been applied it is time to transport the patient to the appropriate location.

a. **Where should you send this patient?**

b. **Which one of you should play the Patient Transport card?**

Before we move this patient, let's anticipate some next steps for management of the disaster that is unfolding at the Food Truck Rally.

How would you coordinate the transfer of this patient to the appropriate department, is there any other information they might want to know?

As a team of intra-hospital personnel, your job is to appropriately prepare and mobilize the remainder of the hospital to meet the needs of the imminent surge of patients. Let's take a look at the remaining cards...

Go ahead and decide as a group which "actions" should be taken next and play them.
Action Cards that can played include one Needs Assessment card, two Communicate cards, and two Allocate Resources cards - allow participants a minute to coordinate who will play which Action Cards).

- ***Communicate (play 2 cards):***
  - ***First Card:*** *this card should be played to let the ED know that there has been an incident in the park and that there are more patients on their way.*

○ ***Second Card:*** *use this card to communicate with Incident Command to make sure that the hospital is aware of what has happened.*

- ***Needs Assessment (play 1 card):***

○ ***First Card:*** *this card should be played to get more information about what is happening at the park. When this card is played, play the following audio:*

"Multiple people have been shot at the food truck rally in the nearby park and police are on the scene. EMRC is headed to scene - our hospital is the closest hospital. At least a dozen patients are on their way by car and foot. We anticipate many more will be delivered by EMRC shortly."

- ***Allocate Resources (play 2 cards):***

○ ***First Card:*** *this card should be played to partially mobilize personnel such as:*

- *ED trauma nurses*
- *Incident Command*
- *Radiology*
- *Public Affairs*

○ ***Second Card:*** *More security should be deployed to anticipate resources needed to manage a moderately sized patient influx.*

<<<<< ROUND 1 COMPLETE @ 15 min.>>>>>>

<u>TRIAGE A:</u>

First Arriving Casualties

<<<<<5 min. time limit >>>>>>

Place 12 Round 1 triage cards on the table. Have participants triage, apply intervention, and move patients to appropriate beds within the hospital.

ED should be declared Code Yellow at this time.

<<<<<TRIAGE A COMPLETE @ 20 minutes>>>>>

ROUND 2:

Prepare for Surge

<<<<<5 min. time limit >>>>>>

UPDATE:

Read the following statement:

Fifteen minutes have passed since the first wounded patient stumbled through the main hospital entrance. You get a call from the Incident Command Center:

"Scene is still active – gunshots have just ended. However, the assailant has not been identified. EMRC estimates 74 casualties ranging from minor to acute. People have been fleeing in all directions by foot, car, and scooter. Patients are imminent – estimated arrival – 5 minutes."

So, it sounds like you have an arriving casualty number well beyond your current capacity. What are your next steps? Remember, as you continue to activate your emergency plan - be sure to play action cards and switch rooms from "normal" to "code yellow."

<<<<<ROUND 2 COMPLETE @ 25 min.>>>>>>

ROUND 3:

Peak Patient Influx

<<<<<11 min. time limit >>>>>>

UPDATE:

Read the following statement:

One hour has passed since you triaged the first patient. The Incident Command Center has another update:

"Media has shown up at the Hospital, the ED is at max capacity and casualties are continuing to arrive to the ER."

You have 11 minutes to triage incoming patients, treat if appropriate, and move them to the appropriate holding area. Don't forget that there are some additional actions you will have to take during this round in order to accommodate the incoming patient influx.

TRIAGE B:

Peak Patient Influx

Deal 30 Round 3 Triage Cards. Have participants triage, treat, and move patients to appropriate beds.

As new rooms get used for incoming patients, Room Cards should be flipped to signify "Code Yellow hospital" status. ICU, OR, Home, Morgue are not usable locations at this time due to the need for advanced assessment.

<<<<<ROUND 3 COMPLETE @ 36 minutes>>>>>>

ROUND 4:

Manage Media

<<<<<5 min. time limit >>>>>>

UPDATE:

read the following statement:

You and your colleagues have been handling the situation for two hours now. Incident Command is on the phone with another update:

"Supplies are running low hospital wide. Media is camped outside the hospital. Some patients are continuing to arrive. Many families are entering the hospital searching for their loved ones. Your ED waiting room is overcrowded with patients, media, and family members"

You have some decisions to make - the faster you make them and take action the more time you have to triage patients. You have 5 minutes to triage and manage the next wave of patients.

TRIAGE C:

Media Managed

Deal 15 Round 4 Triage Cards. Participants continue to triage, treat, and move patients to appropriate beds.

Media and crowd triage cards should be moved to the appropriate location in the hospital once they have been dealt with as well.

<<<<<ROUND 4 COMPLETE @ 41 mins>>>>>>

ROUND 5:

Save the Staff

<<<<<11 min. time limit >>>>>>

6 hours have passed for you and your exhausted colleagues.

"Families are still arriving to search for loved ones. ED and Minor Care has indicated that casualties they have treated are ready for advanced treatment. The shooter is still at large."

You have 11 minutes to take the appropriate steps to deal with the information that you just received and prepare for the process of returning the hospital to normal operations.

<<<<<ROUND 5 COMPLETE @ 52 mins.>>>>>>

ROUND 6:

Return to Normal

<<<<<5 min. time limit >>>>>>

10 hours have passed in scenario time.

"Supplies are once again running low hospital-wide. Media is still camped outside the hospital. Patients are continuing to arrive. Families are also arriving and searching for loved ones"

You have 5 minutes to take the appropriate steps to deal with the information that you just received and return the hospital to normal operations.

<<<<<ROUND 6 COMPLETE @ 57 min.>>>>>>

ROUND 7:

Debrief

Take some time to assess your ability to progress through the game. What were some gaps in knowledge or difficulties you dealt with throughout the game? Discuss errors in decision making made throughout and penalties/repercussions of those decisions. How would these errors play out in a real-life situation?

Appendix D: Scripts for Audio (*Operational Prototype*)

Initial Call

<<<Sirens in background >>>

"Help! Help! My friend has been shot! There is a shooter at the Food Truck Rally, people are going crazy! Oh my God I think I just saw someone die… send help, please!"

<<<Sirens >>>

Round 2

<<<Phone ringing>>>

Woman's voice: (answers phone) "This is Johns Hopkins."

Man's voice: (sirens in background) "Hopkins Hospital this is EMRC. Uh, scene is still active, gunshots have ended, uh, assailant has not been identified. We estimate about 74 casualties ranging minor to acute. People are fleeing in all directions by foot, car, and scooter. Uh, your facility is the closest hospital, patients are imminent. Estimated arrival about 5 minutes. That's all."

Woman's voice: "Thank you."

Round 3

<<<muffled sounds of people talking in the background>>>

Woman's voice: "Incident Command the ED is at max capacity and casualties are continuing to arrive to the ER."

Man's voice (in background): "Media is all over the place, can we find a place for them to go?"

Round 4

<<<Phone Ringing>>

Man's voice: "This is Hospital Incident Command, can you give us an update?"

Woman's voice: "Uh, the media is camped outside the hospital now and patients are continuing to arrive. Families are beginning to arrive and search for loved ones. We're also having trouble getting supplies from the rest of the Hospital."

Round 5

<<<Phone Ringing>>>

Man's voice: "This is Hospital Incident Command, can you give us an update?"

Man's voice (EKG sound in background): "We've stopped elective cases. I've got two adults and three kids in ORs. One OR is ready for trauma. Still running an MTP in one of them. Uh, the PICU and Adult ICU are full – can cross cover in the PACU if we need it. I'll need advanced warning if you've got more to come. The morning staff have been at it for a while. I'll need fresh staff if we keep at this much longer.

Round 6

Man's voice: "This is Hospital Incident Command, ED and OR please advise on status."

Woman's voice: "On the ED end, we have no new trauma patients. We don't expect any more and we're back to normal ED operations."

Man's voice: "This is the OR, we're finishing up our last trauma now."

Man's voice: "OK, we will plan on maintaining Hospital Incident Command for another six hours."

Appendix E: Flowchart for Digital User Interface Design

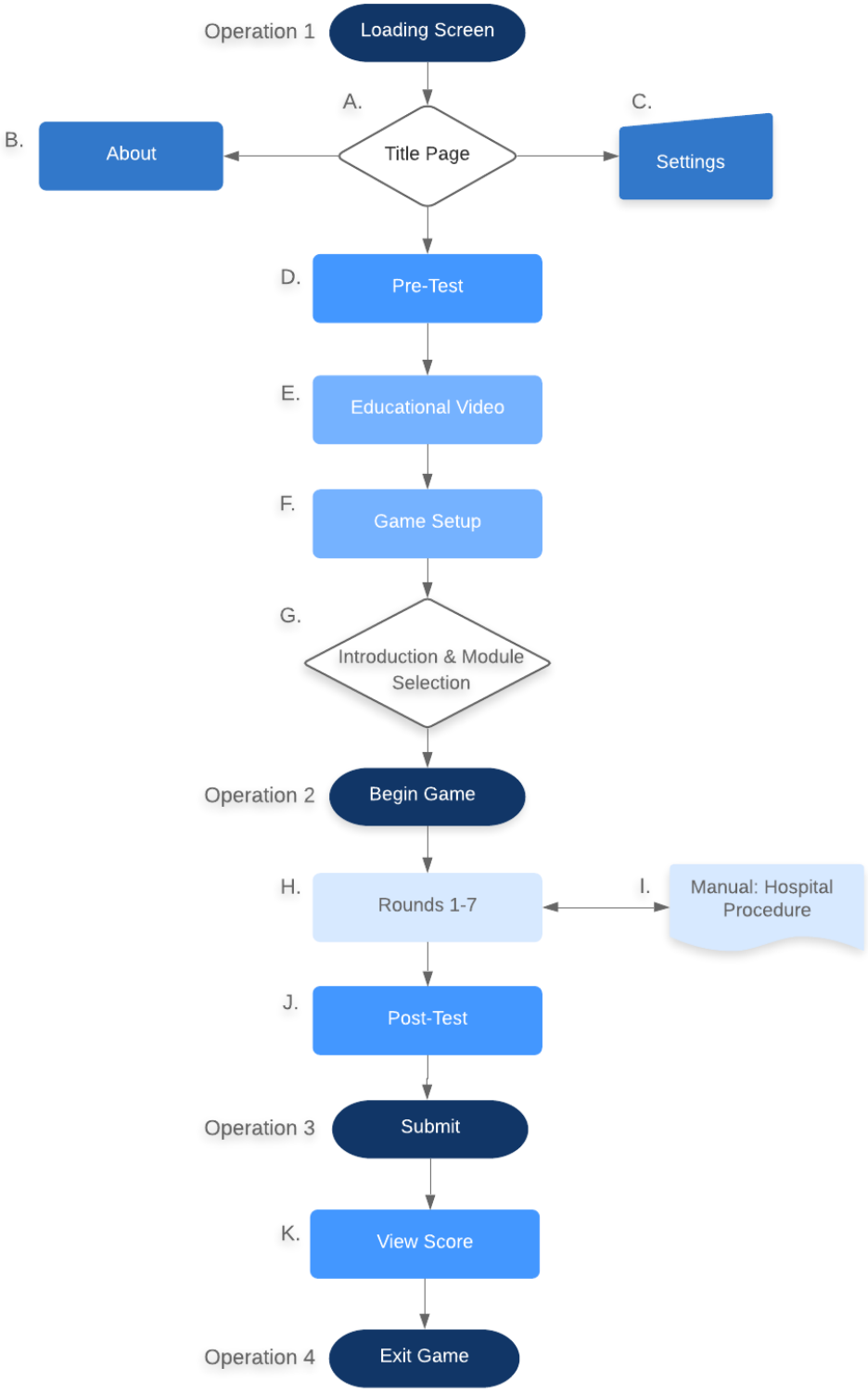


Figure 288. Flowchart for Digital Facilitator

Appendix F: Wireframes for Digital User Interface Design

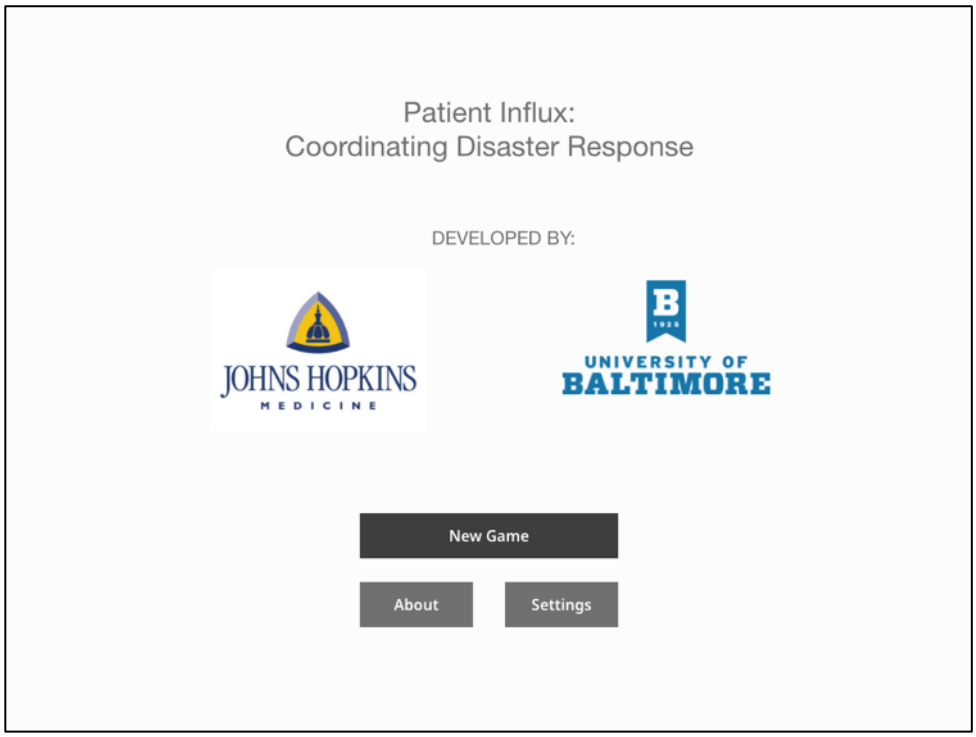


Figure 39. Title Page for Digital Facilitator, Wireframe 1 (A. in flowchart).

Figure 40. About Page, Wireframe 2 (B. in flowchart).

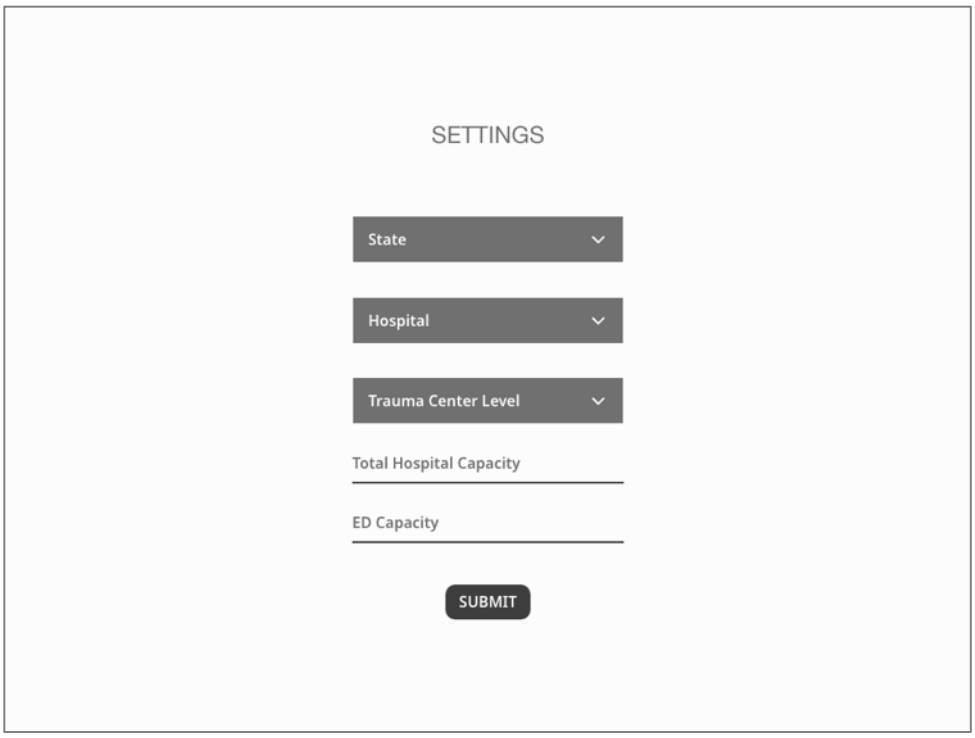


Figure 41. Settings Page, Wireframe 3 (C. in flowchart).

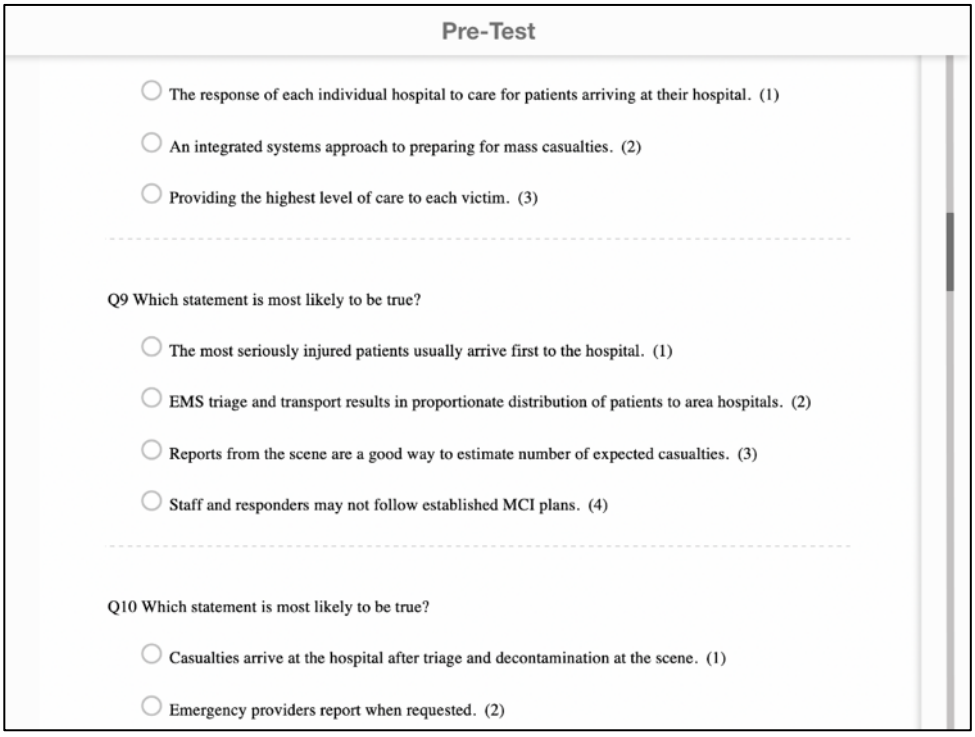


Figure 42. Pre-Test Page, , Wireframe 4 (D. in flowchart)

Figure 43. Educational Video Page, Wireframe 5 (E. in flowchart)

Figure 44. Game Setup Page, Wireframe 6 (F. in flowchart)

Figure 45. Introduction and Module Selection , Wireframe 7 (G. in flowchart)

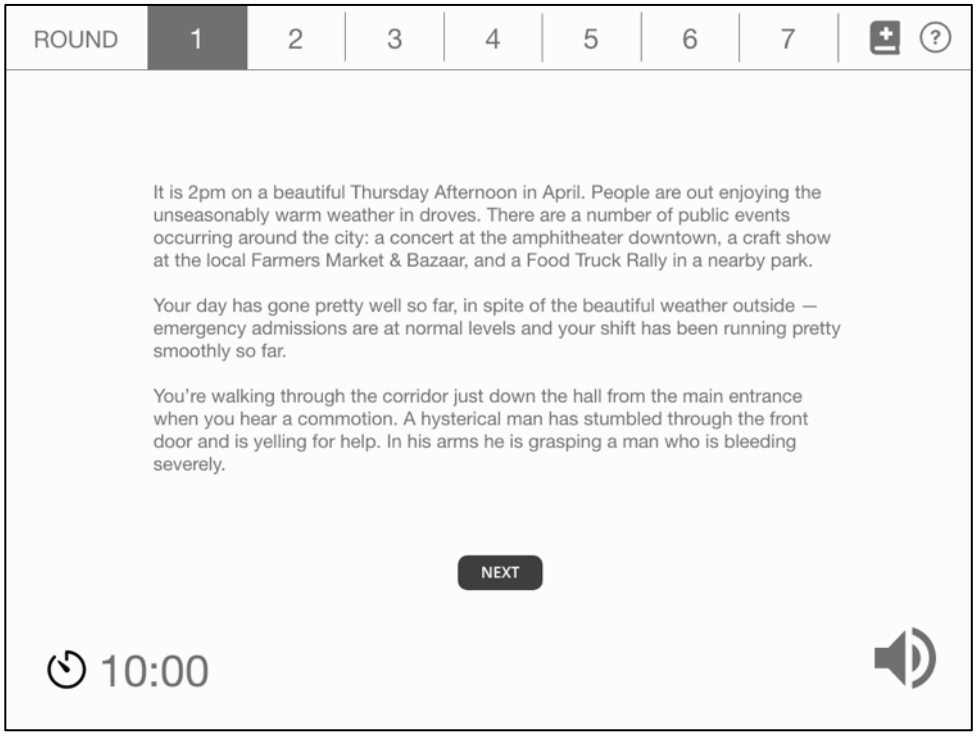


Figure 46. Round 1: Scenario Statement, Wireframe 8. Round 1 scripted audio files played here. (H. in flowchart).

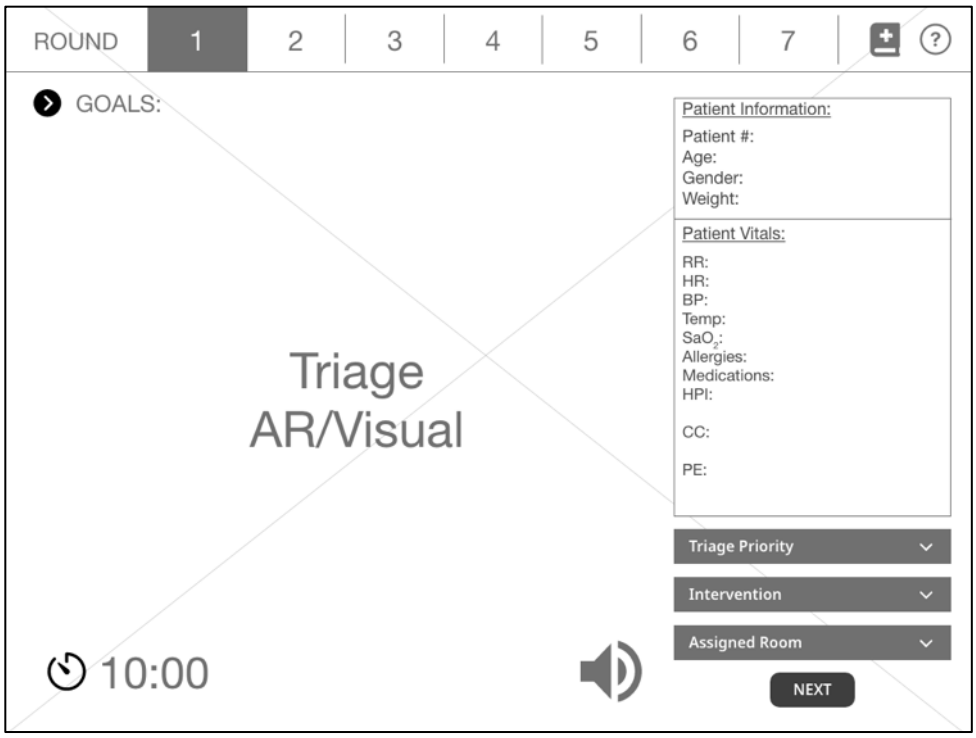


Figure 47. Round 1: Triage of First Patient, Wireframe 9 (H. in flowchart).

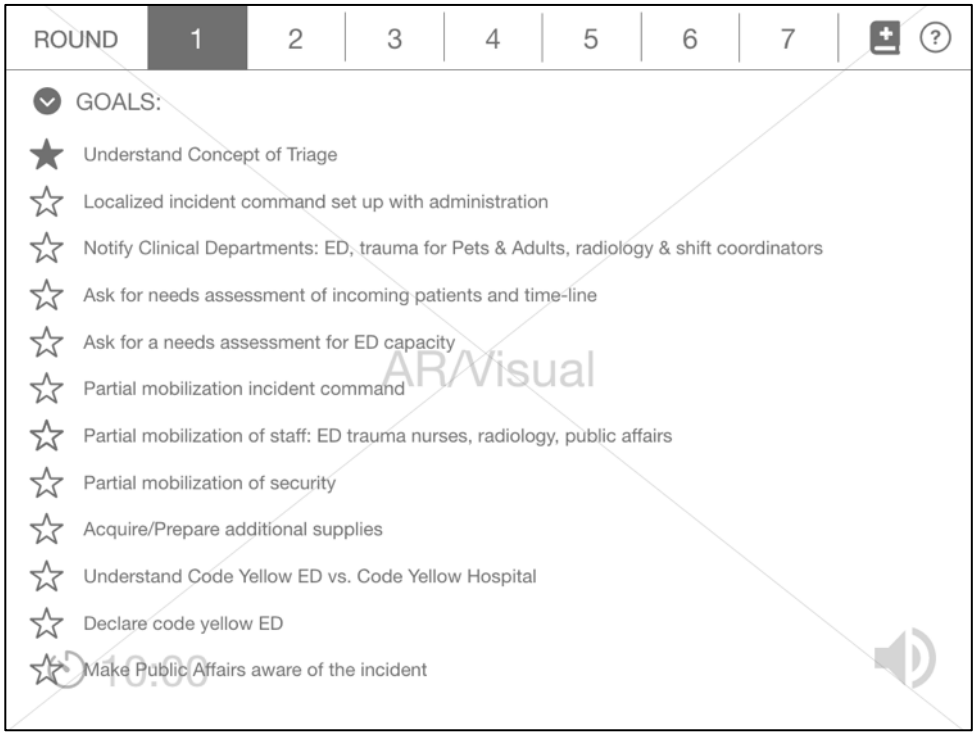


Figure 48. Round 1: Goals Dropdown Menu, Wireframe 10 (H. in flowchart).

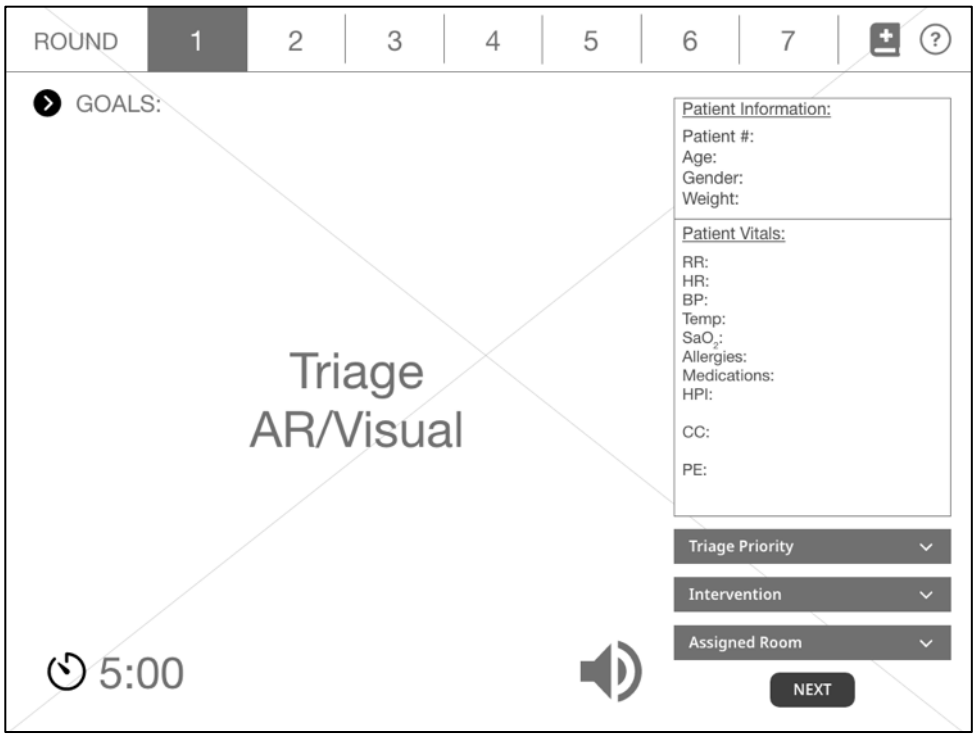


Figure 29. Round 1: Triage A, Wireframe 11 (H. in flowchart).

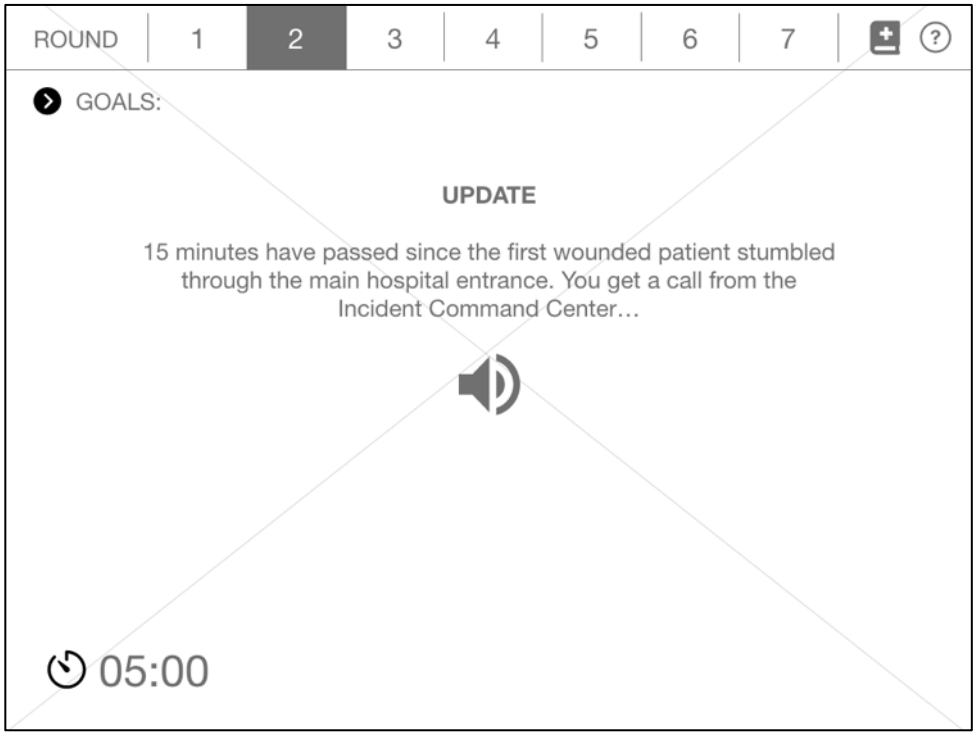


Figure 50. Round 2: Update, Wireframe 12. Round 2 scripted audio files played here. (H. in flowchart).

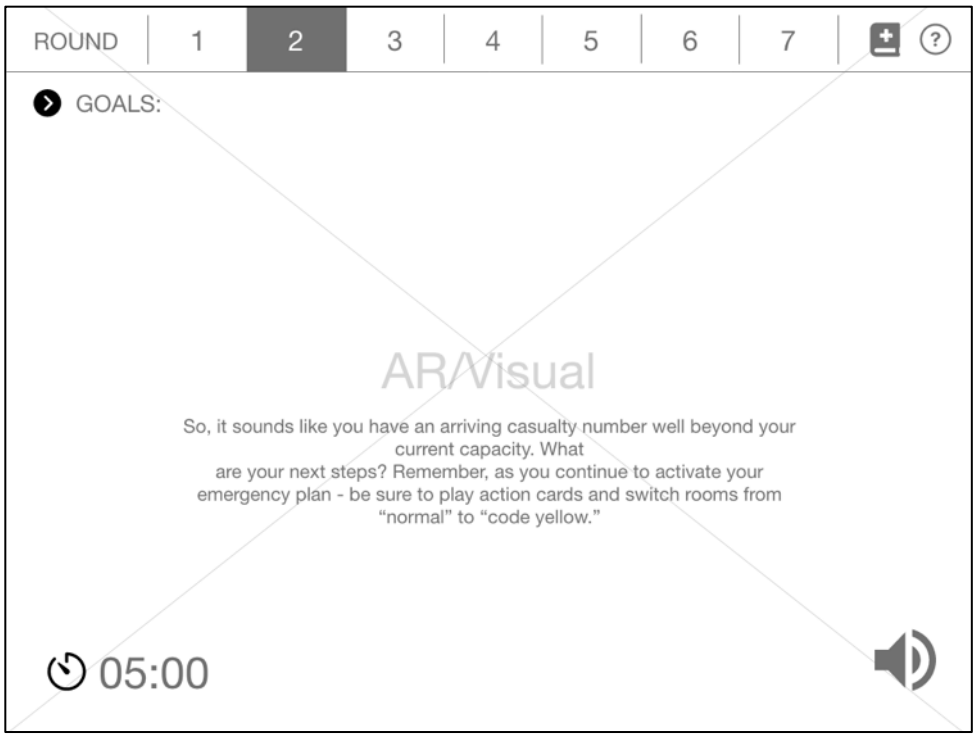


Figure 51. Round 2: Introductory Prompt, Wireframe 13 (H. in flowchart).

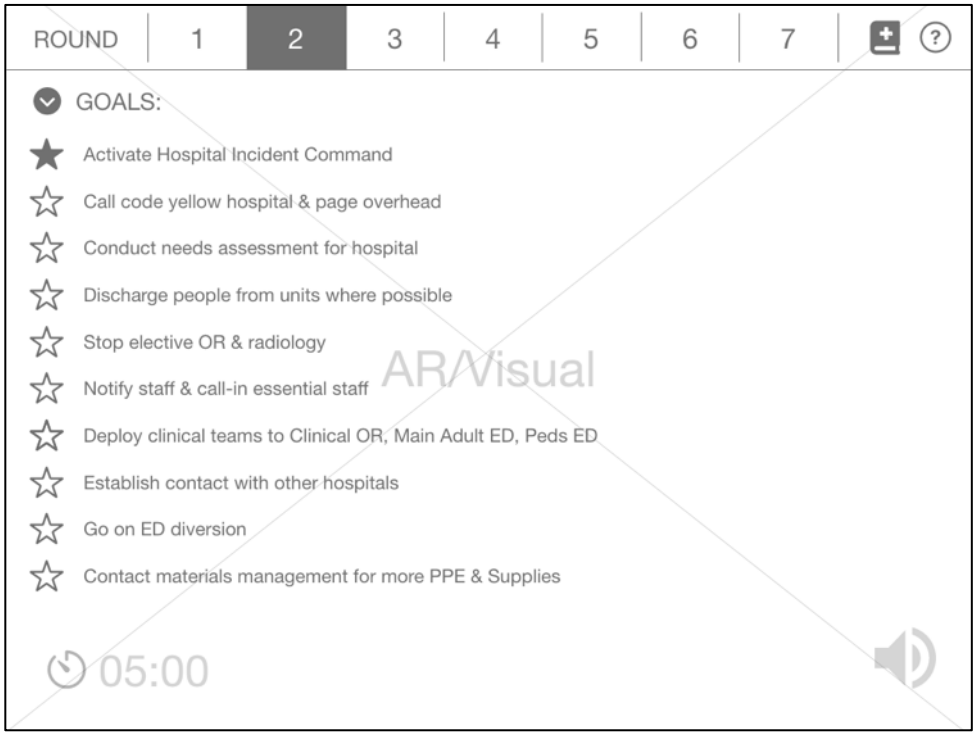


Figure 30. Round 2: Goals Dropdown Menu, Wireframe 14 (H. in flowchart).

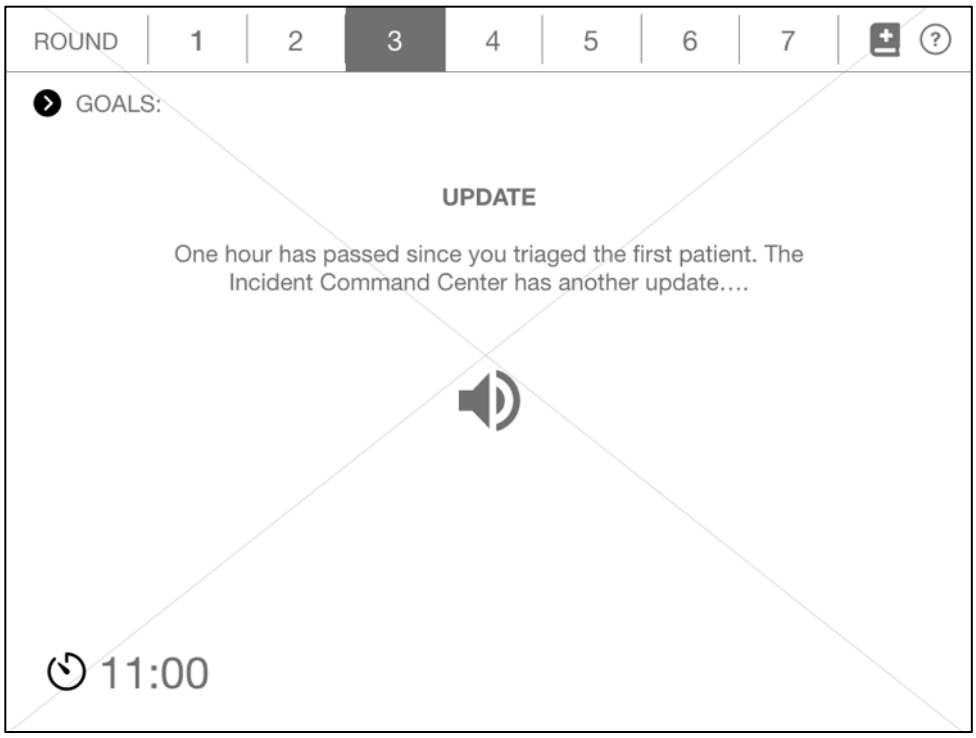


Figure 53. Round 3: Update , Wireframe 15. Round 3 scripted audio files played here. (H. in flowchart).

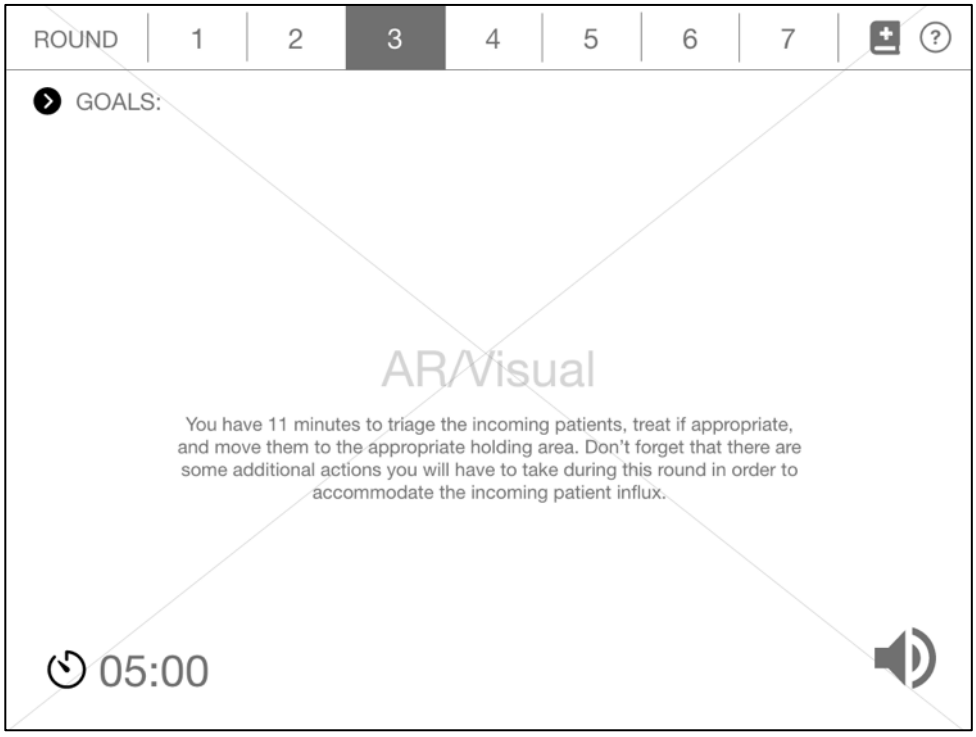


Figure 54. Round 3: Introductory Prompt, Wireframe 16 (H. in flowchart).

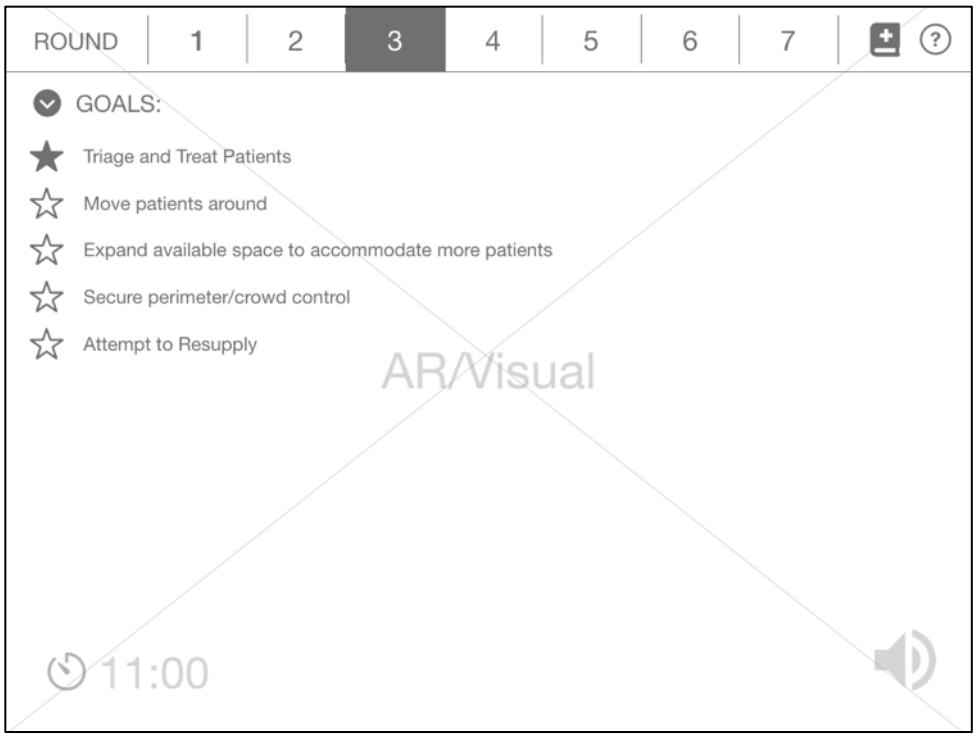


Figure 55. Round 3: Goals Dropdown Menu, Wireframe 17 (H. in flowchart).

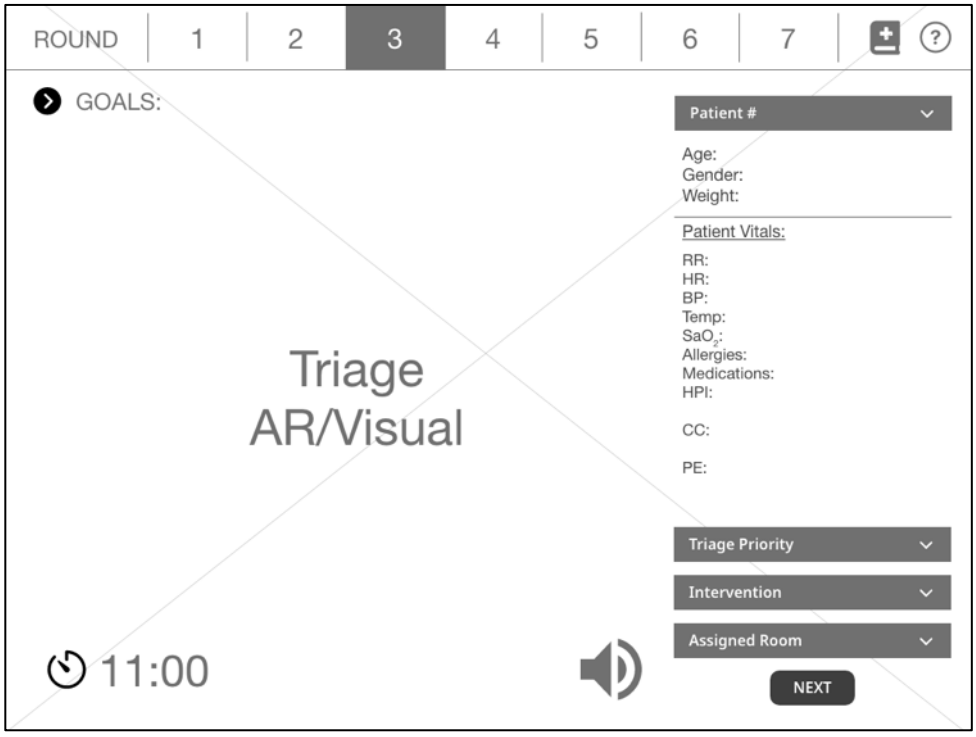


Figure 56. Round 3: Triage B, Wireframe 18 (H. in flowchart).

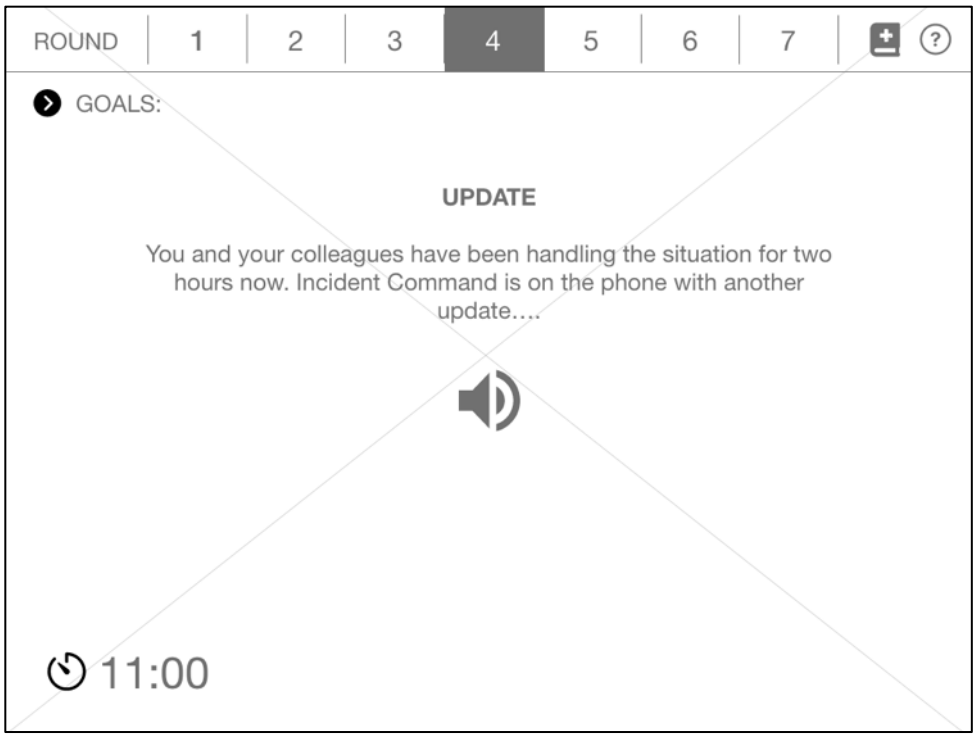


Figure 57. Round 4: Update, Wireframe 19. Round 4 scripted audio files played here. (H. in flowchart).

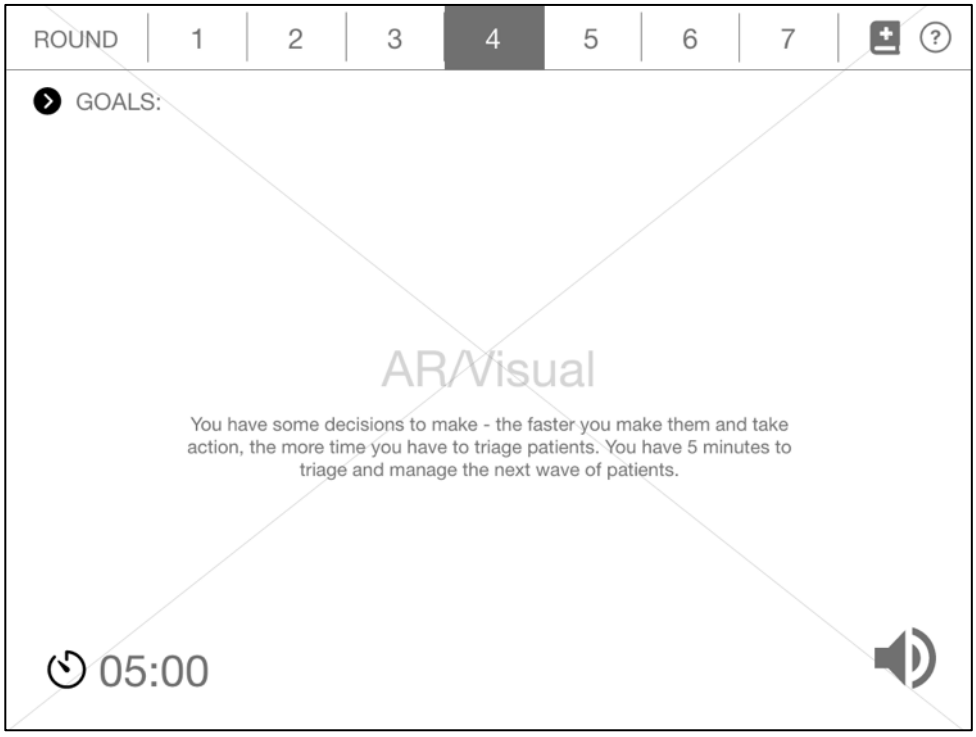


Figure 58. Round 4: Introductory Prompt, Wireframe 20 (H. in flowchart).

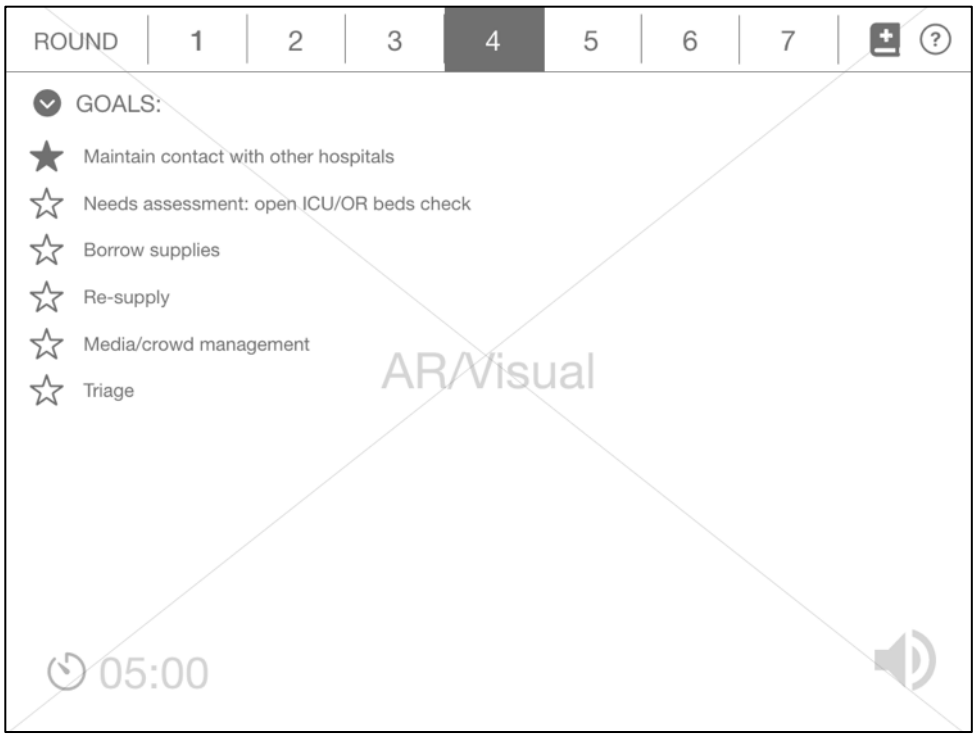


Figure 59. Round 4: Goals Dropdown Menu, Wireframe 21 (H. in flowchart).

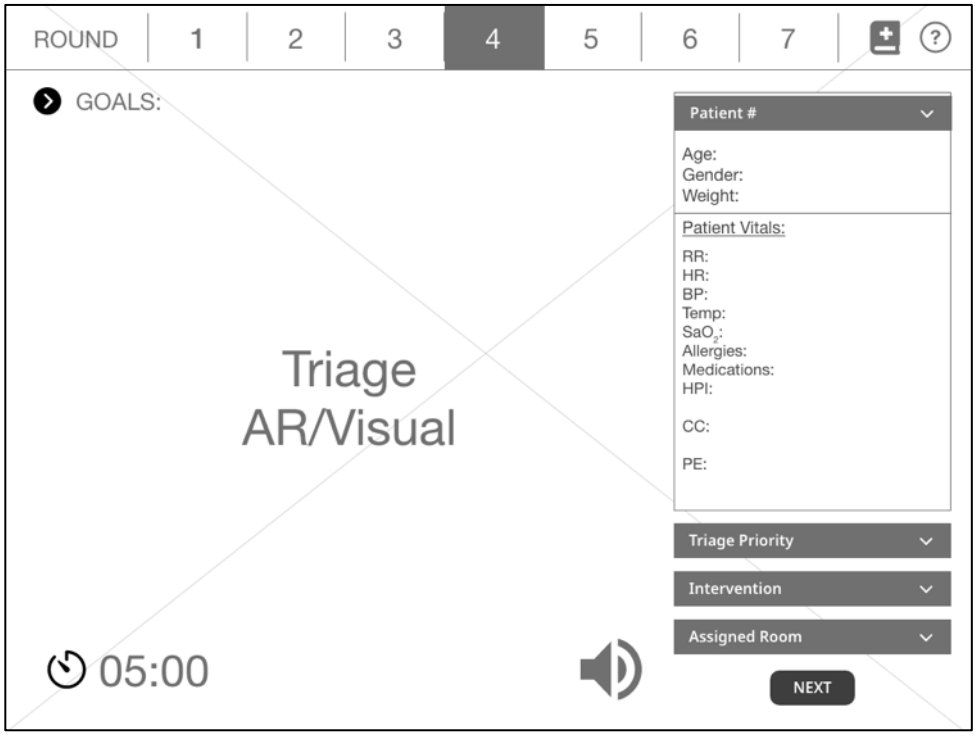


Figure 60. Round 4: Triage C, Wireframe 22 (H. in flowchart).

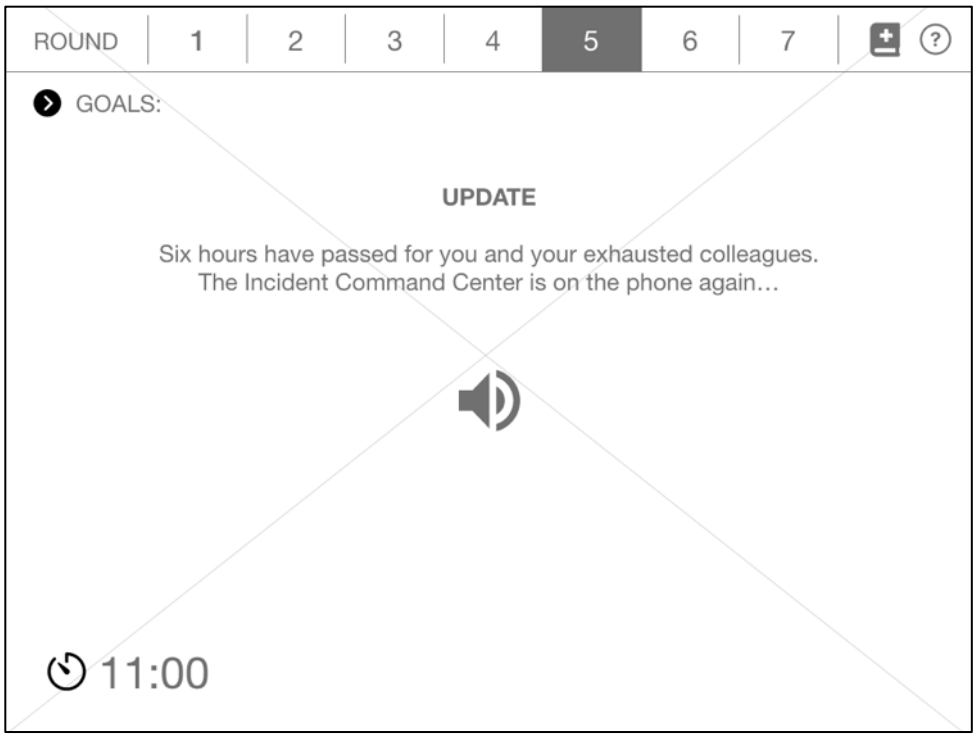


Figure 61. Round 5: Update, Wireframe 23. Round 5 audio played here. (H. in flowchart).

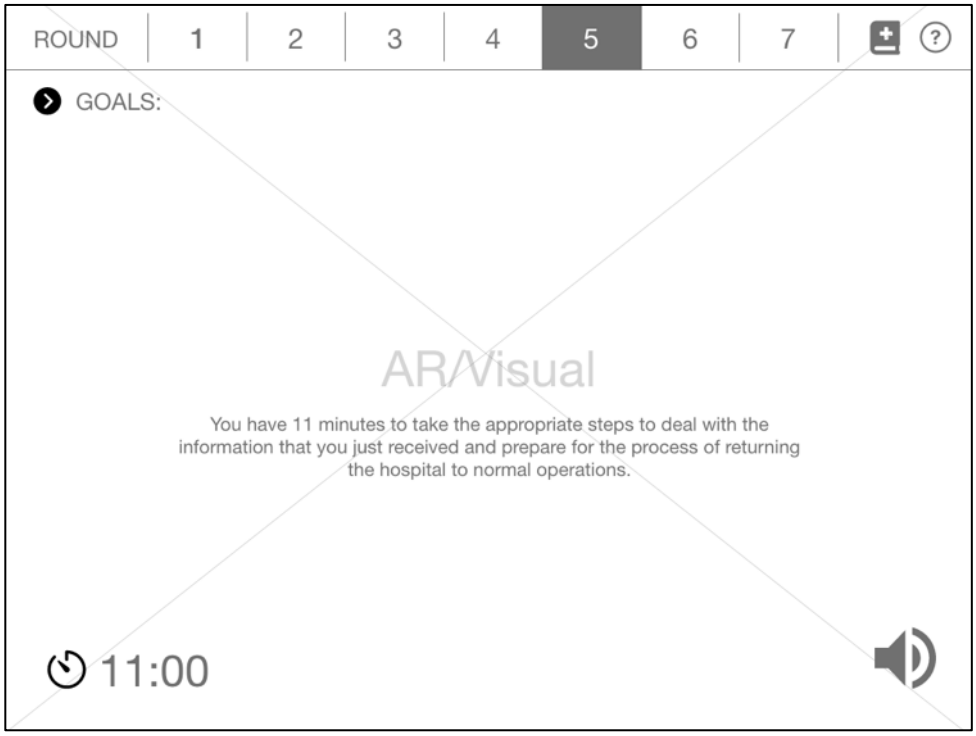


Figure 62. Round 5: Introductory Prompt, Wireframe 24. (H. in flowchart).

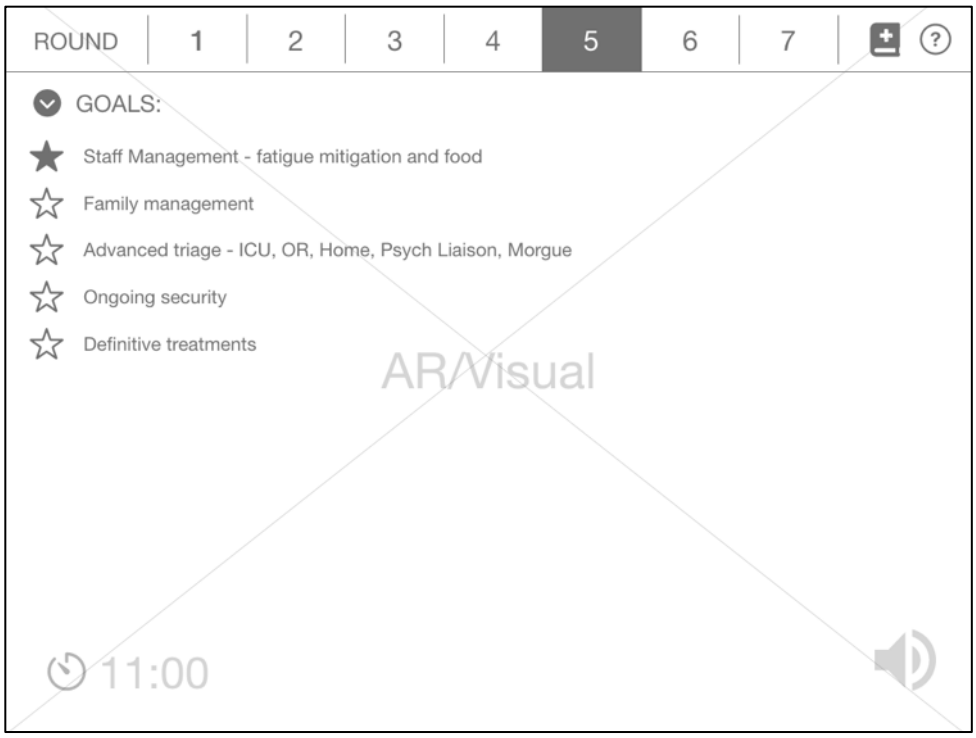


Figure 63. Round 5: Goals Dropdown Menu, Wireframe 25. (H. in flowchart)

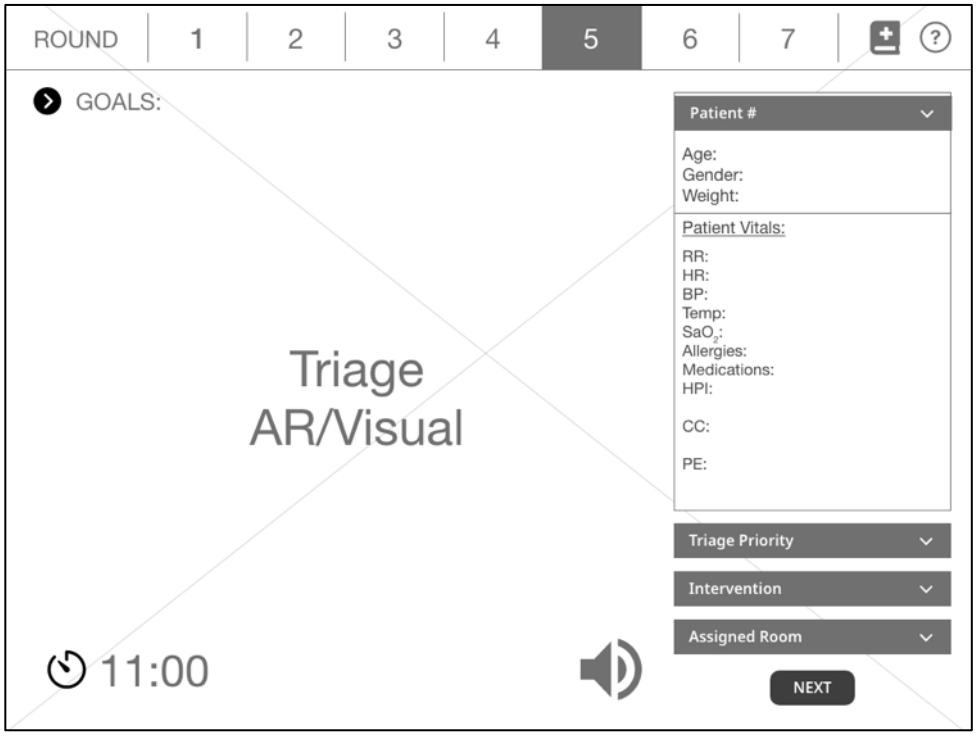


Figure 314. Round 5: Advanced Triage/Definitive Treatments, Wireframe 26. (H. in flowchart).

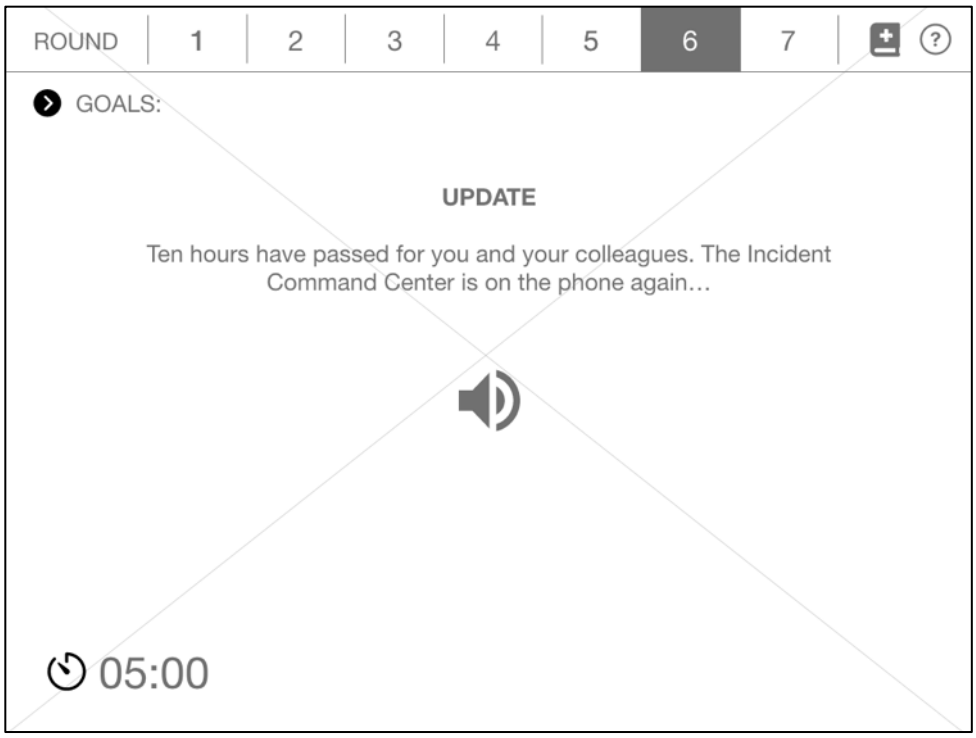


Figure 65. Round 6: Update, Wireframe 27. (H. in flowchart)

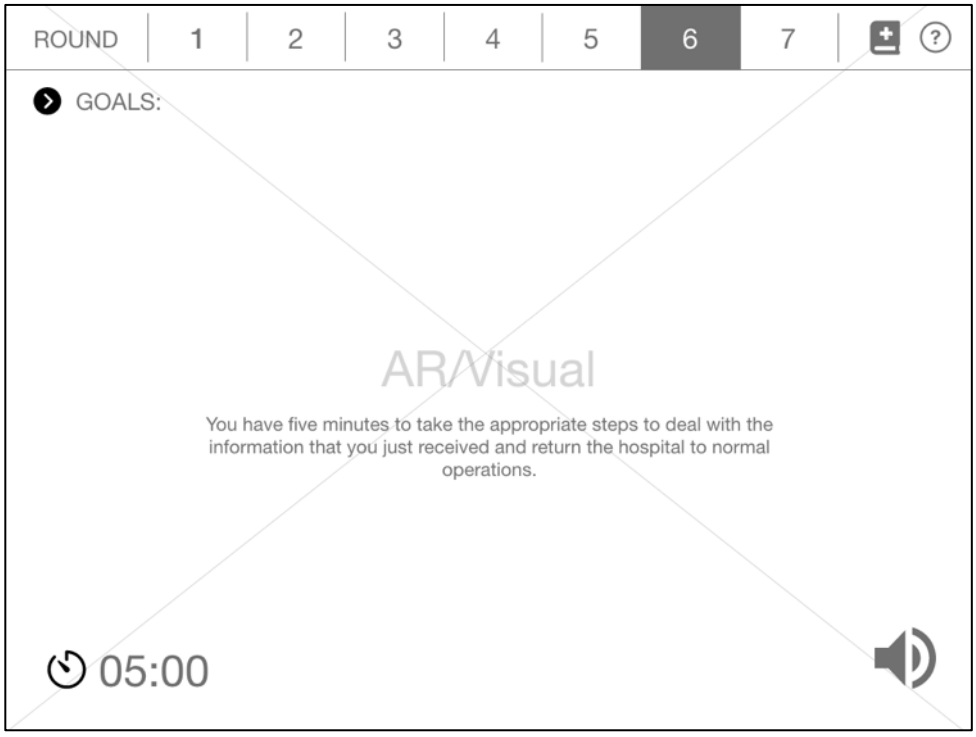


Figure 66. Round 6: Introductory Prompt, Wireframe 28 (H. in flowchart).

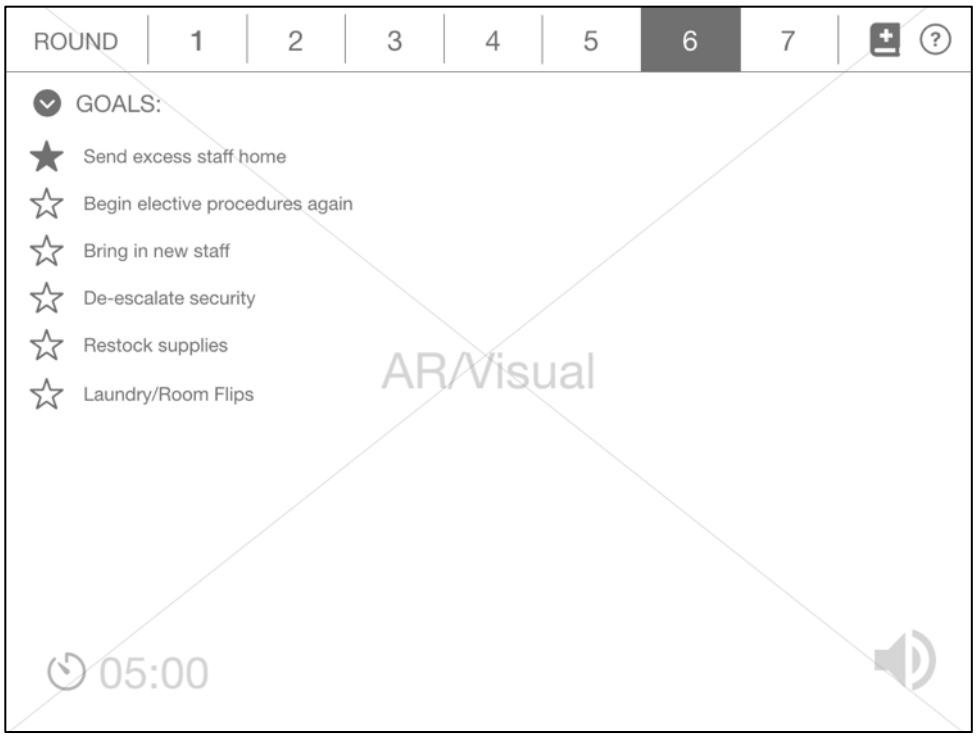


Figure 67. Round 6: Goals Dropdown Menu, Wireframe 29 (H. in flowchart)

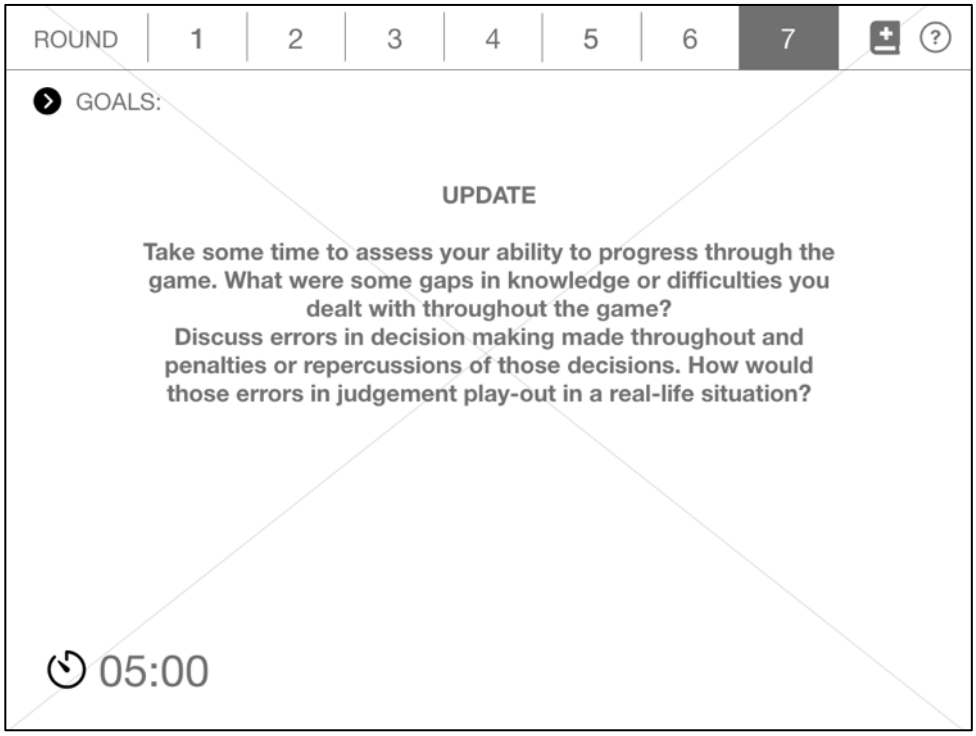


Figure 68. Round 7: Update. Discussion Prompt, Wireframe 30 (H. in flowchart)

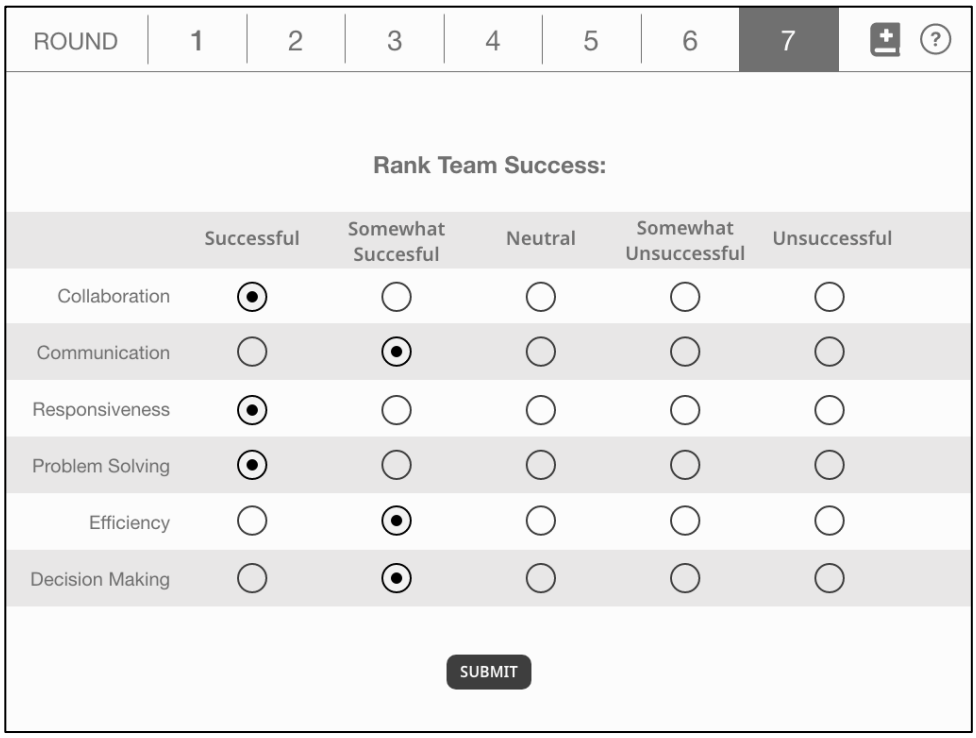


Figure 69. Round 7: Team Success Ranking, Wireframe 31. (H. in flowchart)

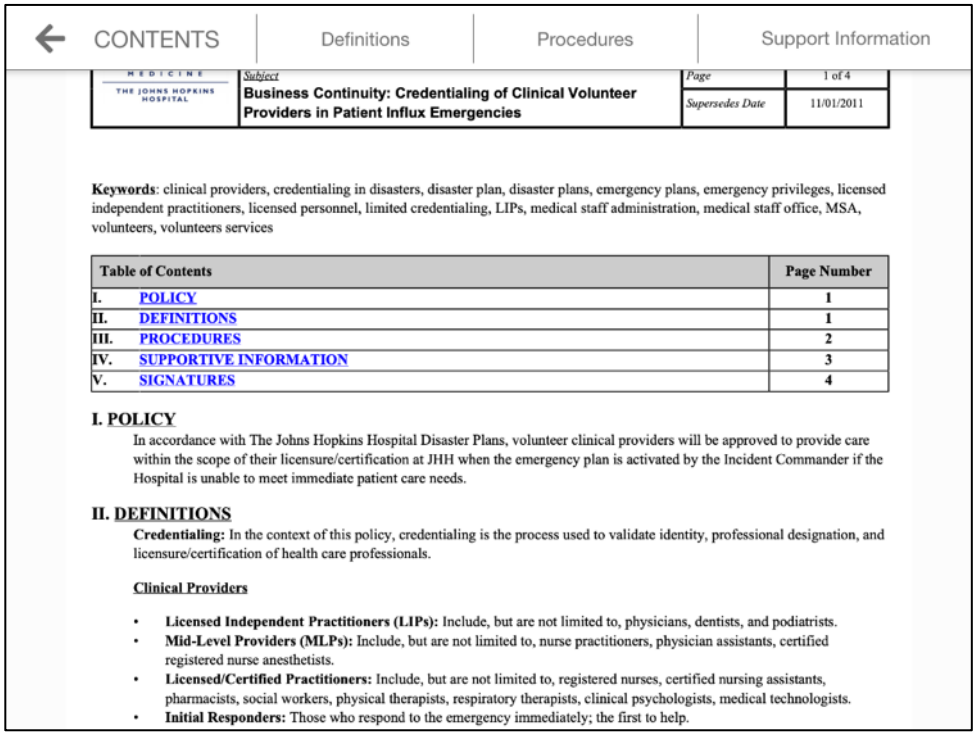


Figure 70. Manual: Hospital Procedure, Wireframe 32 (I. in flowchart)

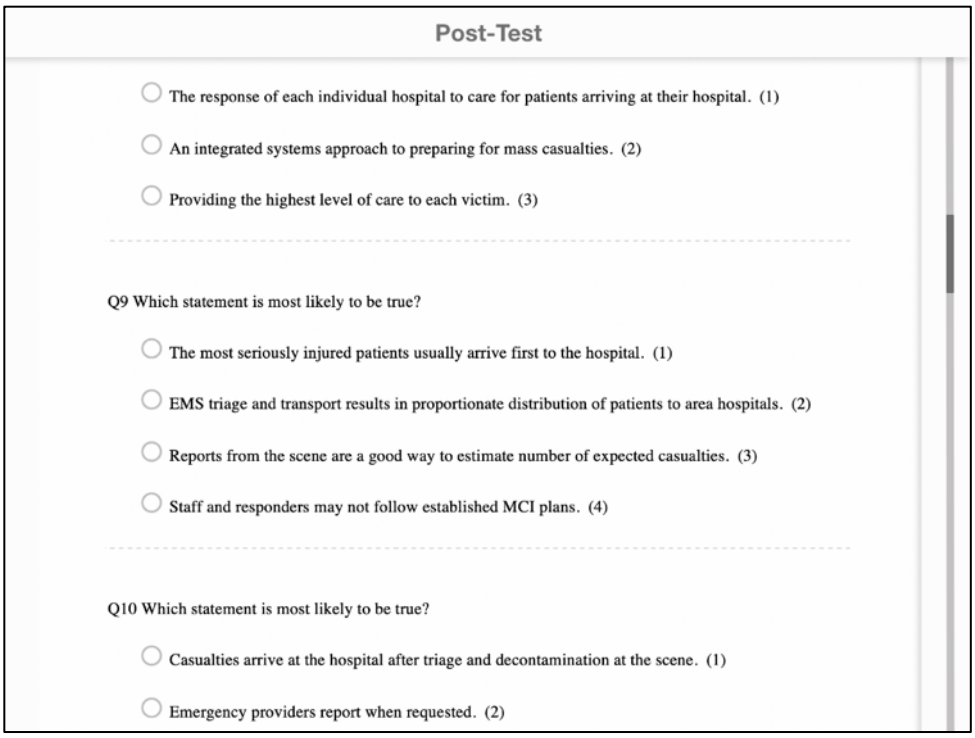


Figure 71. Post-Test, Wireframe 33. (J. in flowchart).

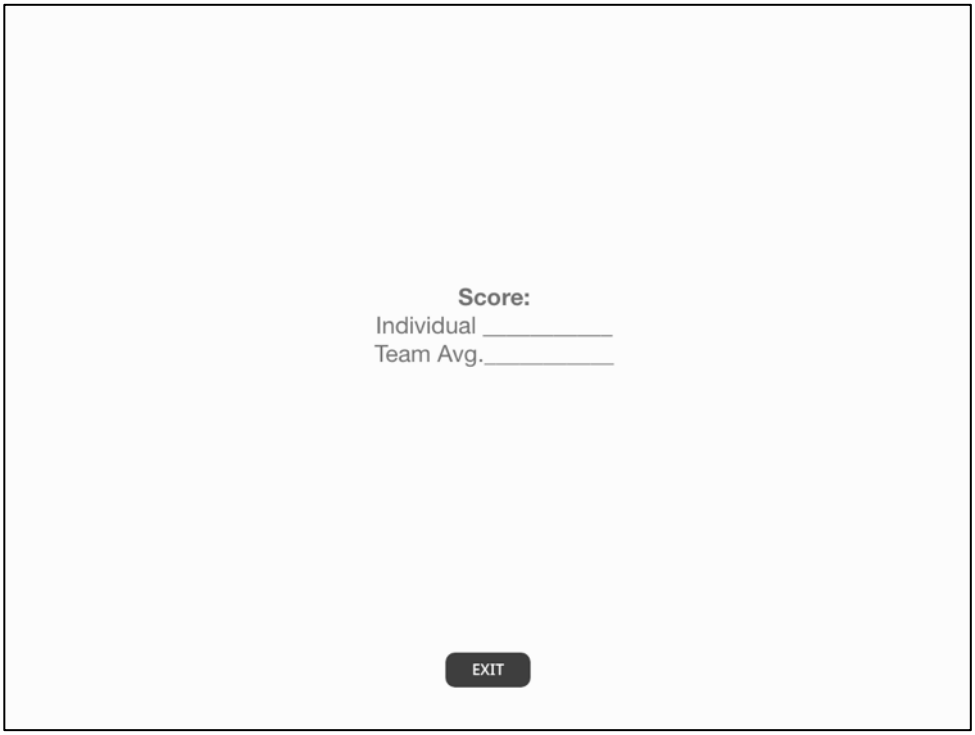


Figure 72. View Score, Wireframe 34 (K. in flowchart).

Appendix G: Style Guide

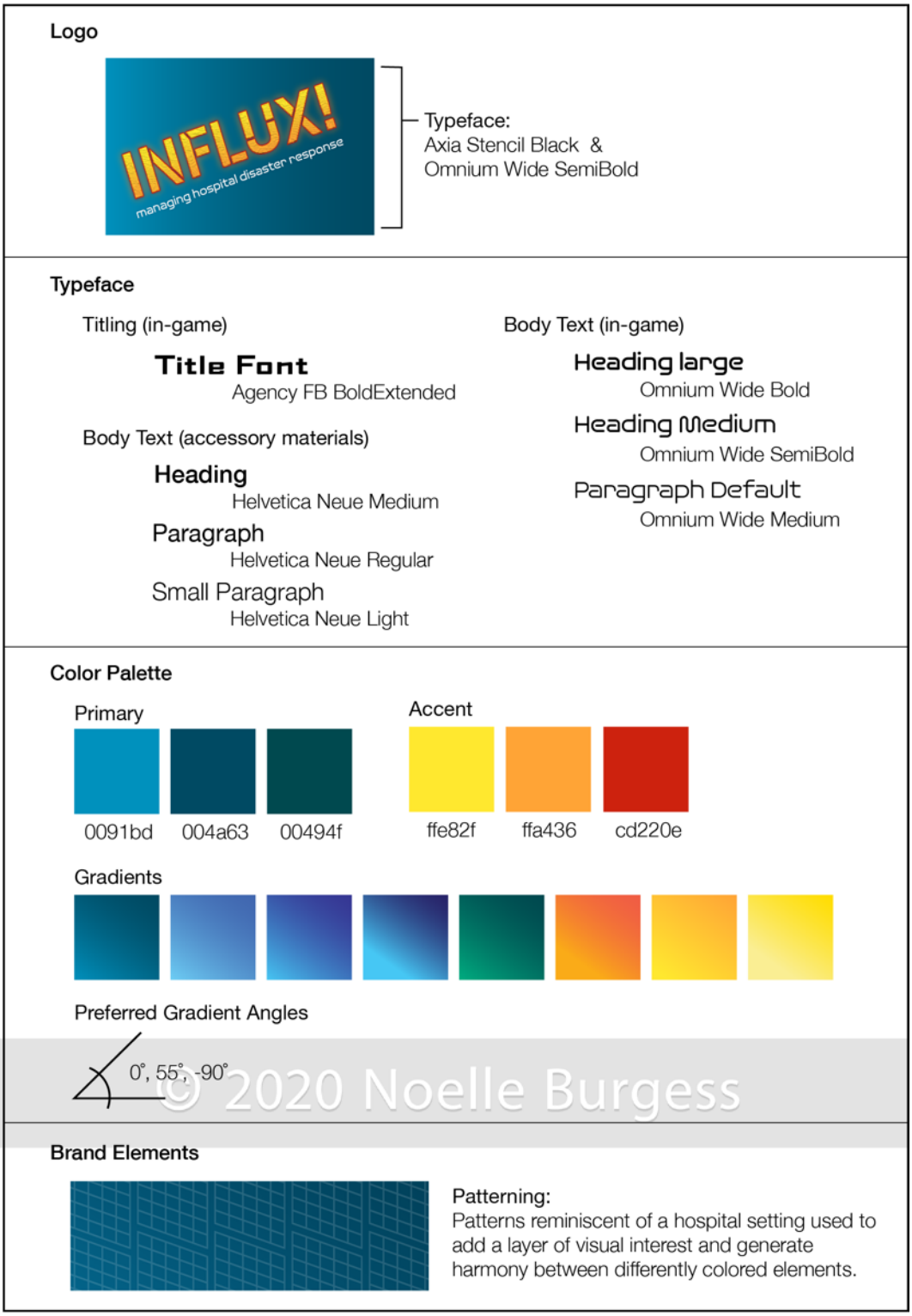


Figure 73. Style Guide

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VITA

Noelle Burgess was born in Fredericksburg, Virginia. She grew up outdoors and heavily involved in athletics. In high school she participated in a trip to Zimbabwe, Mozambique, and South Africa focused on musical and cultural exchange. Inspired by that trip she attended James Madison University in Harrisonburg, Virginia to pursue a Bachelor of Arts with a double major in Anthropology (with a concentration in Archaeology) and Studio Art (with a concentration in Drawing and Painting). Upon completion of that degree in August of 2011, Noelle worked as an aquatics manager, lifeguard instructor, and swim coach at the Harrisonburg Parks and Recreation. She also taught English as a Second Language at a local literacy and citizenship non-profit organization. After a number of years teaching she began to look for ways to combine her expertise in teaching, visual art, and storytelling into a growing career interest in medicine. This is when she discovered the field of Medical Illustration. In order to improve her portfolio and acquire the necessary scientific coursework, she enrolled in Virginia Commonwealth University in Richmond, Virginia. In May of 2018 she received her second undergraduate degree, a Bachelor of Fine Arts in Communication Arts with a concentration in Scientific & Preparatory Medical Illustration, with a minor in Biology.

Shortly thereafter, she matriculated into Johns Hopkins University School of Medicine in pursuit of a Masters of Arts in Medical and Biological Illustration. While studying at Hopkins, she has had the pleasure of learning and collaborating with accomplished medical illustrators, physicians, scientists, and her fellow classmates. Noelle is currently a candidate to receive a Master of Arts in Medical and Biological Illustration in May of 2020.