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**AWARD NUMBER:** W81XWH-16-1-0308

**TITLE:** Design of a Screen-Based Simulation for Training and Automated Assessment of Teamwork Skills

**PRINCIPAL INVESTIGATOR:** STEADMAN, RANDOLPH H

**RECIPIENT:** **University of California, Los Angeles**
**Los Angeles, CA 90095**

**REPORT DATE:** **October 2019**

**TYPE OF REPORT:** **Final**

**PREPARED FOR:** U.S. Army Medical Research and Materiel Command
Fort Detrick, Maryland 21702-5012

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| | **5c. PROGRAM ELEMENT NUMBER** |
| **6. AUTHOR(S)** | **5d. PROJECT NUMBER** |
| Randolph H. Steadman, MD, MS<br>Yue Ming Huang, EdD, MHS, Noreen Webb, PhD, John Lee, PhD, Markus Iseli, PhD, Rukhsana Khan, MPH | **5e. TASK NUMBER** |
| E-Mail: rsteadman@mednet.ucla.edu | **5f. WORK UNIT NUMBER** |
| **7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) AND ADDRESS(ES)**<br>University of California, Los Angeles<br>11000 Kinross Ave Ste 102<br>Los Angeles, CA 90095-2000 | **8. PERFORMING ORGANIZATION REPORT NUMBER** |
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**12. DISTRIBUTION / AVAILABILITY STATEMENT**

Approved for Public Release; Distribution Unlimited

**13. SUPPLEMENTARY NOTES**

**14. ABSTRACT**

Introduction:
The need for teamwork training is well documented, however, teaching these skills is challenging given the logistics of assembling individual team members to train in person. Drawing from serious games, teamwork literature and established team training programs, we designed two screen-based simulation modes with different interactivity to study their effectiveness in training teamwork skills.
Methods:
Mixed, randomized, repeated measures study with licensed healthcare providers block-stratified and randomized to: Evaluation (EVAL) mode or Game-Play (GP) mode. Teamwork construct scores (leadership, communication, situation monitoring, mutual support) from an ontology-based, Bayesian Network (BN) assessment model were analyzed using analyses of variance to compare the two modes on performance across three scenarios, and on pretest and posttest quiz scores.
Results:
109 participants were enrolled and randomized to each game mode. Mean composite teamwork BN scores improved for successive scenarios in both modes, with EVAL scores statistically higher than GP for every teamwork construct and scenario (r=0.73, P=.000). Overall quiz scores also improved from pretest to posttest (P=.004) but the change from pre- to post-testing between modes were not significant.
Conclusions:
Two modes of interactivity for screen-based simulation yielded comparable learning outcomes within three scenarios. Simple online simulations may be useful to augment team training needs.

| 15. SUBJECT TERMS | | | | | |
|---|---|---|---|---|---|
| Team training, automated assessment, screen-based simulation, communication, leadership, situation monitoring, mutual support, psychological safety | | | | | |
| 16. SECURITY CLASSIFICATION OF: | | | 17. LIMITATION OF ABSTRACT | 18. NUMBER OF PAGES | 19a. NAME OF RESPONSIBLE PERSON USAMRMC |
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| Unclassified | Unclassified | Unclassified | Unclassified | 107 | |

**Standard Form 298 (Rev. 8-98)**
**Prescribed by ANSI Std. Z39.18**

**TABLE OF CONTENTS**

1. **INTRODUCTION:** Narrative that briefly (one paragraph) describes the subject, purpose and scope of the research.

While communication and teamwork skills are increasingly recognized as important factors in improving patient safety, team training is not routinely incorporated into graduate training or continuing medical education programs. Opportunities to practice teamwork skills and receive objective feedback are limited. We have developed and tested a screen-based team training to provide healthcare professionals deliberate practice on teamwork skills and improve performance through automated feedback.

2. **KEYWORDS:** Provide a brief list of keywords (limit to 20 words).

Teamwork training, automated assessment, screen-based simulation, communication, leadership, situation monitoring, mutual support, psychological safety

3. **ACCOMPLISHMENTS:** The PI is reminded that the recipient organization is required to obtain prior written approval from the awarding agency Grants Officer whenever there are significant changes in the project or its direction.

**What were the major goals of the project?**

- ❖ Major Task 1. Identify current team training practices, performance gaps, and resources (originally planned mos. 1-6, for revised completion based upon 6-month no-cost extension see below).
- ❖ Major Task 2. Create domain ontology and scenario scripts (originally planned mos. 5-8; for revised completion based upon 6-month no-cost extension see below).
- ❖ Major Task 3. Design a framework for online team training and assessment (originally planned mos. 8-11; for revised completion based upon 6-month no-cost extension see below).
- ❖ Major Task 4. Build the screen-based simulation (*Evaluation* and *Game-Play Modes*) (originally planned mos. 8-13; for revised completion based upon 6-month no-cost extension see below).
- ❖ Major Task 5. Conduct research using the screen-based simulation (originally planned mos. 6-8, 14-24; for revised completion based upon 6-month no-cost extension see below).

**What was accomplished under these goals?**

*For the purposes of this report:*
Sim Team=Randolph Steadman, Yue Ming Huang, Rukhsana Khan and Maria Rudolph
Education Team=Noreen Webb, Federica Raia, Rachel Lewin and Michael Smith
CASIT (Center for Advanced Surgical & Interventional Technology) Team=Areti Tillou and Yen-Yi Juo
CRESST (Center for Research on Evaluation, Standards & Student Testing) Team=Alan Koenig, John Lee, Markus Iseli and Charles Parks

- Major Task 1. Identify team training practices, performance gaps and resources (mos. 1-14).
  - Subtask 1: Review research on existing team training literature, available products and best practices: 100% completed.
    - The purpose of this review was to examine existing literature, research, products, software, and tools to identify current team training practices and performance gaps during high stakes medical team activities. The review focused on areas of research that would be helpful for curricular framework and design of this project's screen-based simulation for training and automated assessment of teamwork skills.
    - We focused on the following topics: teamwork dimensions for team training, effectiveness of team training in healthcare, measuring acquisition of teamwork knowledge and skills, impact of teamwork training on teamwork knowledge and skills, teamwork attributes that are challenging to represent in a single player screen-based healthcare simulation, methods of simulation-based teamwork training, design issues related to authenticity of screen-based simulations, feedback and debriefing in simulated teamwork settings, screen-based simulations versus high fidelity simulators, and screen-based simulations teaching teamwork in medical settings.
    - Major findings for this review will be summarized in Subtask 5, along with a description of the methodology used.
  - Subtask 2: Perform video analysis of medical teams in action: 100% completed.
    - Videos of critical incidents (real and simulated) were reviewed by all members of the research team.
    - Videos were used to develop consensus of what the observable, assessable teamwork actions are in critical care.
    - Challenges were categorized into the following areas of opportunity for improvement: a) communication issues as they relate to noise control, handoffs, closed-loop communication, leadership and anticipating/sharing plan; and b) process issues related to role clarity and delegation.
  - Subtask 3: Interview Subject Matter Experts (SMEs) and healthcare practitioners. 100% completed.
    - The purpose of the SME interviews was to gather information from team training experts to help ascertain the strengths, weaknesses and limitations of teamwork training approaches and factors that contribute to the breakdown of teamwork processes. The research team also solicited input from SMEs on the proposed team training framework and core teamwork skills that were incorporated in the screen-based simulation game.
    - The interviews were conducted in a semi-structured format and led by Michael Smith, due to his expertise in applied linguistics.

        - We interviewed the following team training subject matter experts: David Gaba, MD, creator of Anesthesia Crisis Resource Management; David Baker, developer of TeamSTEPPS; Andrea Amodeo, TeamSTEPPS researcher; and John Holcomb, MD, a combat surgery expert. Although not formally named as an SME on this grant, the team also interviewed Christopher Hund, Director of Clinical Quality for the Health Research & Educational Trust (HRET) due to his expertise in directing TeamSTEPPS projects.
        - Close analysis of the SME interviews helped inform the research team on the following: which context is teamwork crucial, what skills are important for high acuity settings, what undermines teamwork, traits and practices for a "good" team player, challenges to teaching teamwork, advantages and pitfalls of TeamSTEPPS, educational tools for teaching teamwork and military implications that affect teamwork.
        - Major findings from SME interviews will be summarized in Subtask 5.
    - Subtask 4: Conduct/analyze focus groups of healthcare teams: 100% completed.
        - The purpose of the focus group interviews was to gather honest impressions about teamwork and communication from healthcare professionals who work in team settings at Ronald Reagan UCLA Medical Center. The intention was to have a conversation with front-line medical personnel about their personal experience as a team leader/ and or supportive team member, in order to help inform our game development.
        - Four focus group interviews took place between June of 2017 and July of 2017. All interviews were audio recorded with consent from participants. Rachel Lewin and Maria Rudolph conducted the interviews; Ms. Lewin was the primary interviewer and Dr. Rudolph was the secondary interviewer and recorder. Focus groups were comprised of 3-6 front-line medical personnel, including Emergency Medicine and Internal Medicine physicians, respiratory therapists, and ICU and Trauma Surgery nurses.
        - A few recurrent themes were gathered from the interviews including introduction styles from team members, roles/structure of teams, psychological safety to encourage feedback, and clear communication. A formal narrative of findings will be included under Subtask 5.
    - Subtask 5: Prepare report of current practices and gaps in team training. 100% completed.
        - A report of our findings for the literature review, SME interviews and focus group interviews is attached in Appendices section. Please refer to file "Literature Review, Subject Matter Expert Interview and Focus Group Report."
- Major Task 2. Create domain ontology and scenario scripts (mos.5-21).
    - Subtask 1: Create team training core skills domain ontology: 100% completed.
        - Following completion of video review, the Sim, CASIT and CRESST teams began meeting weekly to create a list of all possible assessable teamwork actions pertinent to patient care. This list helped establish the assessable actions used in the screen-based simulation.
        - A final version of the domain ontology was developed based on the assessable teamwork skills and actions that were identified. See file "DoD Team Training Ontology" in Appendices section.

- Subtask 2: Create a set of features, affordances, and actions for user interface: 100% completed.
  - Using the game development software, Unity, an early test environment for the game was developed to highlight potential interactivity elements.
  - Acquired 3D assets (game avatars) including hospital room and medical personnel.
  - Worked on modes of interactivity for the user interface (e.g., how to direct communication to the desired avatar).
  - Presented a mock-up of the first scenario to the research team for feedback on interactivity elements and sequencing of events. Refined interactivity elements based on research team's feedback.
  - Developed an Action Level Ontology that includes a total of 17 possible actions and related game mechanics. See file "Team Training Ontology-Action Level Ontology" in Appendices section.
- Subtask 3: Create a range of scenario settings/events: 100% completed.
  - A subset of the research team composed of the Sim Team and CRESST, met to establish the learning objectives, setting, sequence of events and player affordances for each of the three scenarios of the game.
  - It was decided that each scenario would focus on teaching teamwork leadership skills in the settings of the trauma bay, OR, and ICU.
  - An inventory of skills appropriate for the scope of practice for the roles of the player and non-player characters (NPCs) for each scenario was also created.
- Subtask 4: Create a knowledge assessment (baseline team skills) scenario: 100% completed.
  - The baseline scenario (trauma bay MVA) was intended to serve as a pretest for player/student Knowledge, Skills and Abilities (KSAs); assessing the player's knowledge and skills related to teamwork without any feedback until after scenario completion.
  - The research team also incorporated a pretest composed of a subset of TeamSTEPPS learning benchmark questions prior to the start of the first scenario (see file titled "Baseline and Post-Intervention Teamwork Knowledge Questions" in Appendices). The same exact questions were given as a posttest at the end of the third scenario. This test was added as a supplement to assess baseline teamwork skills since gaining familiarity with the user interface had the potential of interfering with the assessment of players' baseline knowledge.
- Subtask 5: Create 3 scenarios with different settings, events and skill requirements: 100% completed.
  - The research team brainstormed a series of events and skill requirements for incorporation into the game. As stated under Subtask 3 above, the learning objectives, setting and sequence of events for all 3 scenarios of the game have been created.
  - Subsequent scenarios were completed (OR and ICU), and follow the same model and structure used for this first scenario. We incorporated the information gathered from the SME and focus group interviews into each of these subsequent scenarios.
  - All scenarios include the same basic and advanced teamwork skills, including communication, leadership, and team management.

- Major Task 3. Design a framework for online team training and assessment (mos. 8-26).
  - Subtask 1: Design the automatic assessment engine: 100% completed
    - A Bayesian Network (BN) was created from the ontologies. The BN is used to infer competencies related to the teamwork skill constructs. The main constructs (top level nodes) include: leadership, situation monitoring, communication and mutual support. At the observable level, there are the types of actions the player can take and the components of each action that the simulation captures and scores. Figure 1 in the Appendix shows the BN with the four main constructs (leadership, situation monitoring, communication and mutual support) and the player actions assessed during the game.

- Subtask 2: Design the simulation interface: 100% completed.
  - Gameplay mode: The simulation interface includes several affordances through which the player can carry out various actions.
  - Evaluation mode: The interface looks mostly similar to the Gameplay mode, with differences being that this mode has preset pause points for the player to provide feedback via multiple choice questions about noteworthy teamwork skills observed (correctly or incorrectly).
- Subtask 3: Design the after-action review (AAR): 100% completed.
  - Player performance will be presented and explained, including evaluation of player actions with descriptive feedback, and general instruction on the specific team skills required in the game scenario.
  - We finished developing the content that will be presented in the AAR for both simulation modes. The content covers the following teamwork principles: communication; leadership; situation monitoring; and mutual support. The AAR also includes reflection questions and test questions that will assess the player's knowledge of key teamwork concepts.
- Subtask 4: Pilot storyboard workflows for quality assurance piloting: 100% completed.
  - Storyboarding is complete. Continual piloting helped refine features.

❖ Major Task 4: Build screen based simulation (Evaluation and Gameplay modes) (mos. 8-27).

- Subtask 1: Develop software specifications: 100% complete.
  - Agile development of software specifications based on use-cases, with specific associated development sub-tasks. Process consists of Specify -> Develop -> Test -> Iterate/Refine, which inter-links Subtasks 1, 2, and 3. For a description of the software specifications, please refer to file named "Software Specifications Teamwork Version 7" in Appendices section.
- Subtask 2: Develop software-based prototype of two simulation modes: 100% complete.
  - We used an agile development methodology (see Subtask 1, above) to develop both simulation modes.
  - We have completed the authoring and development of all 3 scenarios for both game-play and evaluation modes.
- Subtask 3: Perform software testing for quality assurance: 100% complete.
  - We continually tested our game builds using an agile development methodology (see Subtask 1, above). Although this process is ultimately never-ending, we finalized our version of the game prior to data collection.

❖ Major Task 5. Conduct research using the screen-based simulation (mos. 6-8, 28-37).

- Subtask 1: Obtain IRB approval from UCLA and USAMRMC HRPO: 100% completed.
  - We submitted the UCLA IRB application in December 2016 and received approval on February 15, 2017. We also submitted a Protocol Submission Form for USAMRMC HRPO on March 28, 2017 and received approval on May 11, 2017. An amendment was submitted to the UCLA IRB to expand our subject recruitment pool and was approved on January 23, 2019. A continuing review application was submitted to the UCLA IRB on August 28, 2019 and was approved on September 3, 2019. A copy of the IRB continuing review approval letter and all amendment documents were sent to USAMRMC HRPO.
- Subtask 2: Recruit subjects to test screen-based simulation: 100% complete.
  - Physicians, nurses, and other allied healthcare professionals, including paramedics, pharmacists and respiratory therapists were eligible to participate in the study. Participants were recruited from within the UCLA Health System and the outside community. We successfully enrolled and collected data for 109 licensed healthcare providers. 52 participants were randomized to Game-play mode and 57 were randomized to Evaluation mode.

- Subtask 3: Conduct follow up Interviews with select subjects: 100% complete.
  - Follow-up interviews were conducted 1-8 months post-training. 15 participants agreed to share their experiences playing our game. They were specifically asked about the usability of the game and whether they've applied any teamwork skills they learned in the game to their clinical care. 60% of interviewees stated they had incorporated teamwork skills they learned from the game in their clinical care and 87% stated they found the game content useful enough to recommend as an educational tool.
- Subtask 4: Perform quantitative and qualitative data analysis: 100% complete.
  - We have completed data analysis. We have summarized our findings in a manuscript that was recently submitted to the *Journal of the Society for Simulation in Healthcare*. For a detailed description of our methods and results, please refer to the recently submitted manuscript in the Appendices section. The file is titled, "Screen-Based Simulation for Training and Automated assessment of Teamwork Skills: Two Modes with Different Interactivity Yield Comparable Learning Outcomes."
- Subtask 5: Prepare and deliver final report: 100% complete.
  - This report serves as our final report; summarizing what was accomplished under our project goals.

**What opportunities for training and professional development has the project provided?**

Nothing to Report.

**How were the results disseminated to communities of interest?**

We submitted a manuscript to the *Journal of the Society for Simulation in Healthcare* in order to disseminate our work to the healthcare education community.

**What do you plan to do during the next reporting period to accomplish the goals?**

Nothing to Report.

## 4. IMPACT:

**What was the impact on the development of the principal discipline(s) of the project?**

We developed a screen-based simulation for teamwork skills training, which adds flexibility and convenience to other training options. We scripted three scenarios, each of which was designed to assess increasingly advanced teamwork skills, then weighted each assessment opportunity according to its relationship with the core constructs of leadership, communication, situation monitoring and mutual support. The resulting Bayesian network represents an ontological framework for this and future screen-based assessments.

Additionally, we compared two training modes of differing degrees of interactivity and found that for training encounters limited to a single sitting, higher degrees of interactivity may be unnecessary. One should not assume that high interactivity lacks merit, only that learning the user interface requires time and repeated experiences. This can inform future work in the area of screen-based simulation.

**What was the impact on other disciplines?**

We anticipate that this study will inform the defense community and private sector on the effectiveness of screen-based simulation for teamwork skills training of healthcare providers. We also hope to provide the design methodology for the development of screen-based simulation training on other topics and for other disciplines.

**What was the impact on technology transfer?**

This project will provide the design methodology for the development of screen-based simulation training and the potential to convert this training to virtual reality. We also expect our project to gain interest at our institution as it could serve as an onboarding training module for incoming healthcare employees.

**What was the impact on society beyond science and technology?**

Nothing to Report.

## 5. CHANGES/PROBLEMS:

**Changes in approach and reasons for change**

Nothing to Report.

**Actual or anticipated problems or delays and actions or plans to resolve them.**

Due to the delays we encountered with game development, data collection was also delayed. We requested a 6-month no-cost extension to complete data collection and data analysis. The no-cost extension was approved to cover the period between January 15, 2019 to July 14, 2019. During that time, data collection and analysis were completed.

**Changes that had a significant impact on expenditures**

Nothing to Report.

**Significant changes in use or care of human subjects, vertebrate animals, biohazards, and/or select agents**

**Significant changes in use or care of human subjects**

Nothing to Report.

**Significant changes in use or care of vertebrate animals.**

Nothing to Report

**Significant changes in use of biohazards and/or select agents**

Nothing to Report

**6. PRODUCTS:** List any products resulting from the project during the reporting period. If there is nothing to report under a particular item, state "Nothing to Report."

- **Publications, conference papers, and presentations**
  Report only the major publication(s) resulting from the work under this award.

**Journal publications.**

| |
|---|
| We recently submitted a manuscript to the *Journal of the Society for Simulation in Healthcare*.<br>Author(s): Randolph H. Steadman, MD, MS; Yue Ming Huang, EdD, MHS, Markus Iseli, PhD; John J. Lee; Noreen Webb, PhD; Areti Tillou, MD, MSEd; Maria Rudolph, MD; Rachel Lewin, MA, PhD(c); Alan Koenig, PhD; Rukhsana Khan, MPH; Federica Raia, PhD; Michael S. Smith, MA; Yen-Yi Juo, MD; Cameron Rice, MD, Sophia Poorsattar, MD<br>Title: Screen-Based Simulation for Training and Automated assessment of Teamwork Skills: Two Modes with Different Interactivity Yield Comparable Learning Outcomes<br>Journal: *Journal of the Society for Simulation in Healthcare*<br>Volume: Not Available; pending review and publication<br>Year: Not Available; pending review and publication<br>Page numbers: Not Available; pending review and publication<br>Status of publication: Submitted<br>Acknowledgement of federal support: Yes |

**Books or other non-periodical, one-time publications.**

| |
|---|
| Presented a poster at the American Educational Research Association (AERA) 2018 Annual Meeting. See file, "AGILE Methodology for Developing a Game-Based Assessment of Teamwork Skills" in Appendices section below.<br>**Authors:** Markus Iseli, PhD, Alan D. Koenig, PhD, John J. Lee, PhD, Rachel Lewin and Randolph Steadman, MD, MS<br>**Title of Poster:** AGILE Methodology for Developing a Game-Based Assessment of Teamwork Skills<br>**Type of Publication:** Poster presentation |

**Other publications, conference papers, and presentations**.

Presented a poster at the Annual Scientific Evening 2019 hosted by the UCLA Department of Anesthesiology & Perioperative Medicine. See file, "Developing A Serious Game for Teamwork Skills Training and Assessment" in Appendices section below.
**Authors:** Sophia P. Poorsattar; MD, Cameron M. Rice; MD, Randolph Steadman, MD, MS; Yue Ming Huang EdD, MHS; Markus Iseli, PhD; John J. Lee; Noreen Webb, PhD; Areti Tillou, MD; Yen-Yi Juo, MD
**Title of Poster:** Developing A Serious Game for Teamwork Skills Training and Assessment
**Type of Publication:** Poster presentation

Provided a demo of our screen-based simulation at the 2019 American Hospital Association Team Training National Conference in San Antonio, TX.

- **Website(s) or other Internet site(s)**

Nothing to Report.

- **Technologies or techniques**

Nothing to Report.

- **Inventions, patent applications, and/or licenses**

Nothing to Report.

- **Other Products**

This project yielded the development of a screen-based simulation team training system composed of two modes with different interactivity. Each mode (game-play and evaluation) consisted of three scenarios that aimed to assess the teamwork constructs identified by the research team. For the purposes of this report, we are showcasing a sample of our game by providing the complete script for scenario 1 of game-play mode, along with screenshots of the user interface for this mode. Please refer to the document titled, "Game Play Mode-Scenario 1 Script" in the Appendix. For a more detailed description of our game specifications, please refer to the document, "Software Specification Version 7.0" in the Appendix.

## 7. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

**What individuals have worked on the project?**

Name: Randolph Steadman, MD, MS
Project Role: Principal Investigator
Researcher Identifier: N/A
Nearest person month N/A (No cost extension period)
Contribution to Project: Dr. Steadman has performed work in the area of literature review, product review and video analysis. He served as clinical content expert for development of game scenarios and created content for the after-action review. He provided direction and oversight of the project as principal investigator. He also significantly contributed to conducting the research and writing of the manuscript.

Name: Yue Ming Huang, EdD, MHS
Project Role: Co-Investigator; Project Manager
Researcher Identifier: N/A
Nearest person month worked: N/A (No cost extension period)
Contribution to Project: Dr. Huang has overseen the administration and management of the project. She also performed work in the area of literature and product review, video analysis, game design and objectives and created content for the after-action review. She greatly contributed to conducting the research and writing of the manuscript.

Name: Rukhsana Khan, MPH
Project Role: Research Assistant
Researcher Identifier: N/A
Nearest person month worked: N/A (No cost extension period)
Contribution to Project: Ms. Khan has provided assistance in project management. She has also performed work in the area of literature and product review, video analysis, game development and completion of IRB application. She also contributed to conducting the research serving as the coordinator for all research activities.

Name: Noreen Webb, PhD
Project Role: Co-Investigator
Researcher Identifier: N/A
Nearest person month worked: N/A (No cost extension period)
Contribution to Project: Dr. Webb has performed work in the area of literature and product review, video analysis and provided input for game design and objectives. She conducted the data analysis for the research and contributed immensely to writing the manuscript.

Name: Federica Raia, PhD
Project Role: Co-Investigator
Researcher Identifier: N/A
Nearest person month worked: N/A (No cost extension period)
Contribution to Project: Dr. Raia has performed work in the area of literature and product review, video analysis and provided input for game design and objectives. She also contributed to writing the manuscript.

Name: Rachel Lewin
Project Role: Graduate Student Researcher
Researcher Identifier: N/A
Nearest person month worked: N/A (No cost extension period)
Contribution to Project: Ms. Lewin has performed work in the area of literature and product review, video analysis and provided input for game design and objectives. She led focus group interviews of healthcare teams and helped summarize those findings. She also helped develop and author scenarios for both simulation modes and contributed to the writing of the manuscript.

Name: Michael Smith
Project Role: Graduate Student Researcher
Researcher Identifier: N/A
Nearest person month worked: N/A (No cost extension period)
Contribution to Project: Mr. Smith has performed work in the area of literature and product review, video analysis and provided input for game design and objectives. He also led subject matter expert interviews and helped write a summary of those findings.

Name: Markus Iseli, PhD
Project Role: Co-Investigator
Researcher Identifier: N/A
Nearest person month worked: N/A (No cost extension period)
Contribution to Project: Mr. Iseli has helped plan and design the domain ontology and screen-based simulation interface. He managed the automated assessment data and contributed significantly to writing the manuscript.

Name: John Lee, PhD
Project Role: Co-Investigator
Researcher Identifier: N/A
Nearest person month worked: N/A (No cost extension period)
Contribution to Project: Mr. Lee has managed the CRESST team’s deliverables specifically pertaining to the design and development of domain ontology and screen-based simulation interface. He also substantially contributed to writing the manuscript.

Name: Alan Koenig, PhD
Project Role: Co-Investigator
Researcher Identifier: N/A
Nearest person month worked: N/A (No cost extension period)
Contribution to Project: Dr. Koenig has provided leadership over the planning and design of the domain ontology and screen-based simulation interface. He also helped write the manuscript.

Name: Charles Parks
Project Role: Programmer
Researcher Identifier: N/A
Nearest person month worked: N/A (No cost extension period)
Contribution to Project: Mr. Parks has performed work in framework design and programming test environments for the screen-based simulation game.

Name: Yen-Yi Juo, MD
Project Role: Research Fellow
Researcher Identifier: N/A
Nearest person month worked: N/A (No cost extension period)
Contribution to Project: Dr. Juo has provided clinical direction in the development of potential game scenarios and its objectives. He also contributed to writing the manuscript.

Name: Areti Tillou, MD
Project Role: Co-Investigator
Researcher Identifier: N/A
Nearest person month worked: N/A (No cost extension period)
Contribution to Project: Dr. Tillou provided clinical expertise on ontology and simulation scenario development. She also helped with piloting of the game and identifying recruitment opportunities for data collection. She also contributed to writing the manuscript.

**Has there been a change in the active other support of the PD/PI(s) or senior/key personnel since the last reporting period?**

Nothing to Report.

**What other organizations were involved as partners?**

*Organization Name:* Siminsights Inc.

*Location of Organization:* 20381 Lake Forest Drive, Suite B15, Lake Forest, CA 92630

*Partner's contribution to the project: Collaboration.*
Partner provided programming support for the development of our screen-based simulation.

## 8. SPECIAL REPORTING REQUIREMENTS

**COLLABORATIVE AWARDS:** For collaborative awards, independent reports are required from BOTH the Initiating PI and the Collaborating/Partnering PI. A duplicative report is acceptable; however, tasks shall be clearly marked with the responsible PI and research site. A report shall be submitted to **https://ers.amedd.army.mil** for each unique award.

**QUAD CHARTS:** If applicable, the Quad Chart (available on https://www.usamraa.army.mil) should be updated and submitted with attachments.

**9. APPENDICES:** Attach all appendices that contain information that supplements, clarifies or supports the text. Examples include original copies of journal articles, reprints of manuscripts and abstracts, a curriculum vitae, patent applications, study questionnaires, and surveys, etc.

## Bibliography

1. Iseli M, Koenig AD, Lee JJ, Lewin R, Steadman RH. AGILE Methodology for Developing a Game-Based Assessment of Teamwork Skills. Presented at the: American Educational Research Association (AERA) 2018 Annual Meeting; April 14, 2018; New York, NY.

2. Poorsattar SP, Rice CM, Steadman RH, et al. Developing A Serious Game for Teamwork Skills Training and Assessment. Presented at the: UCLA Annual Scientific Evening 2019; March 5, 2019; Los Angeles, CA.

# Design of a Screen-Based Simulation for Training and Automated Assessment of Teamwork Skills

Log Number: DM142062
Award Number: W81XWH-16-1-0308

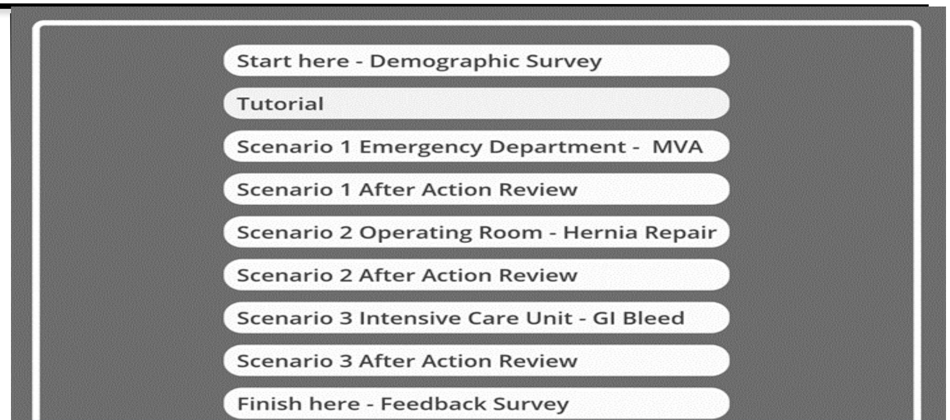
**PI:** Randolph Steadman, MD **Org:** University of California, Los Angeles **Award Amount:** $1,148,000

## Study/Product Aim(s)

- **Aim 1**: Identify team training practices, performance gaps and resources
- **Aim 2**: Create domain ontology (necessary actions, decisions and their inter-relationships) and scenario scripts
- **Aim 3:** Design a framework for online team training and assessment
- **Aim 4**: Build screen-based simulation (evaluation and game-play modes)
- **Aim 5:** Conduct research study using the screen-based simulation

## Approach

A literature review will identify gaps in team training, limitations of current training methods and essential behavioral skills. This phase will identify the core teamwork skills that will be the focus of the simulation-based systems we develop. We will then create the ontology and scenario scripts and conceptualize the framework for the screen-based simulation. Finally, we will evaluate the training effectiveness and user interface of the screen-based simulation systems.




Main menu of screen-based simulation

Accomplishment: We have completed all of our project goals including data collection and data analysis. Our findings have been summarized in a final report and manuscript.

## Timeline and Cost

| | | | | CY 2016 | | | | | | CY 2017 | | | | | | | | | | | | CY 2018 | | | | | | | 6 Mo. Extension | | | | | | Add'l 6 Mo. Extension | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| **Specific Aims/ Tasks/ Milestones** | **Planned Month** | **% Completion** | **Revised timeline as of Month 30 (completion date)** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | **24** | **25** | **26** | **27** | **28** | **29** | **30** | **31** | **32** | **33** | **34** | **35** | **36** | **37** |
| **1. Identify current team training practices, performance gaps and resources** | 1-6 | | 1-14 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | | | | | | | | | | | | | | | | | |
| 1A. Review existing research, products and best practices | 1-2 | 100% | N/A | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1B. Perform video review analysis of medical teams in action | 1-4 | 100% | N/A | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1C. Interview SMEs and healthcare practitioners | 4-5 | 100% | N/A | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1D. Conduct/analyze focus groups of healthcare teams | 5-6 | 100% | N/A | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1E. Prepare report of current practices and gaps in team training **(Deliverable)** | 2-6 | 100% | 2-31 (1/2019) | | | | | | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | |
| **2. Create domain ontology and scenario scripts** | 5-8 | | 5-21 | | | | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | | | | | | | | | | |
| 2A. Create team training core skills domain ontology | 5-7 | 100% | N/A | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2B. Create set of features, affordances and actions for user interface | 6-8 | 100% | N/A | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2C. Create range of scenario settings/events | 6-8 | 100% | 6-16 (11/2017) | | | | | | | | | X | X | X | X | X | X | X | X | | | | | | | | | | | | | | | | | | | | | |
| 2D. Create a knowledge assessment (baseline team skills) scenario | 7-8 | 100% | 7-16 (11/2017) | | | | | | | | | X | X | X | X | X | X | X | X | | | | | | | | | | | | | | | | | | | | | |
| 2E. Create 3 scenarios with different settings, events, skills requirements | 7-8 | 100% | 7-21 (4/2018) | | | | | | | | | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | | | | | | | | | | |
| **3. Design a framework for online team training and assessment** | 8-11 | | 8-26 | | | | | | | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | | | | | |
| 3A. Design the automatic assessment engine | 8-9 | 100% | 26 (8/31/2018) | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | |
| 3B. Design the simulation interface | 8-10 | 100% | 26 (8/31/2018) | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | |
| 3C. Design the after-action reporting | 10 | 100% | 26 (8/31/2018) | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | |
| 3D. Pilot storyboard workflows for quality assurance piloting | 9-11 | 100% | 26 (8/31/2018) | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | |
| **4. Build screen-based simulation (Evaluation and Game-Play modes)** | 8-13 | | 8-27 | | | | | | | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | | | | |
| 4A. Develop software specifications | 8 | 100% | 26 (8/31/2018) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4B. Develop software-based prototype of two simulation modes | 9-13 | 100% | 26 (8/31/2018) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4C. Perform software testing for quality assurance | 12-13 | 100% | 27 (9/31/2018) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **5. Conduct research study using screen-based simulation** | 6-8, 14-24 | | 6-8, 14-37 | | | | | | X | X | X | | | | | | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | x |
| 5A. Obtain IRB approval from UCLA and USAMRMC HRPO | 6-8 | 100% | N/A | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5B. Recruit subjects to test screen-based simulation | 14-22 | 100% | 28-35 (10/2018-5/2019) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5C. Conduct follow up Interviews with select subjects | 16, 19, 22 | 100% | 28-36 (10/2018-6/2019) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5D. Perform quantitative and qualitative data analysis | 22-23 | 100% | 36-37(6/2019-7/2019) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5E. Prepare and deliver final report **(Deliverable)** | 22-24 | 100% | 35-37(5/2019-7/2019) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **6. Write manuscript for publication (Deliverable)** | 6,7,11,12, 18,19,23,2 | | 35-37 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Estimated Budget ($K) | | | | $313 | | | | | | $574 | | | | | | | | | | | | $261 | | | | | | | $0 | | | | | | $0 | | | | | |

**Updated:** (10/07/2019)

**Goals/Milestones**

**CY16 Goal** – Gap analysis

☑ Literature and video review

☑ Interview subject matter experts and focus groups

**CY17 Goals** – Complete screen-based simulation

☑Complete domain ontology and study scenarios

☑ Complete framework design for online team training and assessment

☑ Complete programming of the interactive environment

☑ Recruit subjects to test screen-based simulation

**CY18 Goal** – Complete research data collection

☑Continue to recruit subjects

☑Perform qualitative and quantitative data analysis

**Comments/Challenges/Issues/Concerns:**

Encountered delays in programming and scenario development, which caused delays in subject recruitment and data collection.

**Budget Expenditure to Date**

Projected Expenditure: $1,148,000

Actual Expenditure: $1,148,000

## LITERATURE REVIEW, SUBJECT MATTER EXPERT INTERVIEW AND FOCUS GROUP REPORT

The first phase of our research involved background research to inform design and development of our screen-based simulation. To do so, we explored three methods and combined information gleaned from reviewing the literature, interviewing subject matter experts (SMEs) and conducting focus groups.

## LITERATURE REVIEW

### INTRODUCTION

The purpose of this review was to examine existing literature, research, products, software, and tools to identify current team training practices and performance gaps during high stakes medical team activities. The review focused on areas of research that would be helpful for curricular framework and design of this project's screen-based simulation for training and automated assessment of teamwork skills (ontology design, definition of instructional objectives, assessment design, and scenario development). We examined the following topics:

1) teamwork dimensions for team training
2) effectiveness of team training in healthcare
3) measuring acquisition of teamwork knowledge and skills
4) impact of teamwork training on teamwork knowledge and skills
5) teamwork attributes that are challenging to represent in a single player screen-based healthcare simulation
6) methods of simulation-based teamwork training: observational (vicarious) versus participatory learning
7) design issues related to authenticity of screen-based simulations
8) feedback and debriefing in simulated teamwork settings
9) screen-based simulations versus high fidelity simulators
10) screen-based simulations teaching teamwork in medical settings

### METHODS

The first part of the literature review was a scoping review of teamwork, team training, simulation, feedback, measurement, and outcomes, with special emphasis on gaming environments and the healthcare context. First, content experts identified highly relevant literature. Our search was expanded based on the references from this literature. Second, we completed an extensive search in PubMed, CINAHL, PsycINFO, ERIC, and Business Source Premier in the following areas:

1) Transferability of skill training and feedback
2) Methods in computer gaming, virtual reality, and team training

This extensive search yielded approximately 6,000 results. Using keywords we identified 1,500 of the most relevant articles for further scrutiny. A number of the excluded articles were considered to ensure that relevant articles were not being excluded. These 1,500 articles were then used to create this scoping review. Search terms and keywords can be found in **Appendix A**.

The second portion of our review analyzed research in simulated environments with the purpose of identifying issues especially germane to the design of single-player screen-based simulations. The primary research areas examined were:

1) human-computer social interaction in computer-mediated simulation (live players interacting with virtual agents in a computer-generated simulation using, for example, avatars, virtual reality)
2) human-human interaction in live role-play simulation with live players interacting in face-to-face simulation (i.e., mannequin simulation)
3) human- social interaction in computer mediated simulation with live players interacting in a computer-generated simulation (i.e., avatars, 2nd Life, etc.), and
4) human-robot social interaction in live non-simulated settings.

We began the second portion of the review with a limited set of keywords (ethnomethodology, conversation analysis, simulations, interaction, dialogue, conversation, and debriefing), selected the literature that was most relevant to this project's simulation, and followed further citations using a "snowball" approach. Special attention was given to research that focused on teamwork training in medical and other professional environments and that analyzed social interaction among team members (for example, using video or audio recordings of naturalistic interaction, Stivers & Sidnell, 2016).

The third part of the review focused on screen-based simulations. We reviewed relevant research comparing screen-based and high fidelity simulations, and screen-based simulations teaching teamwork in medical settings.

FINDINGS

**Teamwork Dimensions for Team Training**

Team training programs incorporate multiple dimensions of teamwork that are variously labeled, but cover similar constructs. For example, Salas et al. (2005) identified five core components of teamwork that should be included in training – team leadership, mutual performance monitoring, backup behavior, adaptability, and team orientation—along with a set of supporting coordinating mechanisms (shared mental models, closed-loop communication, mutual trust). Widely used team training programs cover much the same set of dimensions. The key dimensions underlying TeamSTEPPS (Team Strategies and Tools to Enhance Performance & Patient Safety, https://www.ahrq.gov/teamstepps/index.html), for example, are:

- team structure (e.g., assigning or identifying team members' roles and responsibilities)
- communication (e.g., using check-backs to verify information that is communicated)
- leadership (e.g., delegating tasks or assignments as appropriate; briefs/huddles/debriefs to create a shared understanding of/update/review the plan of action and its outcomes)
- situation monitoring (e.g., monitoring fellow team members to ensure safety and prevent errors)
- mutual support (e.g., provides timely and constructive feedback to team members) (Agency for Healthcare Research and Quality, 2006)

Some team training programs are tailored to the particular teamwork skills that are thought to be required in a specific domain or environment. For example, Reader (2017) describes how programs may highlight different decision-making skills depending on the demands of effective patient care in different scenarios: for example, leadership that fosters input from those in junior roles in cancer diagnosis teams vs. anticipating others' needs and supporting others in anesthesia teams.

**Effectiveness of Team Training in Healthcare**
Recent reviews show that healthcare team training is effective for a variety of outcomes, including trainees' perceptions of the usefulness of team training, acquisition of knowledge and skills, demonstration of trained knowledge and skills on the job, and patient and organizational outcomes (Hughes et al., 2016). Moreover, the meta-analytic review by Hughes et al. (2016) reported that a wide variety of moderators generally do not influence the effectiveness of team training, including:

a) the nature of training (e.g., information, demonstration, practice),
b) whether the training program provides feedback,
c) whether the training program uses simulators that are high on physical fidelity,
d) whether the team training is delivered to teams who are homogeneous in terms of profession or discipline
e) whether team training was provided to students or practicing clinicians, and
f) whether patient acuity (health status of the patient) was high or low.

One other moderator showed a counterintuitive relationship with outcomes: training that involved feedback exhibited weaker effects than training that did not involve feedback, at least for selected outcomes (e.g., learning of knowledge and skills). The authors note that the studies that included feedback were characterized by an authority differential between the giver (attending, senior staff) and receiver (junior staff, student) of the feedback and that feedback may have been aimed at the person rather than at the task, creating the possibility that anxiety decreased learning. Neither was the clarity of the feedback specified in the Hughes et al. (2016) meta-analysis. Clarity is a significant moderator of feedback effectiveness, as noted in a meta-analysis by Hysong (2009) that demonstrated a positive effect of audit and feedback effectiveness on patient outcomes. Effective feedback was clear, timely, specific, written, and frequent.

**Measuring Acquisition of Teamwork Knowledge and Skills**
A variety of methods have been used to measure acquisition of teamwork knowledge and skills, including questionnaires, surveys, observations, and interview. Very commonly, rating scales are used to judge teamwork dimensions, such as the 7-point communication rating scale used by Healey et al. (2006) to measure team communication in interprofessional surgery teams (ranging from a high of 6 indicating that team communication was highly effective in enhancing teamwork to a low of 0 indicating that team communication severely hindered teamwork).

Effectiveness described or measured according to specific teamwork behaviors is less common. Most of these studies focus on leadership behaviors, such as the team leader introducing herself or himself, expressing what he or she is thinking, acknowledging vs. ignoring input from other team members (Bank et al., 2014), or the team leader actively seeking feedback, admitting when he or she does not know how to do something, taking notice of others' strengths, and showing appreciation for the unique contributions of others (Owens & Hekman, 2016). Some studies also include behaviors that apply to all team members, most notably communication skills such as relaying problems during attempts to execute technical tasks, or challenging others who are using inadequate or inappropriate therapy (Garden et al., 2010), or calling out the results of exams (Muller-Juge et al., 2014).

Even less often addressed is how teamwork behaviors might be incorporated into simulation-based training at the level of specific, observable behaviors. An exception is Rosen et al. (2008) who describe how simulations can be designed around critical events and the targeted responses that a team leader or team member should demonstrate in response to the event. For example, in the context of a scenario in which a patient suddenly collapses and becomes apneic and pulseless, and team members stand at the patient's bedside awaiting directions or orders, the team leader can demonstrate the leadership skill of observing and helping direct activities of other team members by asking the RN to put the patient on a cardiac monitor and then to secure an IV and asking the ED tech to begin chest compressions.

**Impact of Teamwork Training on Teamwork Knowledge and Skills**

In the many studies on the impact of teamwork training on teamwork knowledge and skills, the training programs cover all of the major dimensions of teamwork, without identifying any dimensions that should receive special focus or priority (for example, leadership vs. communication). Most studies find improvement in all of the major teamwork dimensions (e.g., team structure, leadership, situation monitoring, mutual support, communication, Sawyer et al., 2013; Weaver et al. 2010). There is some variation from study to study in which specific teamwork behaviors are improved by teamwork training, and no systematic pattern emerges about which skills are more (or less) amenable to change. Most studies report that training improves performance on most of the teamwork behaviors studied. The behaviors not showing improvement are quite varied across studies, such as existing teams orienting new members (Miller et al., 2012), or team members clarifying ambiguous orders, clearly identifying the leader, and the leader managing noise appropriately (Roberts et al., 2014). Despite evidence of short-term improvement in many skills following training, there are also indications of decay in many teamwork skills over time (several months to one year following training; see review by Weaver et al., 2014). Again, research reveals no systematic pattern in terms of which specific teamwork skills or behaviors are more (or less) resistant to relapse over the long term.

A review of team training in healthcare by Marlow et al. (2017) suggested future directions for healthcare team training in order to fill gaps in current understanding and improve training outcomes. Suggestions include: implementing team training in non-academic primary care settings; increasing the diversity of disciplines engaged; increasing the breadth of teamwork skills taught; distributing training over multiple sessions; using control groups in team training evaluations; expanding assessment measures to include observer reports, reporting systems, patient chart reviews, and automated performance reports; and evaluating the impact of training on patient care quality and clinical outcomes.

**Teamwork Attributes that are Challenging to Represent in a Single Player Screen-based Healthcare Simulation**

Several important teamwork skills described above present challenges to training via a single player screen based simulation, including addressing hierarchy/power distance in the instructor-learner relationship, managing stress/improving resilience, providing high quality feedback or debriefing, establishing trust/psychological safety, and promoting team cognition through creation of a team mental model and maintenance of team situation awareness.

While there has been significant study of the effects of hierarchy, status, and power on teams, these effects are quite difficult to represent via a single player screen based simulation. Status, the respect or admiration that an individual enjoys in the eyes of others, is a subjective hierarchical measure (Magee & Galinsky, 2008). It is known that high status individuals on a team motivate low status individuals, but can be uncooperative and reluctant to participate on teams in ways that would result in loss of status. Performance on collaborative tasks improves when both high and low status individuals are present on a team, but individual performance suffers when low status individuals must compete with high status individuals. Status and hierarchy disagreements can lead to poor team coordination, relationship conflict, and task conflict (Luan, Hu, & Xie, 2017). Because status is subjective, it is particularly challenging to represent in a single player screen based simulation; the player does not have the time or ability to develop interpersonal relationships and make assessments necessary to develop a status hierarchy.

Power is a non-subjective hierarchical measure, and is conferred by position or title. Power hierarchies are reproducible to some degree within a single player screen based simulation, because a strict hierarchy can be dictated by the game. Power hierarchies are more static than status hierarchies and are more difficult to affect or change. Because of this, low-power individuals spend less time competing for high-power positions. However, because status requires positive estimations from peers, high *status* individuals are more likely to attend to others' opinions and perspectives and to treat others with fairness than are high *power* individuals (Galinsky, Magee, Inesi, & Gruenfeld, 2006). These interpersonal components of a power hierarchy will not be well represented in a single player screen based simulation.

Stress can significantly affect both team and individual performance. Team stress is defined as "the relationship between the team and its environment, including other team members, that is appraised as taxing or exceeding their resources and/or endangering their well-being" (Weaver, Bowers, & Salas, 2001). Team stressors include time pressure, task load, fatigue, role ambiguity, uncertainty, and many others (Driskell, J.E., Salas, & Johnston, 2006). Those participating on a team can also experience individual level stress. The combination of team and individual stressors reduce team performance effectiveness (Burke et al. 2008). Some of these stressors are challenging to reproduce in a single player simulation, but it will be possible for non-player characters to act stressed, e.g., showing decreased cooperation and ineffective communication.

Team trust or psychological safety has been described as a key factor in team effectiveness (for a review, see Costa and Anderson, 2017). High trust in teams appears to lead to an increase in exchange of relevant information, and decreased conflict due to acceptance of the influence of teammates, and decreased efforts to control the behavior of teammates (ibid, 2017). Again, a single player screen based simulation does not afford the opportunity for the player to establish or participate in the creation of a climate of team trust with non-player characters. The simulation may be able to approach skill development in this area by rewarding the player for eliciting information from non-player characters.

Perhaps the highest order team skills are those of team cognition: creating and sustaining a team mental model and team situational awareness. A meta-analysis by DeChurch & Mesmer-Magnus (2010) examined team cognition in relation to team behavioral process, motivational states, and team performance and found a strong positive association. Because the skills of team cognition exist at a group level, a single player game would not afford training or practice of these skills. In the future, creation of a multi-player screen-based simulation may provide an opportunity to explore this important parameter of teamwork.

**Methods of Simulation-based Teamwork Training: Observational (Vicarious) vs. Participatory Learning**

Training using teamwork simulations can involve learners as participants or as observers (or both). Research investigating these two modes of learning from simulations in healthcare settings generally finds that observing teamwork simulations produces gains in knowledge, skills, attitudes, and behaviors regarding technical and nontechnical skills, and, under some circumstances, may be more effective than participating in simulations alone. For example, in a review of nine studies that compared participating in healthcare simulations versus observing simulations for a range of outcomes, O'Regan et al. (2016) found that playing an observer role was as good as, or better than, carrying out a hands-on role in simulations. The benefits of observation were especially pronounced in studies that used tools that encouraged "active" observing rather than passive watching. Research has also documented advantages of observational learning for knowledge of doctor-patient communication skills, and confidence in being able to overcome hierarchy-related issues to resolve disagreements in the team setting, especially when observations are supported by an explicit observation script (Stegmann et al., 2012; McEwen-Campbell, 2015).

**Design Issues Related to Authenticity of Screen-based Simulations**

Research shows that lack of perceived authenticity in simulated scenarios restricts validity of participants' behavior only when players notice deviations in the settings, dialogue, or events in the simulations that they cannot make sense of or appear arbitrarily motivated by the game designers or whenever they see their actions as 'unfairly' assessed (Stokoe, 2011; 2013; 2014). In simulation game settings, participants can generally accept artificiality in their or non-player characters' actions as long as the actions and events in the game retain their applicability to real-life settings (De la Croix & Skelton, 2009). Players can readily accept limitations of the medium (e.g., low-resolution graphics, keyboard text-based input) and constructed elements of the simulation (e.g., storyboard elements, toolbars, etc.) so long as these are provided in an organic, accountable, and—for the player—predictable manner. What appears central to the players' sense of efficacy is their ability to reliably build repeatable actions in that environment even if they are not entirely life-like in execution (Spagnolli, Varotto, & Mantovani, 2003).

The degree to which human participants are likely to treat their virtual-agent interlocutor as a conversational agent depends on the responsiveness of the virtual agent (Corti & Gillespie, 2016; Fischer & Batliner, 2000; Fischer, 2011; Hudlicka et al., 2009; Fischer et al., 2013; Fischer & Kerstin, 2011), and the expressive features of communication like social cues or more general features of prosocial interaction (e.g., "believability," "reciprocity," "reflexivity"). A number of researchers raise cautions against ignoring the ecological validity of the conversational actions and behaviors that they script for the player and non-player characters: simulations that do not adequately anticipate what is routine for a given setting may provide little to no guidance in later informing participants' behavior in the target setting (Husebø et al., 2012; Stokoe, 2013; Sjöberg, 2014; White & Casey, 2016). For example, one reason why medical learners do not always benefit from practicing consultations with simulated patients (Lane & Rollnick, 2007; Lane, Hood, & Rollnick, 2008) may be divergence of simulated interactions from their real-life counterparts. De la Croix and Skelton (2009) found that simulated patients (SPs) in simulated doctor-patient conversations sometimes presented a poor model of how patients might behave; SPs were more dominant and assertive (e.g., asked more direct questions, more likely to initiate topics) than real patients. Recordings of real-life encounters may help inform the design of interactions, composition of talk, and actions produced in simulated settings (Stokoe, 2013).

**Feedback and Debriefing in Simulated Teamwork Settings**

As noted above, the effectiveness of feedback (provision of information) in team training is mixed and may depend on the quality of the feedback and specific circumstances surrounding the feedback conversation. A screen based simulation can be programmed to provide feedback that is clear, immediate, written, and specific to the error(s) noted.

It is more challenging to incorporate debriefing – facilitated back-and-forth discussion of prior performance, usually involving an instructor or other expert – into an automatic simulation. Debriefing with human facilitators has been found to play an important role in students' acquisition of knowledge (Crookall, 2010; Husebø et al., 2012) due to the opportunities for learners' reflection on their performance and thinking, connections the facilitator makes between the learner's performance and the learning objectives of the simulation, the facilitator's guidance of the learner toward certain ends, and the facilitator's alerts about how the real-life situation may differ from the simulation (Schick, 2008; Seale et al., 2007).

In the absence of a physically or virtually co-present facilitator, instructor, or tutor, a simulation can incorporate "self-debriefing" (Walther, 2013). Effective self-debriefing consists of non-ambiguous automatic prompts that encourage players to actively reflect on their performance and make connections to real-world settings. A simulation can be punctuated by multiple debriefings with game play occurring between the debriefings. For valid and effective debriefing, lessons learned in prior game-play or in the debriefing are effective in later game-play (van den Hoogen, Lo, & Meijer, 2014). One way of promoting the internal validity of the simulation and debriefing as a whole process is via event-structure analysis (ibid, p. 3509). This method analyzes causality within the game specifically as a sequencing of events that have a specific temporal ordering, where past actions/events constrain future actions/events, or, through temporal side branches, indirectly trigger later actions/events. “Narratives” for the player and/or facilitators are specifically built from these events for digest and use in the debriefing. Counterfactuals play an important role in this regard. Every event is analyzed as if it were just an instantiation of another possible event that is the negation or modification of that specific event, basically requiring that the participants entertain "what if-questions” (ibid).

**Screen-Based Simulations Versus High Fidelity Simulators**

Some researchers have found that use of screen-based simulations elicited better performance than those of a control group, e.g., when learning cardiac arrest procedures (Bonnetain, Boucheix, Hamet, & Freysz, 2010). Screen-based simulation has also been shown to be as good as high-fidelity simulators in anesthesia training (Nyssen, Larbuisson, Janssens, Pendeville, & Mayné, 2002; Schwid, Rooke, Michalowski, & Ross, 2001). In addition, web-delivered screen-based simulations have also been found to be as good or better as traditional face-to-face teaching in a number of studies for various nursing skills (Cant & Cooper, 2014). Screen-based simulators (level 2 on the 5-level scale in relation to technological simulation, Alinier, 2007) have the advantage of providing feedback and can be used in self-taught environments (Ziv, Small, & Wolpe, 2000). The latter study also showed transfer between the screen-based to mannequin-based simulators but did not show transfer to real-life situations. There is also some variation in performance across scenarios, e.g., with three different emergency resuscitation scenarios (Owen, Mugford, Follows, & Plummer, 2006).

**Screen-Based Simulations Teaching Teamwork in Medical Settings**

One of the programs we reviewed was the Safe Surgery Trainer, a screen-based simulation teaching teamwork skills in the operating room (Murphy, 2014). Research using this software (Kreutzer, Marks, Bowers, & Murphy, Curtiss, 2016, p. 49) demonstrated that:

Participants who played the game demonstrated higher levels of declarative knowledge about effective communication behaviors. Those who played the game were also better able to apply knowledge about effective team communication to novel situations, and displayed higher levels of training transfer in comparison to those who took the knowledge test first. Thus, playing the game was indeed helpful. This suggests that in addition to increased knowledge, behavioral changes are possible if a game delivers appropriate information and provides opportunities for practice.

Our review also included the aspects of the interface and interactivity that could be emulated or enhanced. Having the player take on multiple roles to see different perspective across the team was considered beneficial. We also liked the reduced focus on the medical aspects of the tasks and greater emphasis on the teamwork skills. We felt that the communication dialog boxes could be enhanced by providing more open-ended forms of communication (typed and/or spoken).

Another program we observed was an online video demonstration for the American Society of Anesthesiologists (ASA) and CAE Healthcare's SimSTAT software. This tool is more focused on medical/technical skills versus teaching teamwork skills. We liked the high-fidelity environment. However, the dialog is still limited to a smaller number of menu choices. Also, the assessment is mostly procedural and does not appear to measure higher order latent skills like situation awareness across scenarios. We also did not agree with the use of numeric scores, and what was more confusing was that a higher score is worse. Finally, the use of many icons on the interface could be confusing to the player. It might be enhanced by using a limited number of colors, to group them and label them. Not all icons appeared to be intuitive in what clicking on them would get you to.

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**SUBJECT MATTER EXPERT INTERVIEW SUMMARY**

Five subject matter expects (SMEs) were interviewed by phone, facilitated by the same researcher with at least three other investigators listening in and taking notes. Recordings and notes from each interviewer were transcribed and collated to produce the following summary of themes. Interview questions are in **Appendix B**. All SMEs had a minimum of 10 years of experience working on teamwork program and research.

I. Where is teamwork crucial?

- Several interviewees stated that teamwork was crucial for high-acuity medical situations. In trauma for instance, the fast pace setting and the number of people and disciplines involved make determining the leader difficult. It requires an understanding of the patient before coming to trauma, who should be involved, who will lead and what the leadership role should entail. Leaders should be hands off if possible to maintain situational awareness.

- Such situations highlighted the need for having individuals monitor the bigger picture outside of the patient (i.e., how many cases are coming in and how that affects the team members caring for the current patient). People should share how participants identify as leader. Communication is crucial in making sure vital sign changes, equipment and tests are shared – all in very short timeframe. Teams need a shared mental model of roles and expectations.
- A specific example: The patient was in the lateral position with double lumen tube in ongoing surgery. The surgeon asked if it would be better to finish and flip the patient. The surgeon basically gave permission for something anesthesiology should be requesting, which was both helpful and perceptive.

II. What are important skills for high acuity settings
- One SME noted the top three to be 1) situational awareness and monitoring what's going around you. Need to understand what you're doing but also what's happening around you and what others are doing that might affect what you do (cascading affect). 2) Ability to challenge hierarchy and status quo thinking (i.e. speaking up for patient safety). 3), leadership skills: briefing and debriefing, what/how we can do things differently next time.
- Another SME said that while communication is often listed as the most important skill, but in actuality, participants' ability to define roles, have check-ins and markers, and have common goals are much more important.
- A third SME noted the importance of distribution of work, role clarity, knowing when to call for help, how to designate leadership.
- A fourth SME emphasized the role of consistency in teamwork and felt that expertise was necessary for teamwork.

III. What undermines teamwork?
- Lack of preparedness; undermining trust in one or others' ability to fulfill roles in organization.
- Hierarchy and cultural issues (domain/disciplinary tribe, physicians, nurses, others; production pressure and how that affects individual and team; institutional culture – system created incentives or disincentives to work in a certain way; national culture)

IV. Traits and practices for good team-player:
- Being a good listener, open to critique, and ability to adapt important traits.
- While technical skills are the easiest to teach, assimilating data and decision-making was harder. At the same time, expertise and proficiency are sufficient for effective teamwork suggesting that while teamwork skills are important, they are the outcome of an experienced, proficient professional. (This implies that experts should have effective teamwork skills.)
- Traits and practices for poor team-player: not wanting to change, bad listener, feel that others don't have same knowledge as they do

V. Challenges to Teaching Teamwork:
- Must be taught through experience and experiential learning. Hardest skill to teach is situational awareness and how to recognize need for mutual support.

- Teamwork seems to be an easy concept to grasp; people think they know what teamwork looks like, but that is not always the case. The skills being taught are really common sense. The learner already knows so many tools and strategies, and that's very helpful, but teaching them how to implement is the trickier part. They need to identify that there is a teamwork problem, understand how to implement an intervention, and assess the effectiveness of intervention.
- The problem with teaching teamwork is that you aren't teaching anything new to participants; they may learn or know "SBAR" tool but what's important is teaching them how and when to implement the tool in a sustainable manner.

VI. What skills are easiest to teach?

- Communication is easiest because most people think that is the root problem so they are highly motivated to learn communication tools. The knowledge part is easy, the application part is the hard part.

VII. What skills are difficult to teach?

- Getting practitioners to separate medical practices and procedures from teamwork – use games and activities that have nothing to do with medical setting so learners can focus on teamwork skills. During simulation, assign individuals roles not consistent with their expertise or "day job" in effort to try to get them to focus on teamwork aspect vs clinical aspect. In simulated activities, pre-assigning individuals roles frees learners from having to know what their roles are in the simulation is, allowing them to focus on teamwork for feedback.
- Assertiveness tools are harder to teach to people who are not in leadership role.

VIII. Ad-hoc vs. standing teams:

- There was a lot of consensus on this issue. Good idea to have both but each has particular demands: With standing teams, we teach learners to take whatever teamwork skill they are using and make it their own. With ad-hoc teams who have different people with different toolkits, they depend on having the same language and same set of expectations when coming into a situation.
- Both are important but ad-hoc teams are harder to train.

IX. Advantages of TeamSTEPPS:

- Evidence-based; many skills and strategies are already familiar to learners. Familiarity really helps. You don't have to teach every possible strategy or tool, you can tailor it to their workplace/environment so it's not overwhelming. You just give them a bit of resources to make their work more effective.
- TeamSTEPPS fits with medical training because it was developed explicitly for healthcare situations with a focus on clinical situations.
- TeamSTEPPS has brand recognition, and thus an easier grasp as to why it's important.

X. Pitfalls of TeamSTEPPS:

- One notable pitfall for TeamSTEPPS is that there's not enough specificity: Lacking in giving tools for situation monitoring. It just says be aware of your surroundings. There are so many tools and strategies in the curriculum, it is hard to coach individuals on scope and find the right tools to address and remedy their problem.

- There is a misperception that TeamSTEPPS is a "cure all." Helping individuals know difference between what a teamwork issue is versus what's a personality issue or an organizational barrier is a challenge.
- Sustainment is a challenge and that's not specific to TeamSTEPPS. People need opportunity to practice tools and use them and opportunity to know they are doing them well. Also be able to see benefits in a transparent way (e.g., reduced infection rate or time to intubate has decreased).

XI. Tools for teaching:

- Mixed-methods approach works best in teaching. More important is in designing games or activities that help people think about teamwork in ways that that are not healthcare specific. If entirely clinical they get easily distracted by medical management, so by having games not clinically related they can focus on teamwork skills. In designing games, it's important to make sure not to allow players to get distracted by medical aspects and instead focus on teamwork aspects.
- Focus on in person training, mostly resident level and above, not novice learners. Roles may be played by confederates, or experienced professionals in their own roles. Use ancillary techniques, such as trigger videos or game-like activities.

XII. Military Implications

- People with military backgrounds have different views of each other in clinical settings, what debriefing means, different approaches. We like conversation and nuances, they tend to more cut and dry with objectives so a lot of plus/delta format, feedback sandwiches, more rigid because of nature of how training is done in their setting. Stick to learning objectives and may miss forest to the trees. Look at how hierarchal and collegial, rules and entrepreneurial thresholds. VA has higher hierarchy because a lot of ex-military on administration and among clinicians, inherit structure from military.
- Military has more standardization; less likely for teams to customize how they work – more structured. People with certain titles will have certain roles; problems with speaking up because of hierarchy; ranges in age and general experience in professional settings quite broad affecting performance.

XIII. Goals/Teaching Objectives:

- Based on individual needs, rank and prioritize them
- Consider hybrid of CRM and TeamSTEPPS with context specific for different groups
- Simulation and debriefing are effective tools
- Make adaptive scenario, use progressive order of difficulty
- Take into account previous experiences
- Create environment where it is OK to ask questions, speak up and have dialogue about disagreements

XIV. Feedback/Other Topics:

- Contingency planning
- Concepts of high reliability organization
- You can teach teamwork tools to an individual through a game but the struggle is whether those taught can actually execute the skills – others have to appreciate and

back up those learning the skills. It would be difficult to use against an organization that is not on board with the same skills.

- How to create psychological safety
- Challenge is to design simulations to make them psychometrically sound and measure generalizability.
- How to manage a person who digs in heels or is toxic – what are the strategies and alternatives and their pros/cons

**FOCUS GROUP REPORT**

In addition to a literature review and subject matter expert interviews, focus groups of healthcare professionals with experience in teamwork were conducted by two investigators, Rachel Lewin (primary interviewer) and Maria Rudolph (secondary interviewer and recorder). Focus group participants were recruited by email from UCLA Ronald Reagan Medical Center. Ten healthcare professionals participated in four focus groups composed of physicians, nurses, and respiratory therapists, all with experience in acute care services. One participant now works in quality improvement.

Focus group participants were asked to be frank in their observations. They were informed that the focus group discussion would be used to inform the development of the screen-based simulation. The focus groups were conducted under an agreement of confidentiality: participants agreed not to share the content of the discussion outside of the group and interviewers assured the participants that both their participation and their responses would be de-identified in all verbal and written reports. Focus groups were videotaped for later reference by the interviewers only.

Focus group questions can be found in **Appendix C**. Focus group interviews were semi-structured to allow for exploration of emerging themes. Subsequent to the interviews, participants were asked to rank a list of teamwork actions in order of importance (**Appendix D**). However, only four participants returned their rankings, which was insufficient to make generalizations.

All focus groups lasted for one hour. Participants spoke with intensity and emotion. Their desire for good teamwork, their dedication to their work, and their loyalty to their patients was evident in their engagement with the topic.

The most prominent themes voiced by focus group participants were:

- Introductions
- Roles/team structure
- Composure
- Visual cues
- Brief/huddle/time-out/debrief

- Pyschological safety
- Mutual support
- Norms and courtesy
- Clear communication
- Desire for previously defined shared mental models
- Consideration of dual leadership during critical incidents

INTRODUCTIONS

Introductions were universally seen as critically important to teamwork by the focus group participants, voicing strong opinions such as, “The worst crime is not to introduce yourself.” “You wouldn’t go into someone’s house and not introduce yourself.” On acute care services such as the Pediatric ICU or in emergencies such as Code Blue, it frequently happens that the team members taking care of a patient in crisis may not know each other. Two types of introductions were emphasized: participants felt that it was important for arriving team members and for those already present to introduce themselves to each other, e.g., “I’m from [role], I’m [name]. Who’s in charge? Who’s the nurse in charge?” and “I’m [name], the [role]. Who are you/where are you from?”

ROLES/TEAM STRUCTURE

Clarity of roles and team structure were also emphasized. Participants felt it was important to know each team member’s role. Establishing roles may overlap with introductions, e.g., “Hi, I’m [name], here to relieve [name or role].” If the team leader has not been identified, it is appropriate to ask, e.g., “Who is team captain?” They appreciate visual cues such as uniform color to make it easy to identify the discipline of each team member. If there is more than one person from a given discipline present, e.g., two respiratory therapists (RT), it is important to assign a specific function to each RT. If possible, they like to have roles assigned prior to the event. Participants bemoaned lack of team structure. Participants also decried poor team structure. One participant described the consequences of losing a team structure that had been working perfectly due to new hospital management. The new structure resulted in overlapping roles, creating confusion and conflict.

COMPOSURE

Participants spoke frequently about composure, particularly in the team leader (“The way you lead the code sets the tone.”) A successful leader is able to “keep their cool” and is not responsive to “negativity.” If the team leader loses their self-control and poise it can result in poor team coordination and effectiveness due to loss of trust in the leader. Deliveries always go better “when you have calm people, not fumbling. If the leader is anxious or loud, things fall apart.” One participant said that it may even be necessary to remove someone from leadership if they become agitated.

VISUAL CUES

Participants appreciate nonverbal cues that assist in communication of roles and process. In addition to the uniform denoting the team members discipline, participants cited use of hats, colored stethoscopes, or colored vests to identify roles. Participants also discussed position around the patient, e.g., a team leader standing at the foot of the bed or at the level of the patient's groin so that the femoral pulse can be monitored throughout a trauma resuscitation. Participants also noted the importance of eye contact, particularly when team members work together frequently: "Sometimes we don't say anything but it is flawless."

BRIEF/HUDDLE/TIMEOUT/DEBRIEF

Participants noted the importance of shared communication during briefs, huddles, timeouts, and debriefings. These moments provide opportunities for role clarification, making sure that all necessary personnel and equipment are present, and creating a shared understanding of the patient's condition and plan of care: "It's very helpful to start with an open, inclusive timeout;" "You're ahead of the game if you can have a plan;" "It helps if you have a huddle. If you know your job and your role everything goes more smoothly. It helps if you know people. When it flows like that it becomes very much about the patient;" "A huddle is very important part way through a code. You can say what has happened so far, ask for corrections, and ask everyone if they have any other suggestions." Participants also expressed a desire for more time to debrief following stressful or difficult incidents.

PSYCHOLOGICAL SAFETY

Participants placed high value on a climate of psychological safety in teams. In particular, they felt that the team leader should be open; encourage speaking up; elicit and appreciate feedback; be courteous; be respectful. Participants suggested language such as, "Does anyone have any other thoughts or suggestions?" "I know this is difficult, but please tell me what I can do to help you;" "(during surgery) Does anyone have any concerns? Any thoughts before closure?" "As a leader, I feel it's important to support you." Leaders can promote psychological safety by "taking time to let everyone introduce themselves; be approachable; open the floor to questions, concerns." "The hero of my day is the person who is very inviting and open to suggestions." Participants made additional statements such as, "You have to let people know they are on a team;" "Don't point fingers;" "Building rapport and credibility are personally important;" "Attitude makes it easier to speak up. If the person is judgmental, it's harder to speak up;" "Empower the rest of the staff;" "Try to realize everyone is doing the best they can – even the most seasoned people can be off – be willing to accept feedback. An attending who micromanages affects the outcome;" "If you don't have support, direction, and guidance from top management, you won't care. You have to have buy-in."

One participant related an anecdote demonstrating the importance of psychological safety in the operating room: A surgical technician noticed something amiss. If she had been with a peer she would have spoken up but because she was only with physicians she was afraid to speak up. As a consequence, the patient had to go back to the operating room for a second procedure because she had not spoken up. Upon review, one physician said it was her duty to speak up. Another physician objected, asking, "don't we have a hierarchy?"

MUTUAL SUPPORT

Participants stressed the importance of team members supporting each other and being aware of one another's performance: "There is never a time when you are working by yourself. You are always on a team;" "A team is only as strong as its weakest link;" "Give concrete feedback, for example, slow down/speed up compressions to a rate of 100/minute;" "One-on-one mentoring is most important – mimicking, modeling, asking for feedback;" "The best outcomes are when roles overlap – then you can be prepared to offer mutual support." Lack of mutual support was cited as a major problem: "Before, we had the team/friend approach – we had each other's back – we didn't have to agree but we could discuss without fear."

NORMS & COURTESY

Participants felt that it is important to identify, practice, and reinforce norms and interact with courtesy: "It should be uncomplicated;" "I would like to have a sign in front of the room that says, 'please introduce yourself;'" it helps if people are friendly and "introduce themselves with, 'Good morning, I'm….'"

CLEAR COMMUNICATION

Participants gave many examples of the importance of clear communication, including sharing thoughts and narrating actions. A respiratory therapist said that he might say, for example: "If I need to bag mask, I'll be rotating to the head of the bed," in order to let the rest of the team know what he is thinking and what future actions he may take. Communication helps to create shared mental models between disciplines: "Nurses can be very tracked on their goals;" problems can be remedied by "giving feedback, talking out loud, stating actions, reporting what you can see, for example, 'I see chest rise.'" Communication facilitates teamwork and builds rapport: "You have to describe what you need from your team members. Be clear, respectful, professional." Communication is used for clarification: "You have to have a sense of what you are supposed to do, what is expected of you." In an emergency, "the situation is always very fluid. You need to stay on top of the situation. You need open communication so that you can adjust the plan." "The sicker the patient, the more important the communication."

DESIRE FOR PREVIOUSLY DEFINED SHARED MODELS

Participants evinced a desire for previously defined shared models, for example, algorithms and protocols for patient management; an established understanding of what roles are needed in certain circumstances; an understanding of how other disciplines divide tasks and define roles; a shared culture; and a shared vocabulary. Using resuscitation algorithms or scripted moves is seen as promoting success during a code. Simulation is appreciated as a way to practice performance during critical incidents. Teams need "agreement on crossover/territorial issues to establish boundaries and they need clarity to resolve differences between conceptions of roles." When previous agreement on roles is absent, "resolving problems with roles takes a long time. People get threatened – defensive and angry." For example, at one point a trauma activation protocol was revised and now there is unclear communication and role confusion, leading to dysfunction and anger between services. TeamSTEPPS was considered helpful because it taught a common teamwork curriculum to everybody. The Neonatal Resuscitation Program teaches situation awareness effectively.

CONSIDERATION OF DUAL LEADERSHIP DURING CRITICAL INCIDENTS

Participants felt that the code or trauma leader “should not be ambiguous;” “When the team captain is called out it makes a huge difference.” Participants were not unified on whether there should be a single leader or a code/trauma leader (usually a physician) and also an event manager (usually the charge nurse). “The most chaotic situations are on adult floors-- pediatrics floors have a rapid response team that is well trained. Nurses have training. Nurses should direct everything – if people leave who know the patient the nurse needs to be empowered to say that this is her patient, and give history. The only problem with “putting on the vest” [taking leadership] is-- does that mean that person will remain leader no matter what?”

# APPENDICES

## Appendix A – Literature Search Criteria

An initial search in PubMed, CINAHL, ERIC, and PsycINFO, and Business Source Premier was completed. Separate searches on Simulation & Team Training and Transferability of feedback to team function were conducted and duplicates were excluded. Search terms are detailed below for each database.

<u>Methods in Simulation & Team Training</u>

**PubMed strategy:** ("Patient Care Team"[Mesh] OR "team training"[tiab] OR teamstepps[tiab] OR "team stepps"[tiab]) AND ("Computer Simulation"[Mesh] OR "Virtual Reality Exposure Therapy"[Mesh] OR "Computer-Assisted Instruction"[Mesh] OR "Video Games"[Mesh] OR "virtual reality"[tiab] OR "Computer gaming"[tiab] OR "augmented reality"[tiab] OR simulation[tiab] OR "screen-based"[tiab]) AND ("methods"[Subheading] OR "Methods"[Mesh] OR "Computing Methodologies"[Mesh] OR method*[tiab])

Number of unique citations (total citations minus the transferability & overlap) retrieved on 9/28/16: 520

**CINAHL strategy:** ((MH "Multidisciplinary Care Team+") OR TX ( "team training" OR teamstepps OR "team stepps" )) AND ((MH "Computer Simulation+") OR (MH "Virtual Reality") OR (MH "Computer Assisted Instruction") OR (MH "Video Games+") OR (MH "Simulations+") OR TX ( "virtual reality" OR "Computer gaming" OR "augmented reality" OR simulation OR "screen-based" )) AND ((MH "Data Collection Methods+") OR (MH "Computing Methodologies+") OR TX method*)

Number of unique citations (total citations minus the transferability & overlap) removing PubMed duplicates: 388 (416 before removal of duplicates)

**ERIC:** (DE "Team Training" OR TX ( "patient care team" OR "team training" OR "teamstepps" OR "team stepps" )) AND ( DE "Computer Simulation" OR DE "Computer Assisted Instruction" OR DE "Computer Games" OR TX ( "virtual reality" OR "Computer gaming" OR "augmented reality" OR simulation OR "screen-based" ) ) AND ( (DE "Methods") OR (DE "Training Methods") OR TX method*)

Number of unique citations (total citations minus the transferability overlap) removing PubMed duplicates: 20 (21 before removal of duplicates)

**PsycINFO:** (SU.EXACT.EXPLODE("Teams") OR ("patient care team" OR "team training" OR teamstepps OR "team stepps")) AND ((SU.EXACT.EXPLODE("Simulation") OR SU.EXACT.EXPLODE("Computer Assisted Instruction") OR SU.EXACT("Virtual Reality") OR SU.EXACT.EXPLODE("Computer Games")) OR ("virtual reality" OR "Computer gaming" OR "augmented reality" OR simulation OR "screen-based")) AND (SU.EXACT.EXPLODE("Methodology") AND method*)

Number of unique citations (total citations minus the transferability & overlap) removing PubMed duplicates: 14 ( 14 before removal of duplicates)

**Business Source Premier:** (( DE "TEAMS in the workplace" OR DE "CROSS-functional teams" OR DE "MULTINATIONAL work teams" OR DE "SELF-directed work teams" OR DE "SENIOR leadership teams" OR DE "TASK forces" OR DE "VIRTUAL work teams" ) OR TX ( "patient care team" OR "team training" OR teamstepps OR "team stepps" ) ) AND (DE "SIMULATION methods & models" OR TX ( "virtual reality" OR "Computer gaming" OR "augmented reality" OR simulation OR "screen-based" ) ) AND (TX method* )
Search limited to scholarly articles
Number of unique citations (total citations minus the transferability & overlap) removing PubMed duplicates: 192 ( 193 before removal of duplicates)

Total citations count minus the transferability & overlap before removal of duplicates: 1164
Total citations count minus the transferability & overlap after removal of duplicates: 1134

<u>Transferability of feedback to team function</u>

**PubMed Strategy:** ("Patient Care Team"[Mesh] OR "team training"[tiab] OR teamwork[tiab] OR "team dynamics"[tiab] OR "team functioning"[tiab] OR "team function"[tiab] OR teamstepps[tiab] OR "team stepps"[tiab]) AND ("Computer Simulation"[Mesh] OR "Virtual Reality Exposure Therapy"[Mesh] OR "Computer-Assisted Instruction"[Mesh] OR "Video Games"[Mesh] OR "virtual reality"[tiab] OR "Computer gaming"[tiab] OR "augmented reality"[tiab] OR simulation[tiab] OR "screen-based"[tiab]) AND ("Feedback"[Mesh] OR feedback[tiab] OR transfer*[tiab] OR debrief*[tiab])
Number of unique citations (total citations minus the methods & overlap) retrieved on 9/28/16: 123

**CINAHL strategy:** ((MH "Multidisciplinary Care Team+") OR TX ( "team training" OR teamwork OR "team dynamics" OR "team functioning" OR teamstepps OR "team stepps" )) AND ((MH "Computer Simulation+") OR (MH "Virtual Reality") OR (MH "Computer Assisted Instruction") OR (MH "Video Games+") OR (MH "Simulations+") OR TX ( "virtual reality" OR "Computer gaming" OR "augmented reality" OR simulation OR "screen-based" )) AND ((MH "Feedback") OR TX ( feedback OR transfer* OR debrief* ))
Number of unique citations (total citations minus the methodology & overlap) removing PubMed duplicates: 2172 (2,198 before removal of duplicates)
**ERIC:** ((DE "Team Training") OR (DE "Teamwork") OR TX ( "patient care team" OR "team training" OR "team dynamics" OR "team functioning" OR "team function" OR "teamstepps" OR "team stepps" )) AND ((MH "Computer Simulation+") OR (MH "Virtual Reality") OR (MH "Computer Assisted Instruction") OR (MH "Video Games+") OR (MH "Simulations+") OR TX ( "virtual reality" OR "Computer gaming" OR "augmented reality" OR simulation OR "screen-based" )) AND (DE "Feedback (Response)" OR TX ( feedback OR transfer* OR debrief*))
Number of unique citations (total citations minus the methodology & overlap) removing PubMed duplicates: 42 (42 before removal of duplicates)

**PsycINFO:** (SU.EXACT.EXPLODE("Teams") OR ("patient care team" OR "teamwork" OR "team dynamics" OR "team functioning" OR "team function" OR "team training" OR teamstepps OR "team stepps")) AND ((SU.EXACT.EXPLODE("Simulation") OR SU.EXACT.EXPLODE("Computer Assisted Instruction") OR SU.EXACT("Virtual Reality") OR SU.EXACT.EXPLODE("Computer Games")) OR ("virtual reality" OR "Computer gaming" OR "augmented reality" OR simulation OR "screen-based")) AND (SU.EXACT.EXPLODE("Debriefing (Experimental)") OR SU.EXACT.EXPLODE("Feedback") OR (feedback OR transfer* OR debrief*))

Number of unique citations (total citations minus the methodology & overlap) removing PubMed duplicates: 140 (156 before removal of duplicates)

**Business Source Complete:**
(( DE "TEAMS in the workplace" OR DE "CROSS-functional teams" OR DE "MULTINATIONAL work teams" OR DE "SELF-directed work teams" OR DE "SENIOR leadership teams" OR DE "TASK forces" OR DE "VIRTUAL work teams" ) OR TX ("patient care team" OR "team training" OR teamwork OR "team dynamics" OR "team functioning" OR "team function" OR teamstepps OR "team stepps" ) ) AND (DE "SIMULATION methods & models" OR TX ( "virtual reality" OR "Computer gaming" OR "augmented reality" OR simulation OR "screen-based" ) ) AND (TX ( feedback* OR transfer* OR debrief* ) )
Search limited to scholarly articles

Number of unique citations (total citations minus the methods & overlap) removing PubMed duplicates: 1672 ( 1675 before removal of duplicates)

Total citations count minus the methods & overlap before removal of duplicates: 4194
Total citations count minus the methods & overlap after removal of duplicates: 4149

Methods & Transferability Overlap

**PubMed** - number of unique citations retrieved on 9/28/16: 181
**CINAHL** - number of unique citations retrieved on 9/28/16: 579 (594 before removal of duplicates)
**ERIC:** - number of unique citations retrieved on 9/28/16: 5 (8 before removal of duplicates)
**PsycINFO:** - number of unique citations retrieved on 9/28/16: 2 (4 before removal of duplicates)
**Business Source Complete: -** number of unique citations retrieved on 9/28/16: 488 (494 before removal of duplicates)

Total citations count for overlap before removal of duplicates: 1281
Total citations count for overlap after removal of duplicates: 1255

Keyword Search Refinement
From the initial set of approximately 3000 articles, we searched for articles containing the following words in the title or abstract:

- Feedback

- Debrief
- Observation
- Scenario
- Self-efficacy
- Team
- Teamwork

This search identified a subset of approximately 1500 articles. We completed a first pass review of these articles, including articles that:

- Had details about the scenario used
- Had an incident based simulation
- Had comparative assessments of simulations
- Had a theoretical framework different from that seen in existing literature
- Had a well validated assessment tool
- Had interprofessional assessments
- Assessed particular elements of teamwork dimensions
- Measured self-efficacy
- Looked at the effect of a task on teamwork
- Discussed team roles and their impact or how to simulate them
- Discussed structured debriefing techniques

A sample of excluded articles was screened to ensure that we were not excluding relevant literature. Included articles were read in their entirety and used in the writing of the literature review.

**Appendix B – Subject Matter Expert Interview Questions**

I. INTERVIEWEE BACKGROUND / EXPERIENCE
   A. Clinical setting, teaching teamwork, and design of online training

II. EXPERIENCES WITH TEAMWORK:
   **A. We would like you to describe a specific example of a professional experience where you found teamwork really made a difference or went unusually well (Preferably in a high acuity setting- OR, ER, or ICU)**
      1. What was the context?
      2. Who was present?
      3. What was your role?
      4. How was role clarity established?
      5. What happened?
      6. What were your observations?
      7. What skills, traits, or attributes did you consider most important or necessary?
      8. How were the most critical skills paired with other skills?
      9. What traits or practices tended to undermine teamwork?
      10. How would you describe the outcome of the event?
      11. What did you learn from the event?
      12. How would you generalize to other events?

   **B. We would like you to describe a specific example of a professional experience where you found the teamwork was particularly demanding (Preferably in a high acuity setting- OR, ER, or ICU)**
      1. What was the context?
      2. Who was present?
      3. What was your role?
      4. How was role clarity established?
      5. What happened?
      6. What were your observations?
      7. What skills did you consider most important or necessary?
      8. How were the most critical skills paired with other skills?
      9. How would you describe the outcome of the event?
      10. What did you learn from the event?
      11. How would you generalize to other events?

III. TEACHING TEAMWORK:

**Please describe a specific instance when you were teaching teamwork.**

   A. What was the context?
   B. What curriculum or theoretical construct did you use in creating the learning experience?
   C. Who were the learners?
   D. What were your observations of the process?
   E. What skills did you consider most difficult to teach?
   F. What skills were the easiest to teach?

G. What were the main learner difficulties?
H. How did you address (or would like to have addressed) the main learner difficulties?
I. How would you describe the learning outcomes from this particular experience?
J. What did you learn from teaching teamwork in this particular instance?
K. How would you generalize to other events? Based on the skills identified in this example of teaching teamwork, what educational strategies you would use in different settings or contexts?
L. What are your thoughts about orienting the curriculum toward ad hoc teams vs. standing teams?
M. Did you use TeamSTEPPS as part of your teaching? If yes, what do you see as its advantages or pitfalls?
N. If you incorporated a different teamwork curriculum, what was it and how did you find it helpful? What worked? What didn't?
O. Overall, what educational tools have you found the most effective for teaching teamwork?

IV. MILITARY IMPLICATION:

**Please describe a specific example of teamwork in the military.**

A. What was your role?
B. What was the setting?
C. How was the military experience different from your civilian experience of teamwork?
D. How did the military context affect the teamwork training?
E. How did the military hierarchy affect the event?

V. GOALS/TEACHING OBJECTIVES

Are all of the elements in the attached document entitled "Goals of the Game/Teaching Objectives" equally important, or do you think some are more important than others are? How would you prioritize them?

VI. FEEDBACK

Are there additional topics that you think we should consider in designing education tools for team building? Please describe.

**Appendix C – Focus Group Questions**

Focus group briefing

1. Interviewer introductions.
2. Brief participant intros (just names, field).
3. Review purpose/objectives of focus group.
4. Explain roles (RL main facilitator, MR note-taker).
5. Set ground rules.
a. Confidentiality (we will not share).
b. Confidentiality (ask them not to share).
c. Nothing at stake.
6. Request permission to videotape.
7. Make sure everyone comfortable, has lunch, knows where to wash hands, etc.
8. Begin session with expanded introductions (occupations, roles, experience levels, types of teams they are on).

Focus group questions

"We're looking for specific suggestions about the kind of language that is most effective in teamwork situations"

Tell me about a time when you were on a team and communication and teamwork were excellent.

- What was your role on the team?
- How do you introduce yourself? What would you consider an idela introduction?
- What specifically made you feel the teamwork was excellent?
- What position did the team leader hold?
- What did they do that made it clear they were the leader? What did they say that would make this clear?
- How did they facilitate communication?
- If it was ambiguous, who was in charge, how was a leader determined?
- When has leadership needed to change mid-situation, how has this change in leadership happened? What made it clear that the leader was changing?
- Were other people integral to the team's success? If so, how?

Tell me about a time when you were on a team and communication and teamwork were poor.

- What was your role on the team?
- What specifically made you feel the teamwork was poor?
- Was there a clear leader? If so, what position did they hold? How did they facilitate communication?
- What makes you feel safe speaking up on a team? How have you seen people encourage or stifle feedback?

Have you received any training in teamwork?

- What kind of training?
- What part or parts of this training did you find most helpful and why? Least helpful and why?
- In what ways was this training helpful in a clinical setting?

Have you ever taught teamwork?
- What skills do you find easy to teach?
- What skills do you find hard to teach?

What is important about teams and teamwork that hasn't come up here?

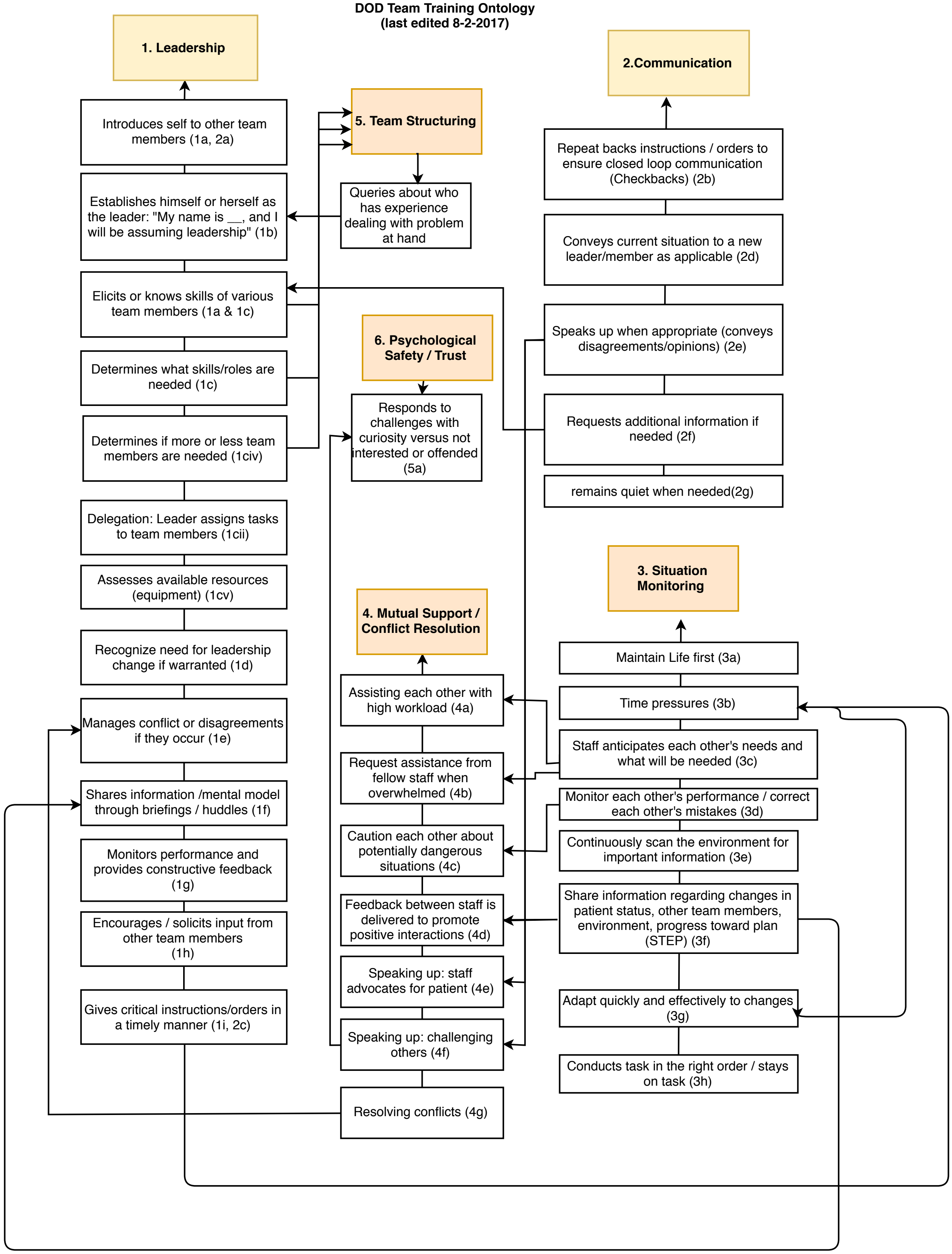
**Appendix D – Focus Group Survey**

It would help us very much to know how you, based on your experience, would RANK these actions, in order of importance:

Team leader or member…
__ introduces him/herself
__ makes their role clear
__ asks team member(s) for information
__ follows up on incomplete information
__ assigns tasks to team member(s)
__ follows up on incomplete tasks (e.g., by reassigning tasks, doing tasks him/herself, or taking other corrective action)
__ performs task that has been assigned to him/her
__ performs task on own initiative (e.g., sees that nobody was assigned to do a needed task, thus performs task him/herself)
__ briefs team members (e.g., with input of team members, assesses situation and makes a plan)
__ huddles with team members (e.g., initiates information sharing with team members and adapts plan if necessary)
__ debriefs team members (e.g., After Action Review: discusses what went well and what could be improved)
__ changes his/her position in room (e.g., to perform a task, to have a better vantage point, to make room for other team members, etc.)
__ answers questions from team members
__ objects (speaks up) to other team members (e.g., to prevent a possible mistake)
__ requests help from other team members
__ provides help to other team members
__ gives feedback to other team member(s) (e.g., "well done!", "next time, please make sure you look at the monitor when doing ...")
__ elicits feedback from team members (e.g., "if you see something that isn't right, please speak up")

If you would send your rankings as a reply to this email, we would greatly appreciate it. Please put a “1” by the MOST important action, a “2” by the next most important action, and so forth. We will collate the responses and use them to guide us as we develop our simulation. Please let us know if you have any questions.

**DOD Team Training Ontology**
**(last edited 8-2-2017)**



## Team Training Ontology-Action Level Ontology

| ActionID | Description: Player... | Category | Available Action | Game Mechanics |
|---|---|---|---|---|
| PCintroducesSelf | introduces him/herself | Supply information | Introduce Yourself | click on button |
| PcrequestsIntroduction | Player requests introductions including name and occupation from team members and anyone new who hasn't introduced themselves | Request information | Request Introduction | click on button |
| PCassumesLead | assumes leadership role, makes their role clear | Supply information | Assume Leadership | click on button |
| PCestablishesReadiness | requests the team to prepare for patient's arrival | Request information | Establish Readiness | click on button |
| PCassignsTasksRoles | assigns tasks to team member(s) | Supply information | | Selected through dialog choices |
| PCrequestsInfo | requests information from or consults with people (inside/outside of team, family member) or other resources (e.g. game) | Request information | | Selected through dialog choices |
| PCprovidesInfo | tell team members about status of patient/situation, express what you are thinking, etc. compare with PCbriefsNPCs | Supply information | Provide Information | Selected through dialog choices |
| PCprovidesClosedLoopCommunication | acknowledges and/or repeats back information provided by an NPC | Supply information | Confirm Information | click on NPC, then button |
| PCprovidesFeedback | gives feedback to other team member(s) (e.g. "well done!", "next time, please make sure you look at the monitor when doing ..."), answers questions, ... | Supply information | Provide Feedback | click on NPC, then button |
| PCencouragesFeedback | elicits feedback from team members | Supply information | | Selected through dialog choices |
| PCprovidesEncouragement | gives positive encouragement to individual, team, and/or to patient | Supply information | | Selected through dialog choices |
| PCbriefsNPCs | briefs team members (e.g. with the help of team members, player assesses situation and makes a plan) Short sesssion prior to start to share the plan, discuss team formation, assign roles and responsibilities, establish expectations and climate, anticipate outcomes and likely | Supply information | | Selected through dialog choices |
| PChuddlesWithNPCs | huddles with team members (e.g. player initiates information sharing with team members and adapts plan if necessary) | Supply information | Call for Huddle | click on button |
| PCdebriefsNPCs | debriefs team members (e.g. After action review: PC states/reflects what went well and what could be improved) | Supply information | Debrief Team | click on button |
| PCobjects | objects (speaks up) to other team members (e.g. to prevent a possible mistake) | Supply information | Encourage Speaking Up | click on button |
| PCprovidesHelpToNPCs | provides help to other team members | Supply information | | Selected through dialog choices |
| PCasksForAssistance | requests assistance from other team member | Request information | Ask for Help | click on button |

PC=player character
NPC=non-player character

## Baseline and Post-Intervention Teamwork Knowledge Questions (Adapted from Agency for Healthcare Research and Quality TeamSTEPPS Learning Benchmarks)

Q1
A nurse is very concerned about a baby he is taking care of and feels it would be best to have the attending pediatrician come to the bedside immediately to evaluate. Checking around the unit, he locates the pediatrician, but she is busy dictating a consultation. The nurse's **best** action is to:

- A. Wait quietly, but tap his foot rhythmically to indicate urgency.
- B. Quickly explain the infant's worrisome appearance and state, "I need you right now!"
- C. Walk away, planning to check back in a few minutes.
- D. Interrupt, shake her shoulder and pull her quickly toward the crib.
- E. Leave his pager number with the clerk with instructions to have her call.
    - **Correct Answer: B.** Quickly explain the infant's worrisome appearance and state, "I need you right now!"
    - **Learning Benchmarks Question #2 Tools, Strategies or Concepts Covered:** Express version of SBAR, Explicit communication, Action oriented, Team priorities

Q2
A surgeon, anesthesiologist, nurse and technologist are in the OR for a complicated case, which will start shortly. The surgeon, as team leader, should:

- A. Go scrub and tell the circulating nurse to "get the ball rolling."
- B. Reassure the new team that she had plenty of experience with tough cases like this one and not to worry, and say, "I'll tell you what you need to know."
- C. Introduce herself, briefly describe the situation, plan, and potential pitfalls and ask for input from the team members.
- D. Explain the need for extra speed during this complicated case and set expectations for rapid turnover between cases.
- E. Pull out the x-rays and textbook and explain the details of the surgery to the rest of the crew, emphasizing the strict need for following protocols.
    - **Correct Answer: C.** Introduce herself, briefly describe the situation, plan, and potential pitfalls and ask for input from the team members.
    - **Learning Benchmarks Question #3 Tools, Strategies or Concepts Covered:** Team brief, Create a shared mental model, Respect for the input from all, Sharing the right information

Q3
The team is making great progress with the procedure until the nurse recognizes that the doctor is clearly making a dangerous mistake in asking for a dose that is ten times the usual dose! Very concerned, she asks the doctor if he's sure that is what's wanted. Giving her a nasty look, he growls, "Well, that's what I asked for, isn't it?.." The nurse, now doubting herself and feeling NOT confident and NOT positive that the dose is too high, should take the following course of action:

- A. Walk away and indicate discouragement at being treated so rudely.
- B. Say loudly, "That's a huge mistake, doctor; nobody uses a dose like that!"
- C. Not say anything for fear of making the doctor even more angry.
- D. Ask the clerk to put in a stat page to the nursing supervisor.
- E. Say, "I'm concerned about the safety of that dose, Doctor; it's much higher than I've ever seen given."
  - **Correct Answer: E.** Say, "I'm concerned about the safety of that dose, Doctor; it's much higher than I've ever seen given."
  - **Learning Benchmarks Question #5 Tools, Strategies or Concepts Covered:** Two-Challenge rule; CUS (Concerned-Patient Safety); Error reduction strategy; Maybe cross-monitoring, Tries to emphasize that the nurse didn't have to know for sure that it was wrong..needs to speak up anyway if concerned; Team dynamic

Q4
The team is making great progress with a procedure until the nurse challenges the doctor about a medication dose being too high. In fact the doctor is correct in her dosage and the nurse was incorrect in his memory of the proper medication dosage. In this situation, the doctor's best action would be to:

- A. Call the pharmacist and ask her to send a package insert to review.
- B. Let the nurse know, in no uncertain terms, how it is inappropriate to challenge a senior physician.
- C. Request that the nurse be sent for retraining and put a notation in her file.
- D. Stop action, verify the correct dose and thank the nurse for her concern regarding patient safety.
- E. Call the team together afterwards and have the nurse explain her mistake.
  - **Correct Answer: D.** Stop action, verify the correct dose and thank the nurse for her concern regarding patient safety.
  - **Learning Benchmarks Question #7 Tools, Strategies or Concepts Covered:** Proper response to the question and concern for patient safety; Stop the line; resolve the confusion; Respect the input; Team dynamic; Focus on the safety, not the error; A debrief would be good, but not to have the nurse "explain her mistakes"

Q5

During closure of a complex surgical case, the sponge count comes up one short after two careful counts. The surgeon ignores the request by the circulating nurse to help find a solution and continues the closure. The **best** action for the concerned circulating nurse would be to:

- A. Explain the current hospital policy and required actions.
- B. Page the medical director.
- C. Call the operating room supervisor.
- D. Scream at the doctor to stop the closure.
- E. Convince the anesthesiologist to make the surgeon respond.
    - **Correct Answer: A.** Explain the current hospital policy and required actions.
    - **Learning Benchmarks Question #11 Tools, Strategies or Concepts Covered:** Conflict; Unreasonable behavior; Solve it within the team if possible; Could DESC-IT, but probably not necessary; Referring to the policy and required actions should bring about the agreement to get an x-ray (as is required)

Q6

The new resident working in the clinic is having difficulties interacting with the nurse (who has been working there for a decade). The nurse continually is telling her what to do, but in front of the patients. The **best** course of action for the resident is to:

- A. Tell the nurse to stop undercutting her.
- B. Ask the nurse for a quick meeting to discuss criticisms in front of patients.
- C. Tell the clinic manager to have a talk with the nurse.
- D. Complain to the attending that the nurse is hypercritical and ineffective.
- E. Just let the patients know that the nurse is having a bad day.
    - **Correct Answer: B.** Ask the nurse for a quick meeting to discuss criticisms in front of patients.
    - **Learning Benchmarks Question #12 Tools, Strategies or Concepts Covered:** Conflict resolution; Solve it at the team level; Power differential; Knowledge differential; Criticism undermining patient relationship; Action: meet to discuss (in private)

Q7
The technologist is setting up for a procedure and notices that the doctor seems to be on the wrong side of the patient and may be making a mistake. The doctor has often been short tempered around the nurses and techs and doesn't take suggestions very well. The **best** action for the technologist is to:

- A. Call for a supervisor to come into the room.
- B. Quietly observe and hope that the doctor notices.
- C. Let the patient and doctor figure it out.
- D. Ask the doctor if he knows what he is doing.
- E. Call for a "time-out" to verify the procedure.
    - **Correct Answer: E.** Call for a "time-out" to verify the procedure.
    - **Learning Benchmarks Question #13 Tools, Strategies or Concepts Covered:** Team dynamics; Speaking up despite the hierarchy and difficult doctor; Use the "time-out" policy on behalf of patient safety; Anyone can call for clarification

Q8
The best **communication tool** or method to get critical information to the whole team during an emergency or complex procedure is:

- A. Call-out.
- B. Check-back.
- C. Write it on the white board.
- D. Write it in the orders.
- E. Time-out.
    - **Correct Answer: A.** Call-out.
    - **Learning Benchmarks Question #B-4 Tools, Strategies or Concepts Covered:** Call-out

Q9
The BEST method of **conflict resolution** for medical teams in the workplace is:

- A. Accommodation.
- B. Avoidance.
- C. Collaboration using the DESC script.
- D. Compromise.
- E. Dominance.
  - **Correct Answer: C.** Collaboration using the DESC script.
  - **Learning Benchmarks Question #B-8 Tools, Strategies or Concepts Covered:** Conflict resolution; DESC script; Collaboration

Q10
In the interest of patient care quality and safety, it is expected and mandatory that:

- A. Conflict is avoided.
- B. People do the right thing.
- C. Members speak up if concerned.
- D. Leaders do not make mistakes.
- E. Everyone agrees with the plan.
  - **Correct Answer: C.** Members speak up if concerned.
  - **Learning Benchmarks Question #15 Tools, Strategies or Concepts Covered:** Speak up about any patient concerns (mandatory); The other choices speak to reality issues for teams, differences from the ideal

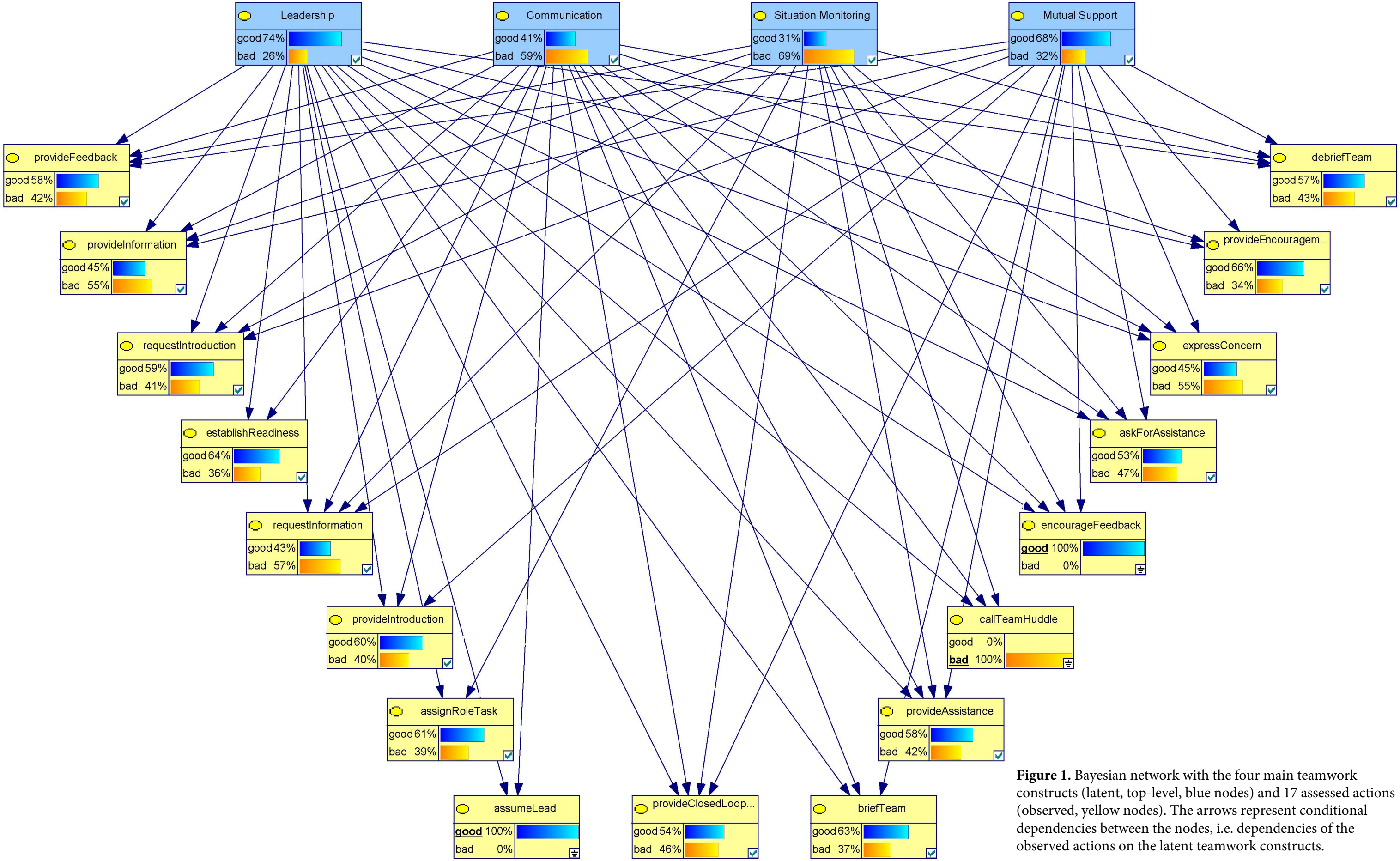



**Figure 1.** Bayesian network with the four main teamwork constructs (latent, top-level, blue nodes) and 17 assessed actions (observed, yellow nodes). The arrows represent conditional dependencies between the nodes, i.e. dependencies of the observed actions on the latent teamwork constructs.

Design of a Screen-Based Simulation for Training and Automated Assessment of Teamwork Skills

Software Specification

Version 7.0

Award Number: W81XWH-16-1-0308

Prepared by CRESST/UCLA

last updated: October 29, 2018

# *1. Introduction*

The purpose of this document is to provide the software specifications for the screen-based simulation software for measuring and teaching teamwork skills. This document also uses an agile methodology and is therefore a living document that will have multiple iterations. Some sections will be more detailed than others.

The software consists of two modes that present scenarios and instruction/feedback to elicit actions from the user. The two modes are:

1) Gameplay mode: This mode is interactive, allowing the users to take actions. If a player action is expected and the player does not do anything, after a designated amount of time (timeout 1) a stimulus is presented. If the player still does nothing, after some defined time (timeout 2), an NPC or intervening dialogue box will move the scenario forward.
2) Evaluative mode: This mode plays back the same scenarios from the gameplay mode and pauses at defined time instances for the player to answer questions (multiple choice, MC) about what was good or bad with respect to teamwork skills in the just presented game play.

## 1.1. Summary

This software is to be used in the research proposed by UCLA Medical School Simulation Center, UCLA Graduate School of Education and Information Sciences, and the UCLA Center for Research on Evaluation, Standards, and Student Testing. This effort is funded by the Department of Defense through JPC-1. The PI is Dr. Randolph Steadman.

## 1.2. Requirements

The requirements for the software include the ability to capture player input (actions in the gameplay mode, or MC answers in the evaluative mode), and to assess a participant's knowledge, skills, and attributes (KSAs) related to teamwork skills in medical settings. The software will also provide feedback/instruction between each scenario (called the AAR or after-action review) and will consist of 3 scenarios of relatively equal difficulty but in different settings: Emergency Department (ED), Operating Room (OR), and Intensive Care Unit (ICU). The primary goal is to assess and teach teamwork skills in medical settings like the emergency department, operating room and intensive care unit.

## 1.3. Numbers

The number of users expected to use the system are in the low hundreds, and to be able to be done over the internet from home or work. The users are expected to be primarily physicians and nurses.

## 1.4. Terminology

PC: Player Character (always the leader)

NPC: Non-Player Character (other team members)

# *2. Functional Description*

**Tutorials (one for each mode)**
Each tutorial's purpose is for familiarizing the user with the given game interface, providing opportunities for the user to practice interacting with the game/simulation. Participants should complete the tutorial successfully to continue on to the other scenarios.

The tutorial will go through:

1. What the different parts of the interface are and give the player an opportunity to tryout different game mechanics themselves.
2. How to perform actions
    a. Gameplay mode:
        i. How to move (i.e., change the view) in the 3D environment (3 hotspots: foot of bed, right side of bed, left side of bed)
        ii. How to delegate tasks to NPCs
        iii. How to perform actions and explain the function of action buttons: select NPC or TEAM, then select action button that then explains the button's function
        iv. How to communicate (dialogue buttons)
        v. How to pause game (using Tab key)
        vi. Explain what this game is about: goals of the game, who you are (leader), what you are supposed to do (lead)

    vii. Navigating to and using After Action Review (AAR)
    viii. Navigating to the next scenario
    ix. Quitting the game
b. Evaluative mode:
    i. How to play back scenarios
    ii. How to provide answers to questions (multiple choice)
    iii. Explain what this mode is about: goals of the evaluation, what you are supposed to do (evaluate team leader performance)
    iv. How to navigate and use the AAR
    v. Navigating to the next scenario
    vi. Quitting the game

**Gameplay Mode**

Gameplay mode can be paused at any time. The interface for the gameplay mode should look something like the following (Figure 1):

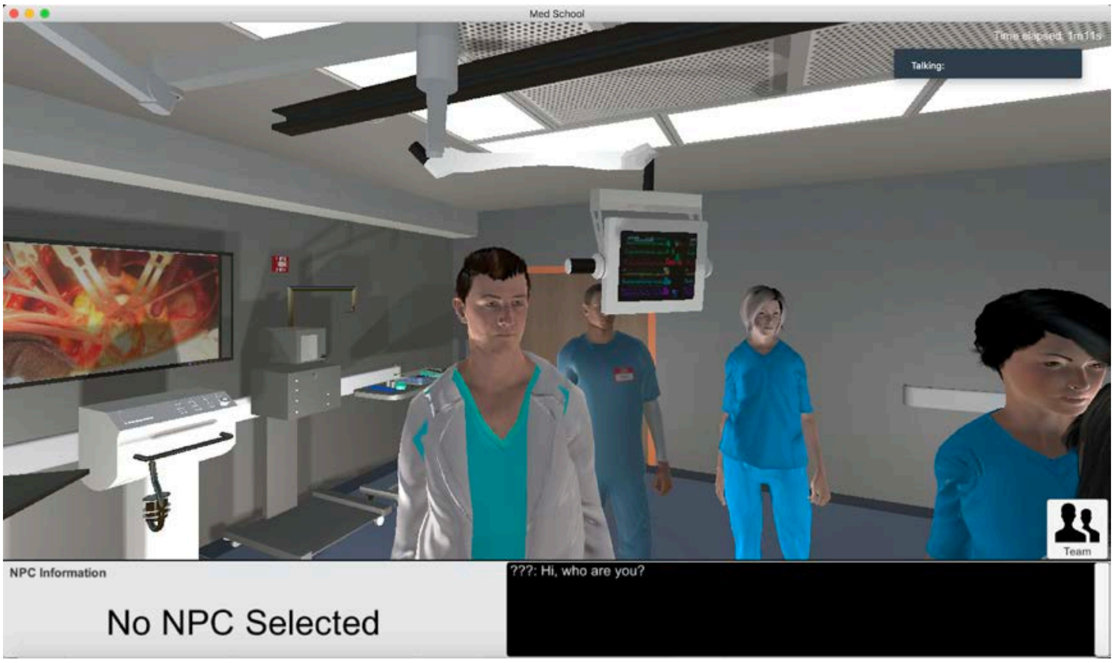



Figure 1. Game Play Mode Interface

**<u>User Interface (UI) Elements</u>**

*Game Window:* The main portion of the screen is the 3D game environment.

*Modes:* NPC, TEAM

In gameplay mode, the scenario should move forward even if the Player Character (PC) does nothing.  One or more NPC's can intervene and either do or suggest the next medical action.

Additional requirements:

| |
|---|
| As a researcher, I can change the events that occur in a scenario without recompiling the simulation. Therefore the timeline of events should be read from a database |
| As a player, I want the simulation to respond appropriately to my input. |
| As a player, I can cancel entering input after selecting an intention. |
| As a player, I want the simulation to evaluate my input. The evaluation should account for previously taken actions, information known to me and other characters in the game, and the appropriateness of my input. |
| As a player, I want the simulation to continue even if I take no action. The simulation should initiate fallback events if an action expected by me does not occur. |
| As a researcher, I can change the events for each scenario that occur when based on the player's input without recompiling the simulation. Therefore the response events should be read from the database. |
| As a researcher, I can change the appearance(model/texture) of characters without recompiling the simulation. Therefore appearance data should be read from the DB. |
| As an instructor, I want the simulation to produce a log of actions taken by the player. |
| As an instructor, I want the simulation to produce scores for the actions taken by the player. |
| As a player, I want to see a report about my performance at the end of each scenario.. |
| As a researcher, I can change the medical information that can be known without recompiling the simulation. Therefore a list of medical knowledge should be read from the DB. |
| As a player, I want the simulation to display the current status of characters whose names I know. |
| |

**Evaluative Mode**

Evaluative mode will play back portions of the same scenarios as gameplay mode with actions done both good and poor. Interspersed throughout each scenario will be a set of questions at evaluative pauses. The interface for the evaluative mode should look something like the following (Figure 2):

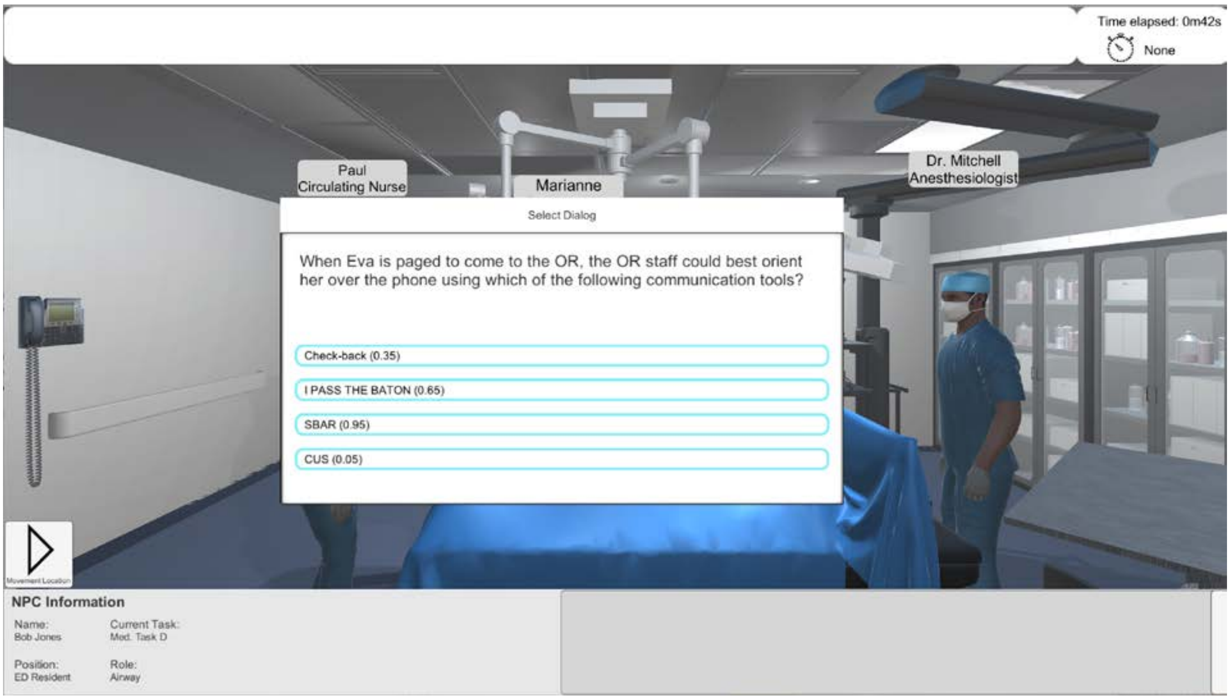



Figure 2: Evaluative Mode

**UI Elements**

*Video Window:* Where scenarios unfold

*Play/Pause:* scenario controls (tab button)

*Evaluation Pop-Up Window*: Displays a prompt and answer choices. Contains an array of checkboxes for the MC answer choices (multiple choices can be selected) and an OK button.

**Scenario Flow**

- Participants will be asked to click OK on the consent form after reading what is required for the study
- Participants will enter a study ID
  - odd-numbered IDs will be given the gameplay mode
  - even numbered IDs will be given the evaluative mode
- Participants will be sequenced through 3 scenarios, with instruction/feedback provided in between
- Scenarios and instructional modules will be the same for both groups
- Scenario settings to be represented: ED, OR, ICU
- Total time: approx. 90+ minutes (~ 15 min./scenario; ~ 10 min./instructional module)

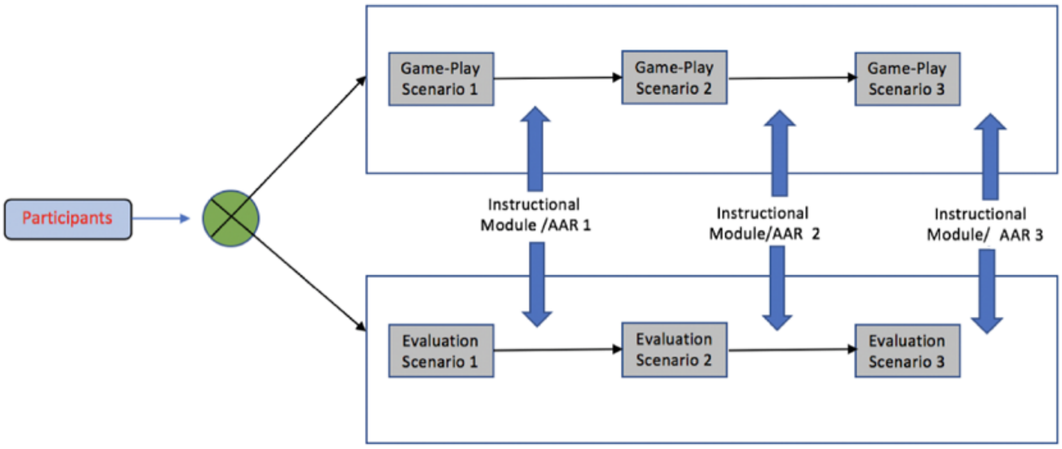



Figure 3. Scenario Flow Chart

## Login Screen

The login screen will have a place for the participant/user to enter an assigned ID. It will is not password protected. See Figure 4.


Figure 4. Simulation Login Screen

## Main Menu

The main menu screen is shown in Figure 5. Participants will go through the sequence specified in the menu from top to bottom. Buttons will be gray for ortions already completed.

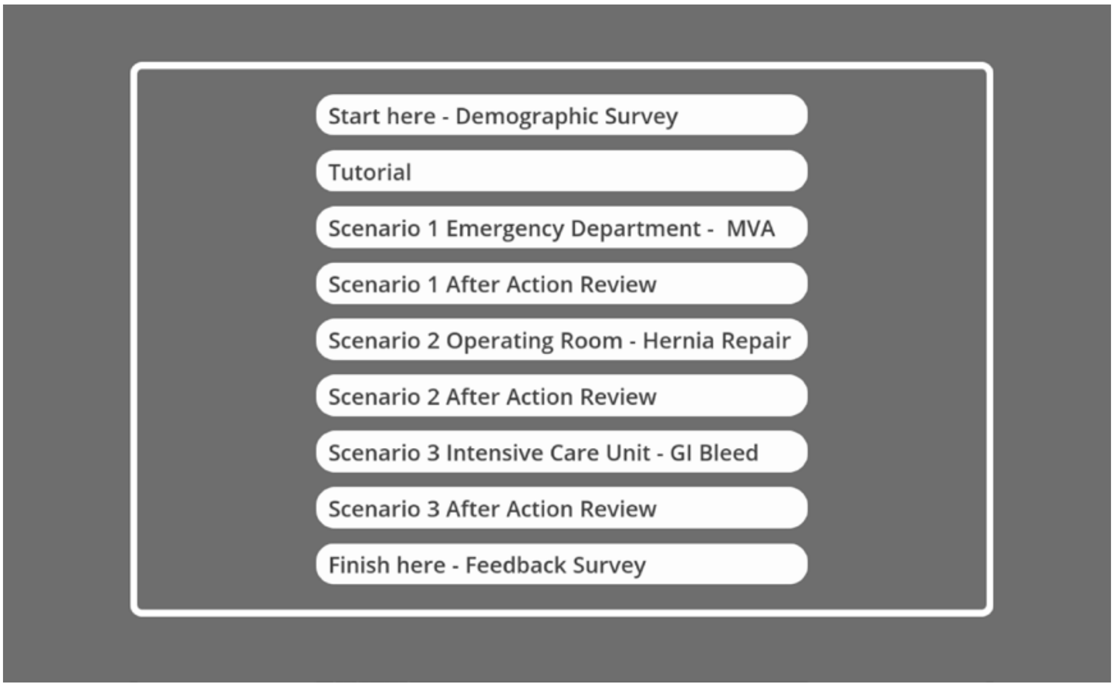



Figure 5. Main Menu

## After-Action Report

An AAR will be generated at the end of each scenario with feedback on how the student performed. The instruction will include content on all teamwork areas, but may emphasize certain areas in a logical sequence that has been used in prior teamwork training (e.g., TeamSTEPPS).

The following screenshots show the process of the participant going through the AAR. The AAR is triggered each time a scenario is completed. Scores will be represented as horizontal bar graphs (see page 3 below) for each of the main TeamSTEPPS dimensions: Leadership, Communication, Situation Monitoring, and Mutual Support.


**Figure 6. AAR, Page 1. Scenario Complete Screen**

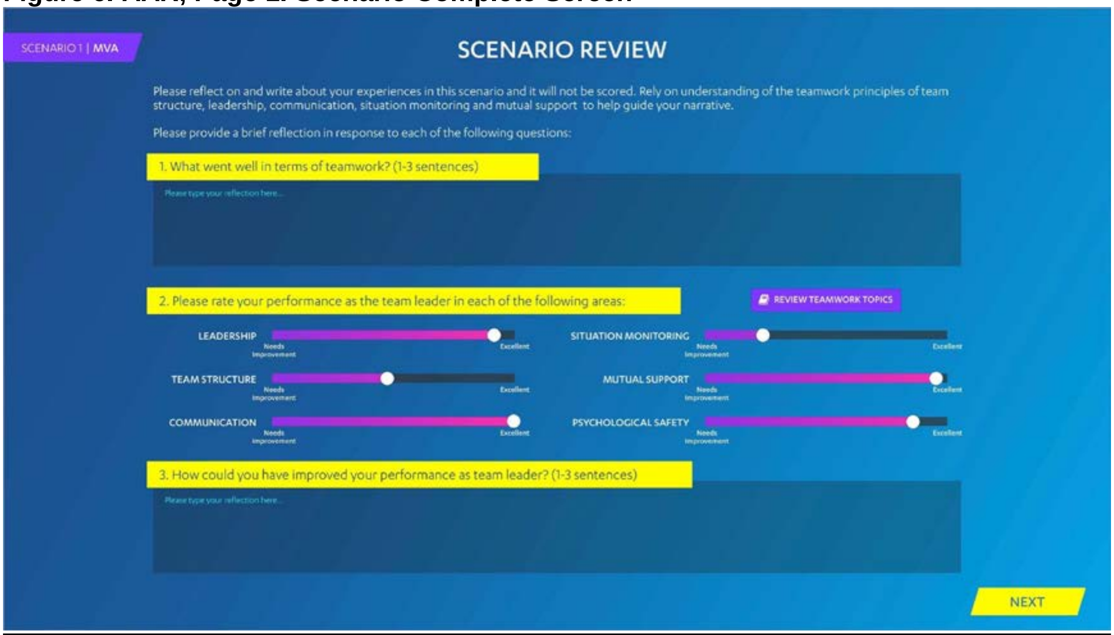



**Figure 6. AAR, Page 2, Reflection Questions**

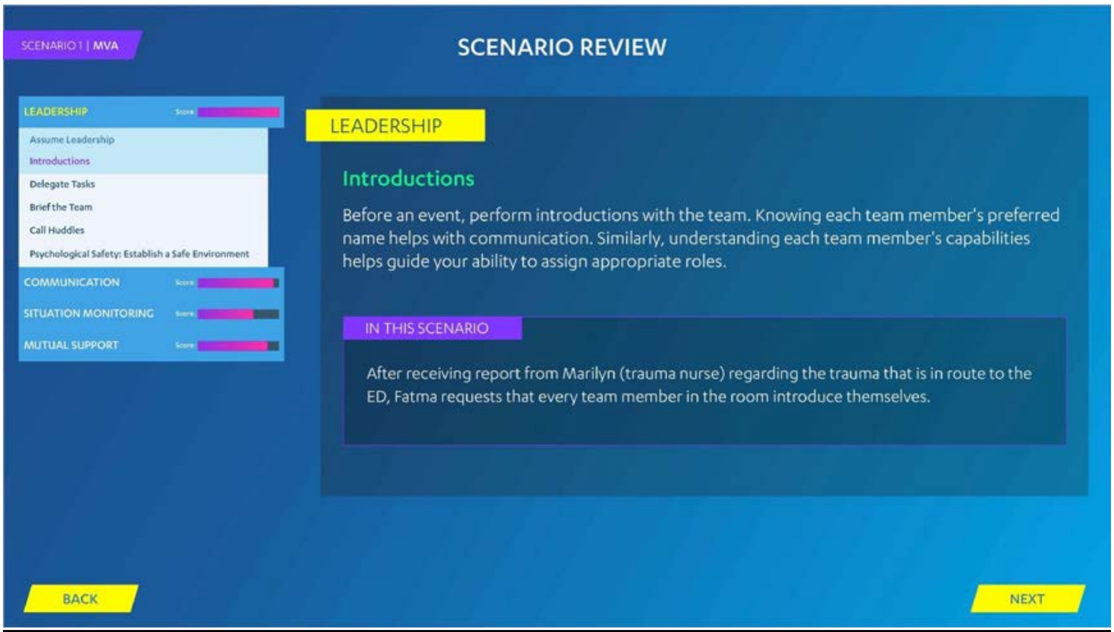



**Figure 6. AAR, Page 3, Content Review**


**Figure 6 AAR, Page 4, Take Away Lesson**

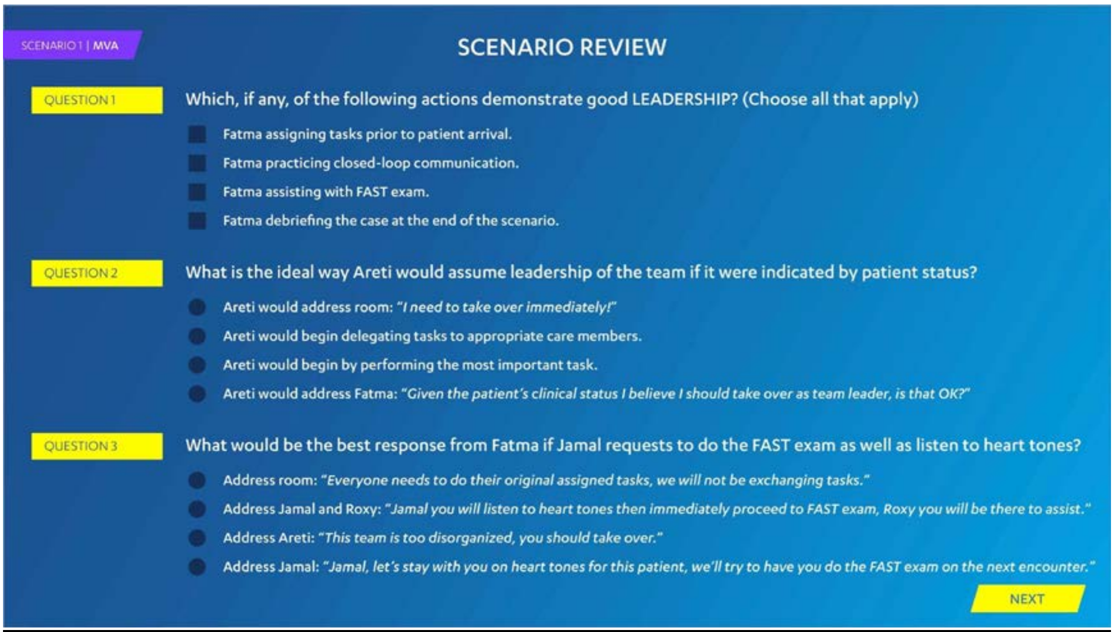



**Figure 6. AAR, Page 5, Quiz to Assess if Participant Understood Instruction**

## Error Handling

If the software crashes, participant should be able to login and navigate to most recent scenario (ideal if system keeps track and automatically takes them to scenario they were working on)

## Tutorial Slides

Help screens will be screenshots of the interface and written instructions on how to carry out different actions (in the gameplay or evaluative mode)

## Platforms

Current supported platforms (PC or Mac-based desktop computer).

Not supported: tablet PCs running android or iOS operating systems.

Supported browsers: HTML5 compatible

**Minimum Requirements**

**OS:** 64-bit Windows 7, Windows 8.1, Windows 10
**Processor:** Intel Core i5-4590
**Memory:** 2 GB RAM
**Graphics:** AMD Radeon R5 240
**Network:** Internet connection required
**Storage:** 4 GB available space

## Configuration Management

Development management will be done using Github or similar repository to maintain core code as well as branches (forks).

## Database

A relational database has been created to store all of the sequence of action and events for each scenario, as well as tables for storing the actual gameplay and user input data.

The database model is depicted below in Figure 7.

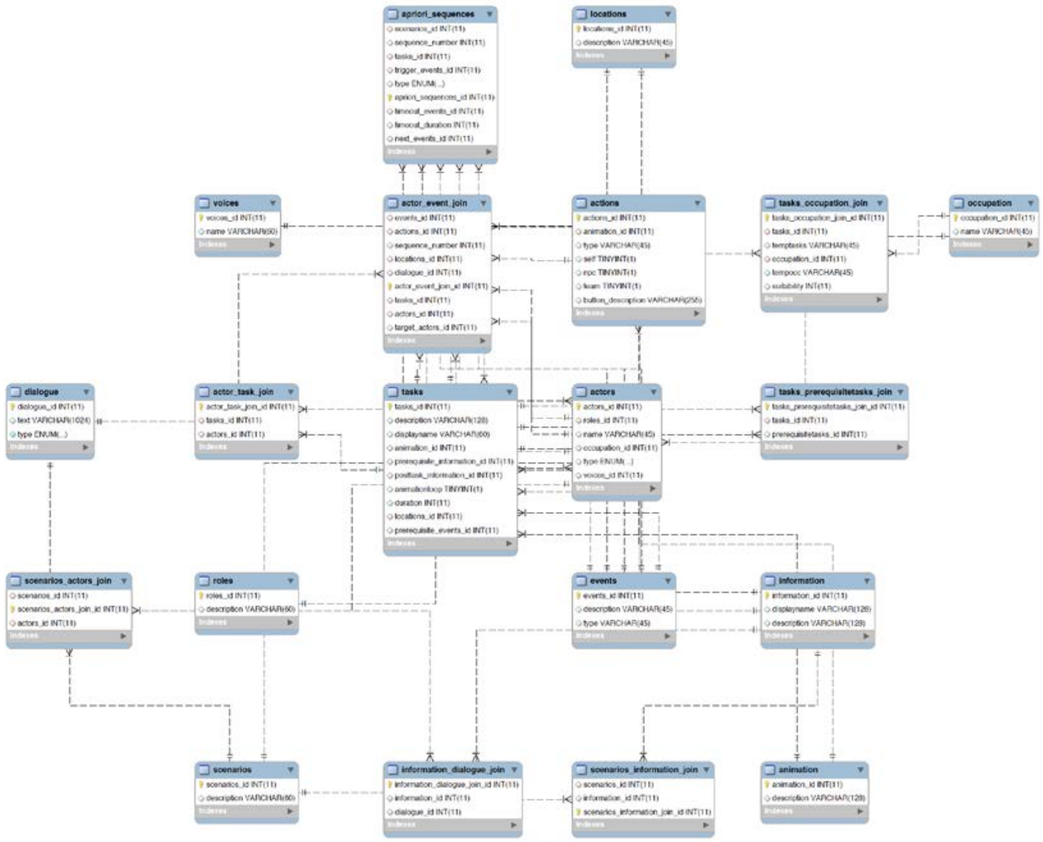
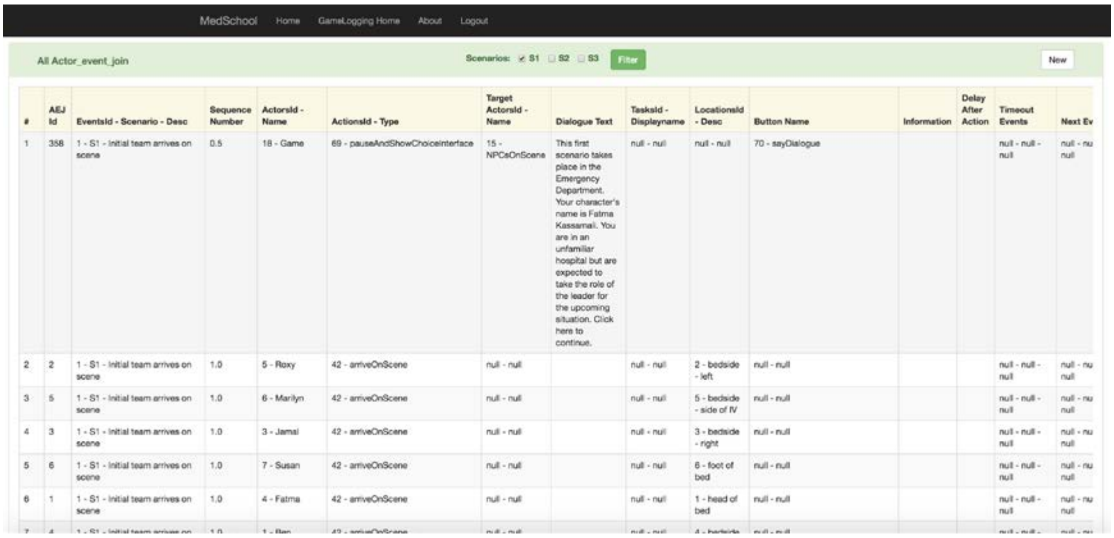



**Figure 7. Database model**

Figure 8 below shows the interface for editing the database. The benefit of sourcing in the events and actions, dialogs, etc., is that changes to the database can be immediately instantiated in the game.




| # | AEJ Id | EventsId - Scenario - Desc | Sequence Number | ActorsId - Name | ActionsId - Type | Target ActorsId - Name | Dialogue Text | TasksId - Displayname | LocationsId - Desc | Button Name | Information | Delay After Action | Timeout Events | Next Ev |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 358 | 1 - S1 - Initial team arrives on scene | 0.5 | 18 - Game | 69 - pauseAndShowChoiceInterface | 15 - NPCsOnScene | This first scenario takes place in the Emergency Department. Your character's name is Fatma Kassamali. You are in an unfamiliar hospital but are expected to take the role of the leader for the upcoming situation. Click here to continue. | null - null | null - null | 70 - sayDialogue | | | null - null - null | null - nu null |
| 2 | 2 | 1 - S1 - Initial team arrives on scene | 1.0 | 5 - Roxy | 42 - arriveOnScene | null - null | | null - null | 2 - bedside - left | null - null | | | null - null - null | null - nu null |
| 3 | 5 | 1 - S1 - Initial team arrives on scene | 1.0 | 6 - Marilyn | 42 - arriveOnScene | null - null | | null - null | 5 - bedside - side of IV | null - null | | | null - null - null | null - nu null |
| 4 | 3 | 1 - S1 - Initial team arrives on scene | 1.0 | 3 - Jamal | 42 - arriveOnScene | null - null | | null - null | 3 - bedside - right | null - null | | | null - null - null | null - nu null |
| 5 | 6 | 1 - S1 - Initial team arrives on scene | 1.0 | 7 - Susan | 42 - arriveOnScene | null - null | | null - null | 6 - foot of bed | null - null | | | null - null - null | null - nu null |
| 6 | 1 | 1 - S1 - Initial team arrives on scene | 1.0 | 4 - Fatma | 42 - arriveOnScene | null - null | | null - null | 1 - head of bed | null - null | | | null - null - null | null - nu null |

**Figure 8. Interface for editing the database**

**END OF DOCUMENT**

**Title:** Screen-Based Simulation for Training and Automated Assessment of Teamwork Skills: Two Modes with Different Interactivity Yield Comparable Learning Outcomes

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**ABSTRACT**

**Introduction:** The need for teamwork training is well documented, however, teaching these skills is challenging given the logistics of assembling individual team members together to train in person. Drawing from serious games, teamwork literature, and established team training programs, we designed two modes of screen-based simulation modes with different interactivity and studied their effectiveness for training teamwork skills.

**Methods:** Mixed, randomized, repeated measures study with licensed healthcare providers block-stratified and randomized to: Evaluation (EVAL) – participant observes and evaluates the team player in three scenarios; Game-Play (GP) – participant is immersed as the leader in the same three scenarios. Teamwork construct scores (leadership, communication, situation monitoring, mutual support) from an ontology-based, Bayesian Network (BN) assessment model were analyzed using mixed randomized repeated measures of analyses of variance to compare the two modes on performance across the three scenarios, and on pretest and posttest quiz scores. User experience was evaluated using Chi-square analyses.

**Results:** Among 166 recruited and randomized participants, 120 enrolled in the study and 109 had complete data for analysis. Mean composite teamwork BN scores improved for successive scenarios in both modes, with EVAL scores statistically higher than GP for every teamwork construct and scenario (r=0.73, *P*=.000). There was no significant difference between modes in overall quiz scores.

**Conclusions:** Two modes of interactivity for screen-based simulation yielded comparable learning outcomes within three scenarios.

**MANUSCRIPT**

## INTRODUCTION

Teamwork and communication failures between healthcare team members are responsible for up to 70% of medical errors.[1,2] Applying these skills in medical practice remains challenging as members of healthcare teams come from separate disciplines and isolated educational programs.

Training in teamwork skills has the potential to improve teamwork, clinical performance, and patient outcomes.[3,4] Recent reviews show that healthcare team training is effective for a variety of healthcare outcomes, including trainees' perceptions of the usefulness of team training, acquisition of knowledge and skills, demonstration of trained knowledge and skills on the job, and patient and organizational outcomes.[5] Neily et. al demonstrated an association between healthcare team training and reduced surgical mortality rate by as much as 18%.[6]

Despite a growing literature examining the effect of teamwork training, there are limited data regarding how best to teach teamwork and communication skills to healthcare providers. Traditional team training sessions have consisted of classroom-based didactic presentations and/or resource-intense simulator-based programs requiring in person attendance and facilitated debriefing.[7] The publicly available Team Strategies to Enhance Performance and Patient Safety (TeamSTEPPS) curriculum developed by the Agency for Healthcare Research and Quality has limited registration capacity to train instructors.[8] The TeamSTEPPS online course can reach a wider audience.[9] However, there are limited opportunities to apply newly acquired skills within relevant contexts, repeat practice and feedback, and follow-up to assess skills acquisition and retention. Consultants offer customized training to specific groups at significant cost and time commitment. Those with simulation programs have utilized more immersive, in-person interprofessional training sessions, but scheduling can be challenging.

Our project addresses team training through development of an interactive screen-based serious game, a simulation platform with the capability for customized learning, flexible learning objectives, and easy accessibility.[10] Our design is based on educational principles of cognitive engagement and builds upon relevant models of learning for skills acquisition and long-term retention.[11,12] We emphasize best practices and principles of team training effectiveness as reviewed by experts in the field.[13,14]

Our research aim is to evaluate the usability, learning, and performance differences between two modes of screen-based simulated team training, which utilize the same scenarios but differ in interface interactivity and in game user experience. The two modes manifest as the player observing and assessing non-player character performance (Evaluation or EVAL mode) or as the player interacting with non-player characters (Game-Play or GP mode).

We expected similar participant performance gains in both modes, in the more interactive but more resource-intensive (i.e., game programming efforts) GP mode and the less interactive and less resource-intensive EVAL mode. Our hypotheses were: 1) Both modes will effectively teach and evaluate teamwork skills as identified by pretest and posttest quizzes and improvement in performance scores across three successive scenarios, and 2) EVAL mode will provide non-inferior performance gains to GP mode.

## METHODS

### Development

This project was designed and created by an interdisciplinary team of clinicians, simulationists, educators and computer programmers. The screen-based team training application was developed in the following stages: 1) identification of teamwork constructs to be assessed; 2) identification of evidence required to infer selected teamwork constructs; 3) mapping between evidence and teamwork constructs; and 4), creation of scenarios and tasks that provide the defined evidence.

Based on extensive literature review, input from external subject matter experts (SMEs) and focus group interviews, the team defined the following four main teamwork constructs: leadership, communication, situation monitoring and mutual support. We identified evidence required to infer these constructs, using literature reviews and input from SMEs. The team defined 17 actions, such as “request introduction,” which was defined as “Player requests introductions including name and occupation from team members and anyone new who hasn't introduced themselves,” or “encourage feedback,” which was defined as “Player encourages others to speak up and give feedback.”

Twelve members of the research team independently rated the 17 actions according to their association with each of the four teamwork constructs. We assessed rater agreement by conducting a generalizability analysis for each teamwork construct.[15] The coefficient indicating the level of agreement among raters (index of dependability) was high for all four constructs, ranging from .90 to .93. The average mapping over all raters was used to define Bayesian network (BN) parameters. Scenarios were scripted to engage the user in situations that assess understanding of the various teamwork actions and behaviors considering common or frequent pitfalls as well as knowledge or skill gaps.[16]

**Trial Design**

This project, approved by the UCLA Institutional Review Board (IRB), is a mixed randomized repeated measures design with an allocation ratio of 1:1 between the two modes of the game. For an estimated effect size of 0.5, a significance level of 0.05, and a power of 0.8, the resulting sample size calculation yielded 102 participants (51 per group).

Eligibility criteria for participants included nursing (floor, operating room, emergency department, critical care), resident and attending physicians (anesthesiology, critical care, surgery, emergency medicine, internal medicine), and other allied health professionals including paramedics, pharmacists, and respiratory therapists. Participants had the option to perform the game on a computer at the simulation center or on their own personal computer with an internet connection. Data were collected by an online server.

Randomization was accomplished by a block stratified sequence generation design, based on professions and specialties, with a goal of 12 participants per group and equal distribution between modes: physicians, nurses, and others (paramedics/EMTs, respiratory therapists, pharmacists). Physicians had two additional stratifications: attendings vs. residents in four specialties Anesthesiology, Emergency Medicine, Surgery and Internal Medicine. There were four targeted specialties for nurses: operating room, floor, intensive care unit and emergency medicine. Participants were randomized to one of two study conditions, EVAL or GP mode, by computerized coin flip generator. We enabled participants to contact coordinators about issues related to running the program under their assigned mode to allow for rapid intervention in the event of software glitches.

Although aware of the labels Game-Play and Evaluation mode, participants had not received descriptions for each mode and were blinded to the treatment arm to which they were assigned (they received a number code for login). The same home screen was used for both modes and navigation and both groups went through the scenarios in the same order. Participants were asked to complete the game in one sitting to reduce possible bias from discussion about the game or communication with other participants, or by interval experiences. Performance ratings were generated by an automated assessment engine designed for the study, and automatic scoring of the quizzes. There were no subjective ratings performed by researchers.

**Intervention**

Participants in both modes progressed through three healthcare scenarios in different settings: emergency room (ER), operating room (OR) and intensive care unit (ICU). They were asked to implement teamwork skills in four areas: leadership, mutual support, communication, and situation monitoring. In GP mode, participants assumed the role of the team leader whereas in EVAL mode participants evaluated the decisions and actions of the non-player character leading the team. Knowledge of these clinical environments was not required, as technical skills (diagnostic and medical management) were not evaluated (diagnoses, evaluation results and medical management cues were provided in both modes).

In GP mode, the participant selected actions to take, determined the timing/sequence of actions, and designated non-player characters to perform an action. Participants made these decisions prospectively, that is, prior to non-player characters initiating action. Whenever a player action was expected (e.g., a response to a non-player character query*)*, a countdown clock wound down and blinked noticeably after 20 seconds. Once the player chose an action, a pop-up window appeared asking the player to choose from four possible dialogue options (that varied from best to least good). If the player failed to take a proper action within the allotted timeout, the player was prompted by leading dialogue from a non-player character, and if still no action occured, finally, a pop-up window appeared which contained the same dialogue choices as described above. GP scoring was affected by the action selected, action timing, and appropriate dialogue choice.

In EVAL mode, the participant observed scripted action and intermittently evaluated the actions taken by the team leader. Periodically, the scenario paused, and a multiple-choice question appeared on screen to assess the most appropriate decision, action, or dialogue for the situation. EVAL mode scoring was based on participant answers to prompted questions. After each scenario, all players received an identical after action review (AAR) that provided reflection and contextualized learning.

**Outcomes**

The primary measured outcome of this study was teamwork scores from an original Bayesian network (BN) assessment model designed for the study. Our choice was based on the model requirements of: a) multidimensionality - enabling assessment of four different teamwork cognitive constructs (leadership, mutual support, communication, and situation monitoring); b) interdependence between tasks and constructs; and c) probabilistic belief nature of our inference. As a graphical probabilistic model that can represent joint probability distributions based on conditional independence relations, the BN fulfills all these requirements.

Secondary measured outcomes included scores from completed pre- and post-game quizzes and surveys. Quiz questions were drawn from the TeamSTEPPS learning benchmark question set. A survey using a scale of 1 (strongly disagree) to 4 (strongly agree) measured participant reactions regarding the user interface and overall usefulness of the screen-based training.

**Statistical Analysis**

Mixed randomized repeated measures of analyses of variance were conducted for the four teamwork constructs, expressed by four BN proficiency variables, to compare performance between GP and EVAL modes and to examine changes in performance over the three scenarios. Data was de-identified prior to analysis. Values for the BN proficiency variables range from 0 to 1 and indicate our inferred probability or belief of proficiency, given observed behavior: A value of 0 means the examinee has no proficiency, a value of 1 means the person has complete proficiency, and a value of 0.5 means that there is insufficient evidence to infer either presence or absence of proficiency. In addition, the same analyses were conducted for improvement scores between adjacent scenarios. Analyses were conducted for each of the four teamwork constructs separately as well as for an overall teamwork composite score (equally weighted combination of the four teamwork construct proficiency values). For significant mode x scenario interactions, simple main effects analyses were conducted and specific comparisons were examined with Bonferroni adjustments for multiple comparisons where appropriate[17].

A mixed randomized repeated measures analysis of variance was conducted for average pretest and posttest quiz scores of teamwork knowledge to examine differences between the two modes and changes from pretest to posttest. Using data from the feedback survey, Chi-square analyses were used to compare modes in the pattern of self-reported ratings, and a t-test was conducted for each survey item to compare mean ratings in the two modes. All statistical analyses were performed using SPSS (Statistical Package for the Social Sciences) Statistics for Windows Version 25 (IBM Corp., 2017).

## RESULTS

Figure 1 shows recruitment and randomization efforts. We emailed the link to the game to 166 licensed healthcare providers who expressed interest in study participation. Among the randomized subjects, 120 started the game with 109 finishing and providing complete data for analysis; 46 never started and were lost to follow up. Of the 120 who attempted the activity, 61 were in the EVAL group and 59 in the GP group. Among the 46 lost to follow up, 23 had been randomized to EVAL and 32 to GP mode.

Participant randomization was achieved as shown in Table 1, Participant Demographics. Both EVAL and GP groups had equivalent numbers of participants in terms of age, gender, profession, hours of video gaming, and team training experience.

After removing 13 subjects who did not finish the study in one sitting, the duration of the entire encounter was similar between participants in EVAL and GP modes (n = 96, EVAL: median = 1.39 hours, mean = 1.48 hours, SD = 0.5 hours; GP median = 1.19 hours, mean = 1.32 hours, SD = 0.5 hours). The difference between modes in duration was not statistically significant ($P = 0.13$).

### *Difference between Modes in Teamwork Skills*

While BN proficiency values were high in both modes, scores in EVAL mode were higher than in GP mode for every teamwork construct and for every scenario (Figs. 2 and 3). For the composite score (Fig. 2), differences between EVAL and GP means were 0.16 for Scenario 1 (simple main effect of mode: F1,107 = 169.01, $P < 0.001$, effect size (partial eta squared) = .61), 0.12 for Scenario 2 (F1,107 = 290.33, $P < 0.001$, effect size = 0.73), and 0.11 for Scenario 3 ($F_{(1,107)} = 219.37$, $P < 0.001$, effect size = 0.67). For the separate teamwork constructs (communication, leadership, situation monitoring, mutual support), differences between EVAL and GP means ranged from 0.09 to 0.22 for Scenario 1 (simple main effects of mode: $F_{(1,107)} = 22.25$, $P < 0.001$to $F_{(1,107)} = 259.91$, $P < 0.001$, effect sizes = 0.17 to 0.71), 0.07 to 0.18 for Scenario 2 ($F_{(1,107)} = 61.99$, $P < 0.001$ to $F_{(1,107)} = 392.40$, $P < 0.001$, effect sizes = 0.37 to 0.79), and 0.05 to 0.17 for Scenario 3 ($F_{(1,107)} = 62.37$, $P < 0.001$ to $F_{(1,107)} = 402.22$, $P < 0.001$, effect sizes = 0.37 to 0.79).

Quiz scores were high in both modes (Fig. 4) and improved from pretest to posttest overall (main effect for time: $F_{(1,68)} = 8.75$, $P = .004$), although there was no significant difference between modes in the change from pretest to posttest (nonsignificant effect for mode: $F_{(1,68)} = 1.21$, $P = .276$; nonsignificant mode x time interaction effect: $F_{(1,68)} = 1.71$, $P = .196$).

### *Improvement in Teamwork Skills*

Inferred BN proficiency values improved over the course of the scenarios (Figs. 2 and 3), although, the improvement pattern was nonlinear. Teamwork proficiency improved more from Scenario 1 to 2 than from Scenario 2 to 3. Moreover, the improvement pattern was different in the two modes; the quadratic effect for the scenario x mode interaction was statistically significant for the overall teamwork composite and each teamwork construct except leadership: $F_{(1,107)} = 10.32$, $P = 0.001$ to $F_{(1,107)} = 39.21$, $P < 0.001$. Specifically, the improvement from Scenario 1 to 2 was greater in GP mode than in EVAL mode for the teamwork composite score and for each teamwork construct except leadership (pairwise comparisons comparing modes in improvement scores from Scenario 1 to Scenario 2 for communication, situation monitoring, mutual support: $F_{(1,107)} = 18.15$, $P < 0.001$ to $F_{(1,107)} = 53.49$, $P < 0.001$).

***Participants' Ratings of the Training Experience***

Whereas all respondents in EVAL mode agreed or strongly agreed with the statement that the interface was easy to use, only a third of respondents in GP mode did so (chi-square(3) = 53.73, $P < 0.001$; $t_{(103)} = 8.52$, $P < 0.001$) (Fig. 5). Despite the differences in reported ease of use, participants in the two modes did not differ significantly in whether participating in the training helped them learn teamwork skills (Fig. 5, chi-square(3) = 0.25, $P = 0.969$; $t_{(103)} = 0.31$, $P = 0.711$).

***Follow-up Phone Interviews***

Follow-up interviews were conducted one to eight months post training to query participants in both EVAL and GP modes about the usability and application of teamwork skills learned in the game. Interviews concluded once a saturation of themes was reached (n = 15). More than half (60%) of participants indicated they had incorporated teamwork skills they learned from the game in their clinical care. Participants noted that the game reinforced communication tools like making introductions and using closed-loop communication. One participant stated, "I found that the tools I learned from the game were particularly helpful for when I was on surgical ICU and running codes. It primed me for understanding how to be an effective leader and what to tell the nurses to do and better utilize them as a resource." The majority of participants (87%) found the game content useful enough to recommend as an educational tool: "The game is helpful, convenient to be able to do it at home and scenarios give you a better approach to unique situations that you may not have encountered before."

## DISCUSSION

We created and compared two modes of screen-based learning for the acquisition of teamwork skills. The primary finding of our study is that Evaluation (EVAL) mode, which featured the players' observation and evaluation of teamwork skills demonstrated within the game by non-player characters, resulted in performance gains that were non-inferior compared to Game Play (GP) mode. The level of interactivity did not affect participants' view of the usefulness of the experience, and learning occurred in both modes. This is consistent with a review comparing observational roles to hands-on participation in scenario-based simulation.[18] In this review, learner outcomes and role satisfaction for observers was as good or better than hands-on roles when the learner was engaged, and given tools to direct their observation. We included these elements in the EVAL mode experience through observer evaluation of team actions, scoring and a context-specific after action review with feedback.

The positive analysis of EVAL mode has important implications for online scenario development, as EVAL mode is significantly less time consuming to script and program than GP mode. In GP mode the script is dynamic with branch points determined by individual choices made by players. While each branch-point can be constrained to a finite number of options, the timing and sequence of players' selections are not predictable, which leads to even greater script and programming complexity in GP mode compared to EVAL mode, where the scenario is linear without branching. In addition, the user interface for GP mode is more complex and must contain the affordances sought by the player, listed in a way that is intuitive and unambiguous. Participants rated the ease of use of GP mode considerably lower than EVAL mode, due to difficulty using the interface. The overall lower BN scores in GP mode indicate that participants found the GP interface difficult to use, and likely account for the steep trajectory of score improvement between Scenario 1 and 2 in GP mode.

Our trial was designed to assess performance gains after three scenarios, so learning the user interface quickly was important. This may have favored EVAL mode with an easier to learn interface. If we had designed a more lengthy encounter, with more scenarios, the increased interactivity of the GP mode may have been found to be more engaging, and the difficulty learning the GP user interface mitigated by repeated exposure. However, we were unable to test this hypothesis with our study design.

One strength of our study is the Bayesian Network model for automated assessment. BN models have been used extensively in the artificial intelligence community as student models for intelligent tutoring systems. They provide an intuitive framework for modeling content domains at a diagnostic level and, by explicitly modeling the internal domain relationships, assessments become powerful tools for teachers to make rapid, accurate instructional decisions based on what students know.[19] Our use of BNs represents an innovation over multiple choice knowledge tests as knowledge inferences are generated in the background, unbeknownst to the player, during game play, and every in-game decision contributes to the final inferences.

Bayesian Networks have considerable potential for use as tools to assess the validity of research evidence. The key strength of such networks lies in the provision of a statistically coherent method for combining probabilities across a complex framework based on both belief and evidence.[20] Researchers describe the use of BNs in educational assessment and show that these models can fully operationalize evidence-centered design, an approach that incorporates assessment construct validity by design.[21] When modeling the teamwork domain using BNs, we used the evidence-based design approach to maximize model validity. Regarding model reliability, BNs are computational models and thus have full reliability.

Another feature of our study is the choice of participants to allow generalizability of the findings to a variety of licensed healthcare providers. With appropriate modifications of the scenarios and learning objectives, we suspect that additional scenarios could be designed for non-licensed individuals working in healthcare environments, including for onboarding to familiarize individuals with challenging situations and institutional expectations.

In addition, this study incorporates features not often present in research on screen-based simulation: an experimental design, moderately large sample size, and both affective reactions and learning outcomes. A recent systematic review assessing the use of virtual training for non-technical skills, particularly teamwork, communication and situational awareness, showed few studies published (a median of two articles per year from 2010 to 2017), an average number of study participants of 40, relatively few studies incorporating an experimental design (pretest/posttest or group comparisons), and most measuring usability and acceptability but not learning outcomes.[22]

The study design had several limitations. We elected not to compare traditional in-person training to screen-based training, as we were more interested in comparing more distributive training modalities with different characteristics. As a result we are not aware of how the performance gains we report would compare to other types of team training of a similar duration. Whether live simulations would result in greater performance gains than screen-based simulation was not tested. In follow-up interviews, a majority of participants described post-training instances in which their clinical encounters reminded them of their online training, making them more aware of peers' modeling of teamwork and communication.

There were intrinsic differences in how similar learning objectives were presented and assessed in each of the modes. EVAL mode participants were asked to evaluate *retrospectively* for potential improvements in communication and teamwork, while GP mode participants *prospectively* determined the type and timing of actions and requests. Because the timing of the evaluations in EVAL mode were predetermined, EVAL mode did not take action timing into account, while GP mode did, an intrinsic difference in the design of the two modes. The cognitive components were also different: EVAL mode emphasized recognition of concepts while GP mode required both recall and recognition.

Because of differing interfaces in the two modes, participants' performance was not the sole determinant of differences in Bayesian probability values. We suspect that the generally lower BN values in GP mode are accounted for by difficulties navigating the user interface in that mode. In comments made immediately post-play, a number of GP mode participants noted that "I knew what I wanted to do" but had trouble implementing the intended action because of lack of familiarity with the interface. Similar difficulties were minimal in EVAL mode.

While baseline imbalances in the participant demographics and/or teamwork skills may exist, stratified randomization by profession/discipline was used to ensure group comparability. We did not assess for an order effect, as the scenario order was the same between modes, starting with the ER scenario, then the OR scenario, and finishing with the ICU scenario. While few participants work in all of these clinical settings, knowledge of these environments was not required, as technical skills (diagnostic and medical management) were not evaluated.

## CONCLUSION

Online serious games or simulations, designed for healthcare learning, offer a number of advantages: They are scenario-based, engaging, accessible on demand and can be programmed to provide automated scoring and feedback. We took advantage of these features in our study. However, obstacles exist in disseminating virtual simulations: Programming needs are significant, development times are lengthy and the necessary development expertise is extensive, including a mix of subject matter experts from the worlds of medicine, instructional design, game design, computing and business. In addition, game play environments are not intuitive to first time users. Efforts to identify necessary design elements can help tip the scales in favor of online gaming's advantages by making the process more efficient and less costly. We have shown that for training teamwork skills with a short (1-2 hour) encounter on one occasion, interactivity of the player with the non-player characters is not necessary for performance gains or for player satisfaction with the experience. Online teamwork training may serve as an asynchronous simulation modality and primer for the more resource-intense in-person team training simulation sessions.

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**Table 1.** Study Participant Demographics

| | Game-Play (GP), N=52 | | Evaluation (EVAL), N=57 | | Statistics | |
|---|---|---|---|---|---|---|
| | **Count** | **% of Total** | **Count** | **% of Total** | **chi-square** | **P value** |
| **Gender** | n=52 | | n=57 | | **0.150** | **0.699** |
| Male | 20 | 18% | 24 | 22% | | |
| Female | 32 | 29% | 33 | 30% | | |
| **Age** | n=51 | | n=57 | | 0.198 | 0.699 |
| Under 20 | 0 | 0% | 0 | 0% | | |
| 20-30 | 16 | 15% | 19 | 17% | | |
| 31-40 | 21 | 19% | 22 | 20% | | |
| 41-50 | 7 | 6% | 9 | 8% | | |
| 51-60 | 3 | 3% | 4 | 4% | | |
| Over 60 | 4 | 4% | 3 | 3% | | |
| **Profession** | n=52 | | n=57 | | 1.140 | 0.565 |
| **Physician** | 30 | 28% | 35 | 32% | | |
| Anesthesiology | 16 | 15% | 17 | 16% | | |
| Emergency Medicine | 3 | 3% | 7 | 6% | | |
| Internal Medicine | 5 | 5% | 7 | 6% | | |
| Surgery | 6 | 6% | 4 | 4% | | |
| **Nurse** | 14 | 13% | 17 | 16% | | |
| Critical Care | 5 | 5% | 6 | 6% | | |
| Emergency Medicine | 3 | 3% | 3 | 3% | | |
| Floor | 3 | 3% | 3 | 3% | | |
| Operating Room | 3 | 3% | 5 | 5% | | |
| **Other** | 8 | 7% | 5 | 5% | | |
| Respiratory Therapist | 0 | 0% | 1 | 1% | | |
| EMT/Paramedic | 4 | 4% | 1 | 1% | | |
| Pharmacist | 4 | 4% | 3 | 3% | | |
| **Hours of video game play / week** | n=51 | | n=56 | | 0.845 | 0.655 |
| None | 28 | 26% | 32 | 29% | | |
| 1-2 hrs | 18 | 17% | 16 | 15% | | |
| 2-5 hrs | 3 | 3% | 6 | 6% | | |
| 5-10 hrs | 2 | 2% | 2 | 2% | | |
| > 10 hrs | 0 | 0% | 0 | 0% | | |
| **Prior team training experience** | 33 | 30% | 41 | 38% | 0.651 | 0.420 |

**Figure 1. Study Flow Diagram**

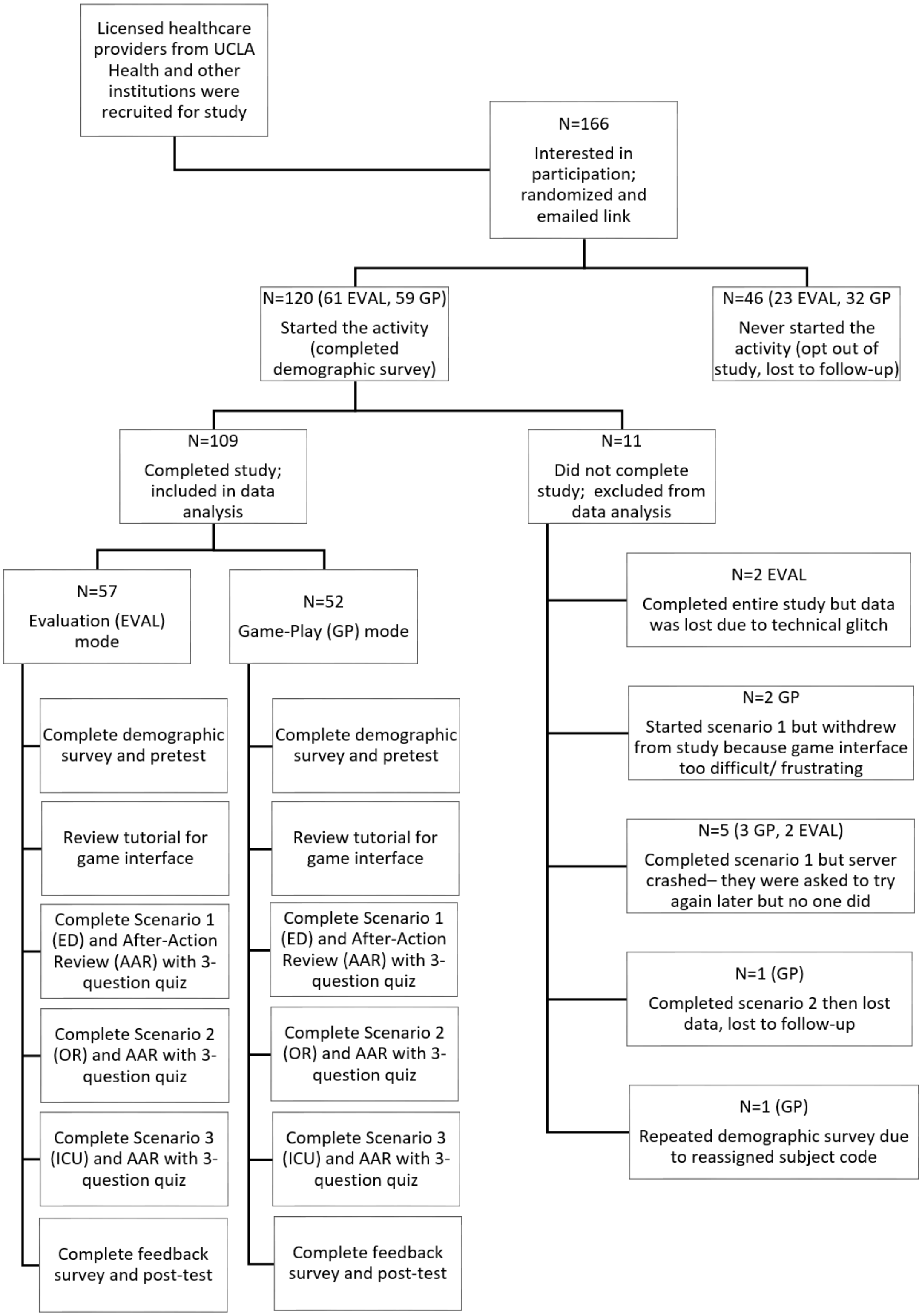


**Figure 2. Composite Teamwork Score.** Mean performance as inferred by Bayesian network proficiency values for the teamwork composite score (average of communication, leadership, situation monitoring, and mutual support proficiency values) for game-play and evaluation modes. Error bars are 95% confidence intervals.

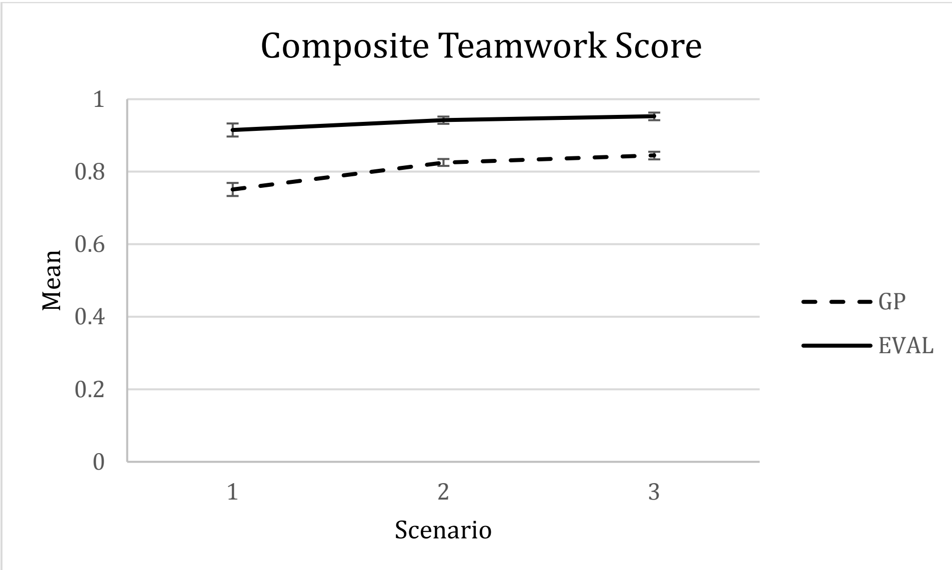


**Figure 3. Teamwork Construct Scores.** Mean performance as measured by BayesNet scores for four measures of teamwork skills: communication (A), leadership B), situation monitoring (C), and mutual support (D) for game-play and evaluation modes. Error bars are 95% confidence intervals.

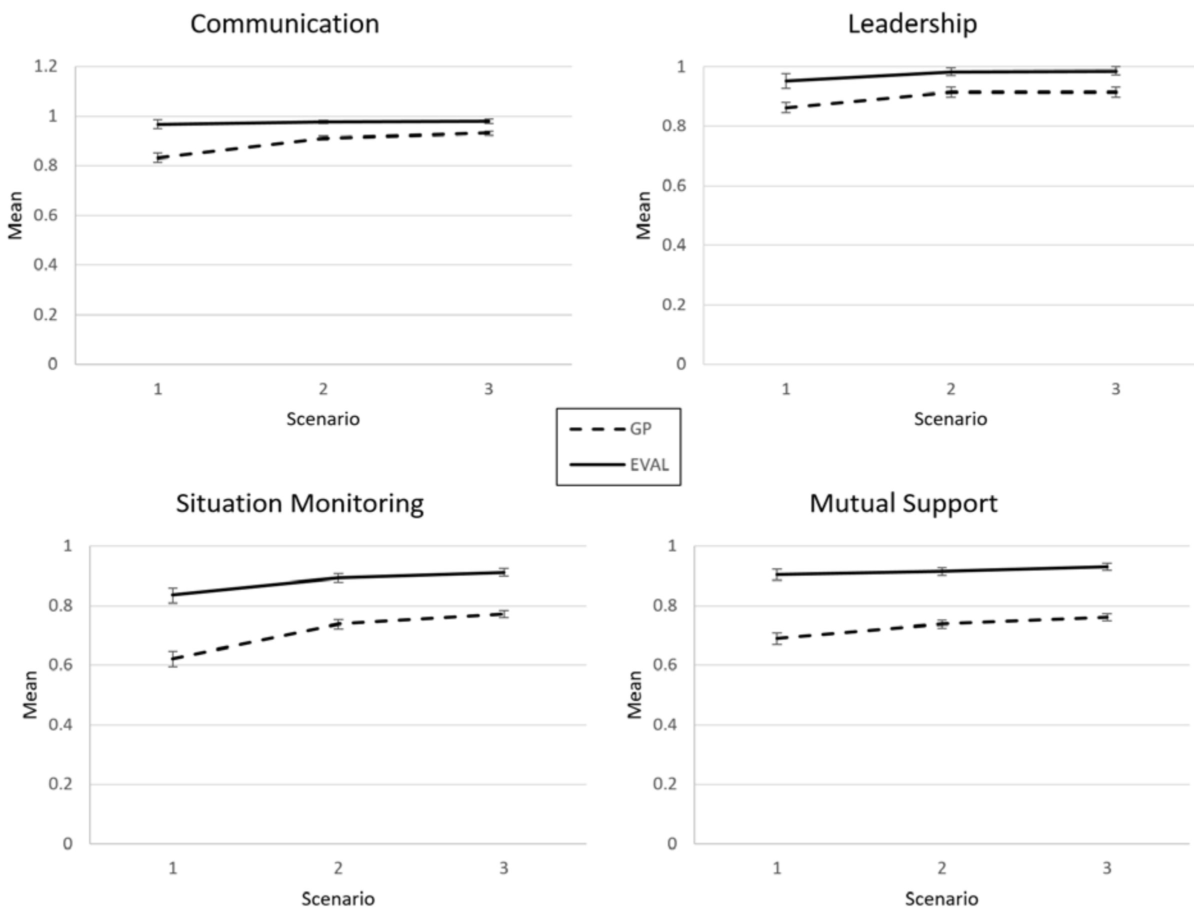


**Figure 4. Quiz Score.** Mean performance for quiz pretest and posttest scores. Error bars are 95% confidence intervals.

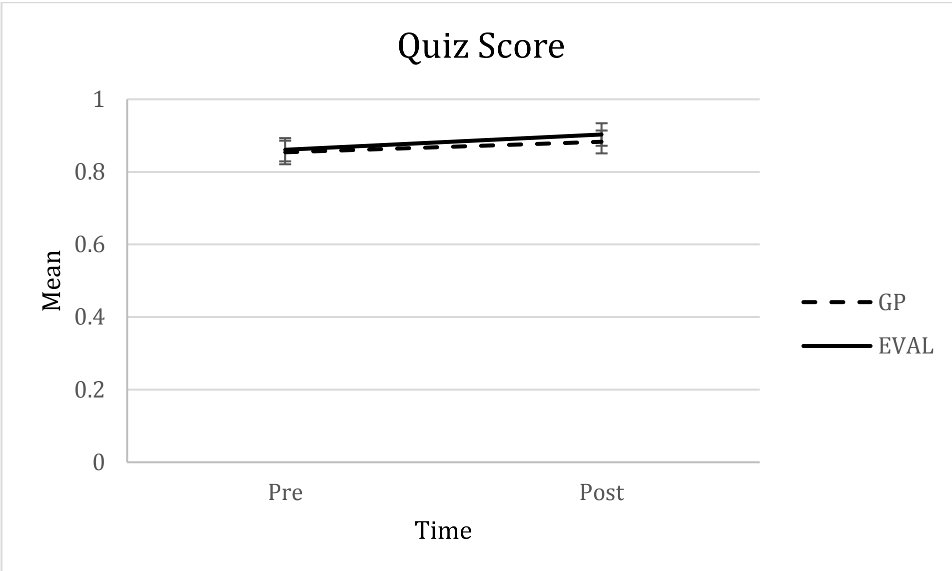
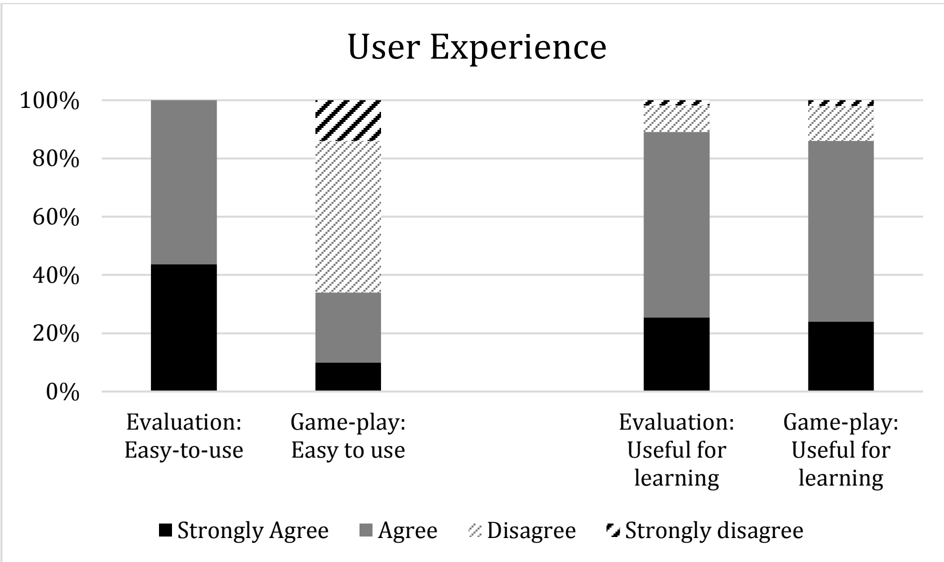


**Figure 5. User Experience.** Self-reported user reactions and experience show that both EVAL mode was easier to navigate but both EVAL and GP modes were equally useful for learning.

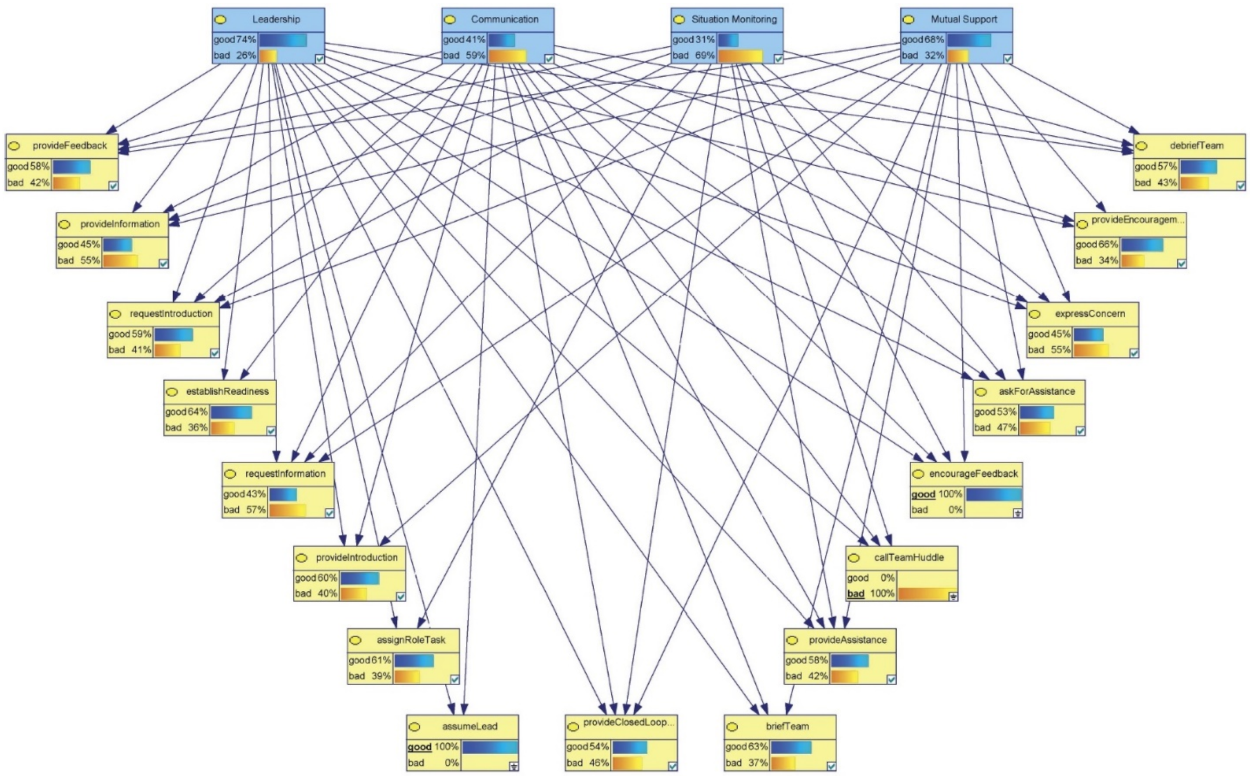


**Appendix A**

**Table A.1.** Player actions and their descriptions (EVAL and GP mode).

| Action | Description |
|---|---|
| Request introduction | Player requests introductions including name and occupation from team members and anyone new who hasn't introduced themselves |
| Request information | Player requests needed information to improve their situation awareness |
| Provide introduction | Player provides complete introduction with name and occupation initially to team and to anyone who enters the room |
| Provide information | Player provides needed information to non-player characters (NPCs) |
| Provide encouragement | Player gives positive encouragement to individual, team, and/or to patient |
| Provide closed-loop communication | Player acknowledges and/or repeats back information provided by an NPC |
| Provide feedback | Player responds to NPC's question or action with affirmative or negative response |
| Establish readiness | Player checks in with NPCs on their level of preparation for the event |
| Encourage feedback | Player encourages NPCs to speak up and give feedback |
| Debrief team | Player gathers the team at conclusion of event to discuss what went well and what could be improved |
| Call team huddle | Player gathers the team to get them all on the same page midway through event, update plan as necessary, reassign roles if necessary, answer questions |
| Brief team | Player gathers the team together to get them all on the same page, assigning roles, tasks, encouraging team to speak up |
| Assume lead | Player communicates to team members or new people arriving on scene that she/he will be assuming the role as Leader |
| Assign task/role | Player assigns medical task or role to the appropriate NPC who is best suited |
| Ask for assistance | Player asks or calls for help from existing team or consultation |
| Provide assistance | Provides help to other team members |
| Express concern | Player brings up a concern about the patient’s condition which wouldn’t require a full huddle |

**Figure A.1.** Bayesian network with the four main teamwork constructs (latent, top-level, blue nodes) and 17 assessed actions (observed, yellow nodes). The arrows represent conditional dependencies between the nodes, i.e. dependencies of the observed actions on the latent teamwork constructs.



cornerstone to developing effective team management and behavioral skills is having the ability to practice those skills in fidelity-relevant settings. Synthetic environments in the form of computer-based games or simulations can provide robust, authentic settings in which to teach, practice, and assess team skills. **This paper describes the AGILE methodology employed in the design and development of a screen-based simulation used to train and assess medical personnel to more effectively function as ad-hoc teams in critical-care situations, while also addressing competing stakeholder perspectives and requirements.**

## Teamwork Constructs & TeamSTEPPS™

TeamSTEPPS™ is a teamwork system developed by the Department of Defense's Patient Safety Program and the Agency for Healthcare Research and Quality to improve patient safety by improving healthcare professionals' teamwork and communication skills.

The main TeamSTEPPS™ constructs addressed in this project include:

1) **leadership**, including methods for asserting and maintaining leadership of a team
2) **situation monitoring**, the process of "continually scanning and assessing a situation to gain and maintain an understanding of what's going on around you"
3) **communication**, including techniques designed to communicate critical patient information quickly and effectively
4) **mutual support**, the process of assisting teammates to avoid work overload and improve patient safety
5) **psychological safety**, the process of creating a safe environment in which team members feel able to ask for help and raise concerns

Effective teamwork requires an appropriate team member to **establish leadership, maintain awareness of the evolving situation, manage team structure** (i.e., roles, responsibilities, tasks, etc.), and **clearly communicate information and goals**. It also requires that members of the team participate actively in teamwork by utilizing **closed loop communication** and **checkbacks** (i.e. acknowledging what has been said by a teammate and repeating back the information provided), **speaking up** when needed, and maintaining **situational awareness**.

## Teamwork in Our Game

Acute care contexts in which game play occurs:

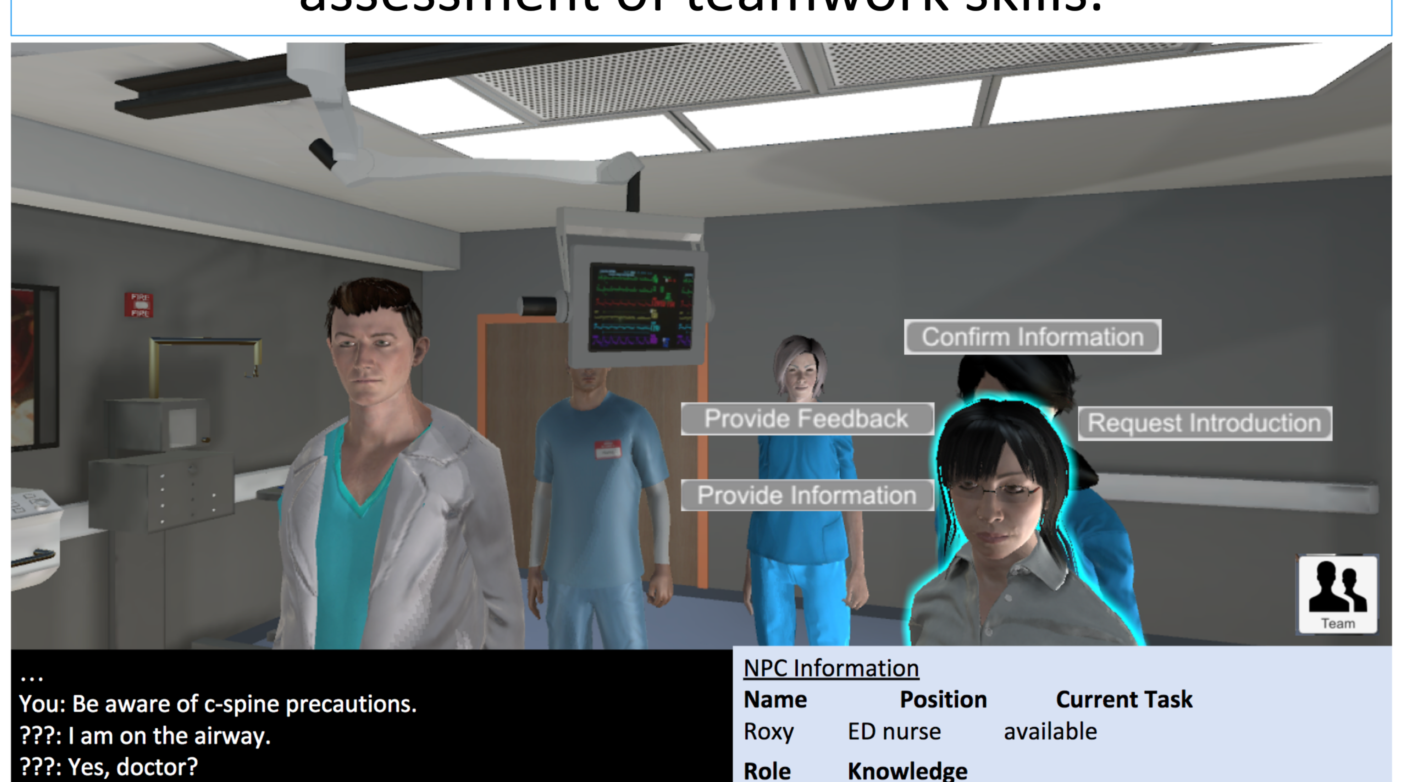
1) Emergency Room
2) Operating Room
3) Intensive Care Unit

Game player assumes role of team leader, and must:

- Assume leadership
- Assign roles and tasks
- Brief the team on the patient and plan at the beginning of the scenario
- Call huddles to update the team's plan and mental model during the scenario
- Provide feedback and closed loop communication as needed during the scenario
- Debrief following the scenario to discuss the teamwork that occurred

Various dialogue options are provided to the game player to assess content and manner of communication

*Figure 1:* Main interface screen of the game-based assessment of teamwork skills.



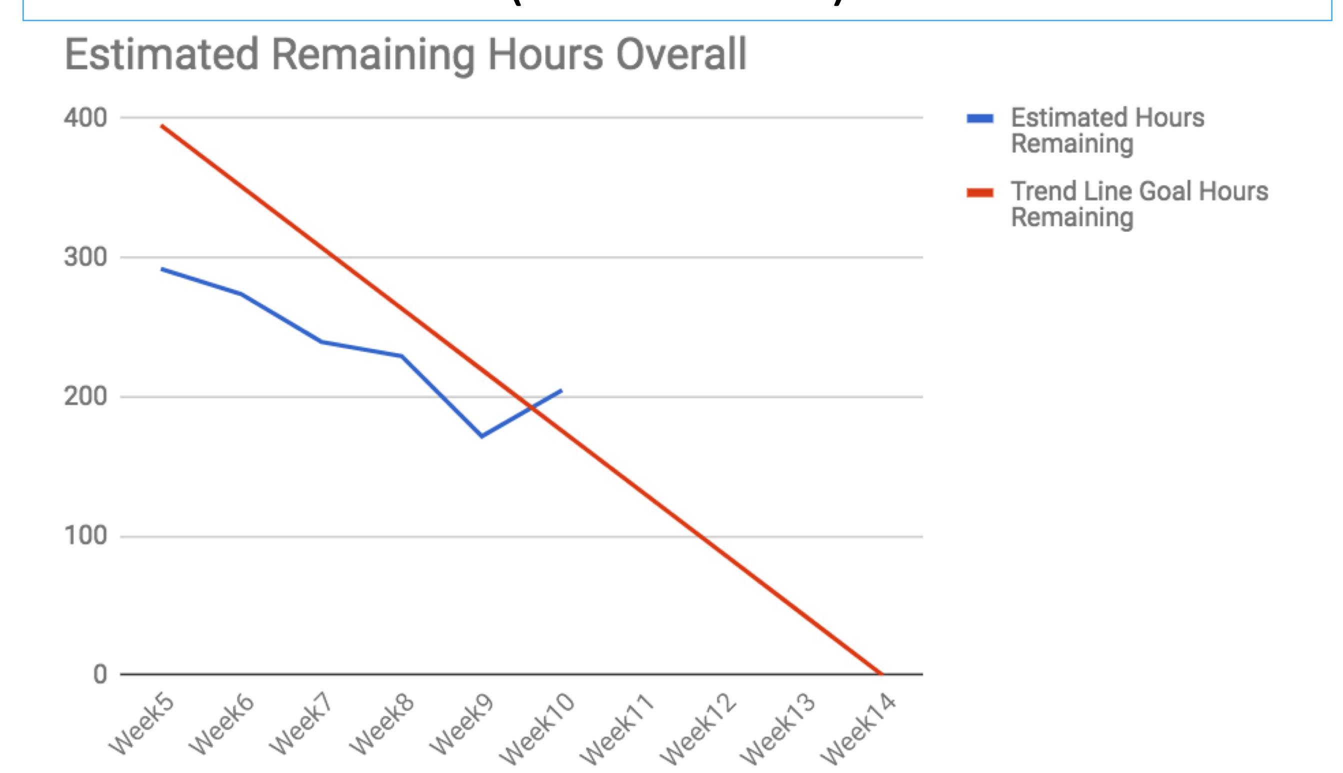

Agile methodology is highly iterative in nature, breaking tasks into small, chunk-sized modules that can be built, tested, and refined.
It allows for all stakeholders to maintain active involvement from the project's start to finish.

To facilitate our Agile process, we used:

- Zoom online meeting software
- Google Docs
- Google Sheets

This allowed our twenty-two member study team—including staff from the UCLA Simulation Center (David Geffen School of Medicine, Departments of General Surgery/Trauma and Anesthesiology), the Graduate School of Education and Information Sciences (GSE&IS), the Center for Research on Evaluation, Standards, and Student Testing (CRESST, GSE&IS), the UCLA Center for Advanced Surgical and Interventional Technology (CASIT), visiting scholars, and SimInsights Inc. (a game development company)—to hold weekly hybrid in-person and virtual meetings. Google Docs and Sheets were used for sharing information, including progress of software development and links to download software builds.

*Figure 2:* Estimated Remaining Hours Overall (Weeks 5-14)




## Structure for Task Breakdown

To break the development of this game down into smaller, more manageable tasks, we used development concepts from Atlassian: **epics and stories.**

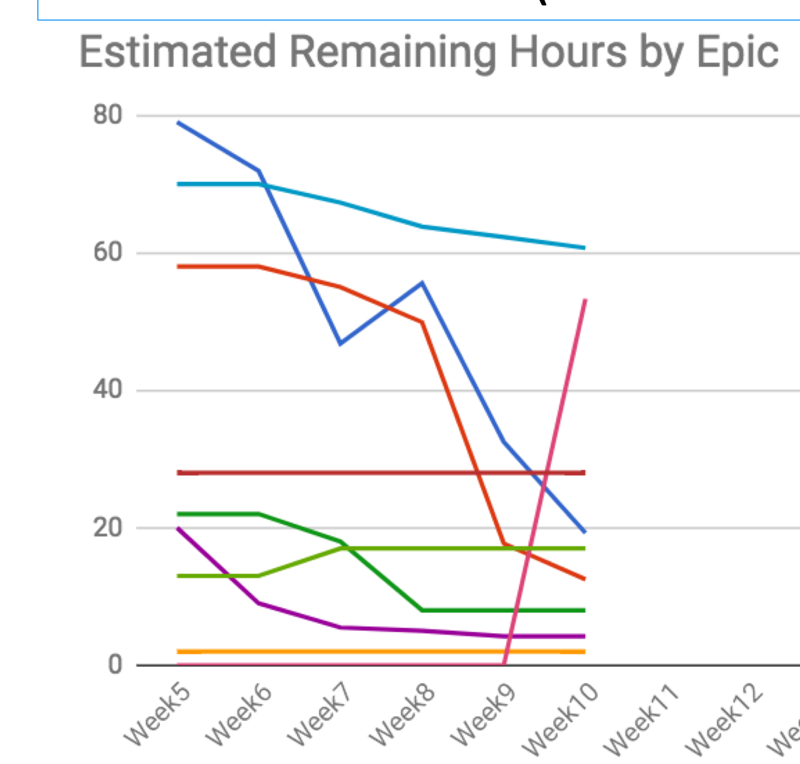
**Epics** are the largest strands of work, comprised of stories.
**Stories** are descriptions of features or capabilities a stakeholder would want related to the game. For example: "As a player, I need to be able to initiate actions and interact with other non-player characters (NPCs). These include: assume leadership, assemble team, create a shared mental model (brief/huddle/debrief), speak-up, provide acknowledgment, provide encouragement, provide introduction, request introduction, provide information, request information, assign tasks, perform tasks, resolve problems." Stories are comprised of tasks.
**Tasks** are the lowest level, the individual units of work that must be completed for each story.

We used the Google sheet to track epics, stories, and tasks and to log the estimated and actual hours of work expended on each task. Due to the iterative nature of the work, the estimated hours shown in Figures 2 and 3 changed and were updated as additional subtasks were identified. For example, the spike in hours for the after-action review (AAR) between weeks nine and ten was due to gaining a better understanding of what programming would be involved, such as feeding scored performance data from the database via an application programming interface (API) to the AAR interface.

Nine epics were identified which comprise the total scope

| | |
|---|---|
| **Game Logic:** | Game initialization, scenario prog |
| **Game User Interface** | Availability of affordances that en including moving around the spac (NPCs) |
| **Evaluative Mode** | Scenario playback in an alternativ environment but where the playe |
| **Assessment Measures and Telemetry** | Definition of assessable moments determine a player's competency |
| **Assessment Engine** | A Bayesian inference probabilistic teamwork skills |
| **After-Action Review** | Reflection, assessment feedback, |
| **Scenario Scripting** | Definition of team members, the ideal and problematic cases |
| **Game Tutorial** | An introduction to the game mec how to move, monitor statuses, a |

*Figure 3.* Estimated Remai (Weeks 5-1




## Lessons Learned: P

**Pros:**

- Easy to identify, design, and test ideas quickly
- Efficient platform for incorporating competing stakeh
- Allows unforeseen issues to surface early
- Provides for low-cost corrective action when problem

In terms of challenges, the development process require week, and a process was put in place, instantiated in a G into stories and epics , list who they were assigned to, ar important to include an estimation of the time required maintenance of the tasks in the Google sheet or similar t

**Cons:**

- Must be certain to include sufficient transparency an
- Must estimate project management, administrative, a development time

**Key takeaway:** The iterative nature of the AGILE process which facilitates getting to the desired goal state quicker utility not only to our team training simulation, but to an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# BACKGROUND

Lapses in teamwork and communication are responsible for the majority of medical errors.[1] Team training is critical in addressing these barriers, particularly in crisis conditions: leaders must designate roles of team members, ensure accurate and timely communication, encourage mutual support and conflict resolution, and ensure situation awareness to reduce or eliminate errors. Teamwork and interprofessional collaboration are increasingly identified as crucial educational objectives in clinical care settings.[2,3]

This project addresses team training through an interactive screen based serious game. Assessment of team training is limited by subjective evaluation criteria/metrics, which has been addressed by in-game decision analysis of the screen-based simulation system.[4]

Our project augments existing team training programs and addresses these gaps by the development of an innovative, accessible, and interactive simulation that allows practice and assessment of teamwork skills. Created by an interdisciplinary group from the UCLA Departments of Anesthesiology and Surgery, the UCLA Simulation Center, the UCLA Graduate School of Education, and the UCLA National Center for Research on Evaluation, Standards, and Student Testing (CRESST), this serious game evaluates usability, learning and performance differences between two modes of screen-based simulated team training, which utilize the same scenarios but differ in interface and how the user experiences the game: as an observer assessing non-player performance (Evaluation Mode) or as a game-player (Game-Play Mode) interacting with non-player characters.

We hypothesize that each mode will effectively teach and evaluate training skills, while the less complex, more cost effective system (Evaluation Mode), will offer non-inferior performance gains.

# METHODS

The overall design is a mixed randomized repeated measures design, with participants randomly assigned to one of two training modes, Evaluation Mode or Game-Play Mode. Participants' knowledge, skills, and attributes (KSA) are measured across three scenarios using an automated assessment engine via a constructed ontology, or node-based Bayesian network (BayesNet). We conducted an interim analysis (60% of 100 users) distributed amongst varied scopes and settings of medical practice including nursing (floor, operating room, emergency department, critical care), physician residents and attendings (anesthesiology, critical care, surgery, emergency medicine, internal medicine), and other allied health professionals (paramedics, pharmacists).

Participants progress through three scenarios, each in different clinical settings (ER, OR and ICU, in that order) while implementing teamwork skills in five main constructs of leadership, mutual support, resource management, communication,

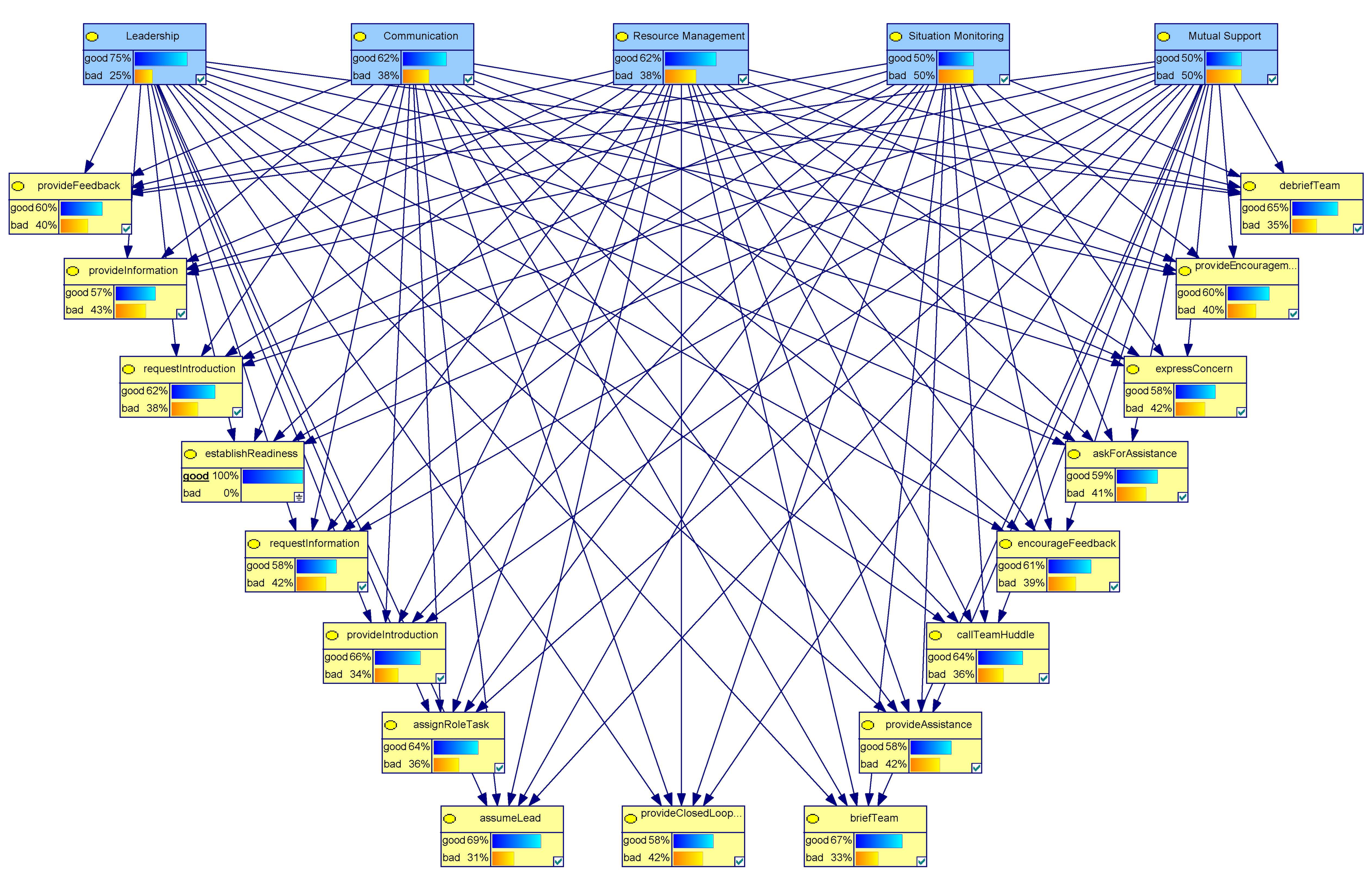


Figure 1. Bayesian Network. All five latent variables (Leadership, Communication, Resource Management, Situation Monitoring, and Mutual Support) are arranged in the top row of nodes. All observable variables are arranged in a V-shape below the five latent variables and dependency links point from the latent to the observable variables.


and situation monitoring. Components of these teamwork constructs are emphasized and assessed with an observable action mapped to each construct. Based on the relationships between these different entities as informed by the literature and experts on team training, a BayesNet was created (Figure 1), and an algorithm applied to the participant data to infer a person's KSAs. An after action review provided reflection and debriefing topics after each scenario. A pre and post-game multiple choice quiz measured knowledge of team concepts. Using data from BayesNet probabilities, we used a one-way repeated measures analysis of variance to look at learning outcomes in each mode, and a mixed randomized repeated measures of analysis of variance to look at learning trajectory in the two modes. Usability and ease of user interface was measured via a survey using a scale of 1 (strongly disagree) to 4 (strongly agree). Self-reported rating modes were evaluated with Chi-square analysis, and a t-test was conducted for each item to compare mean ratings in the two modes.

# PRELIMINARY RESULTS

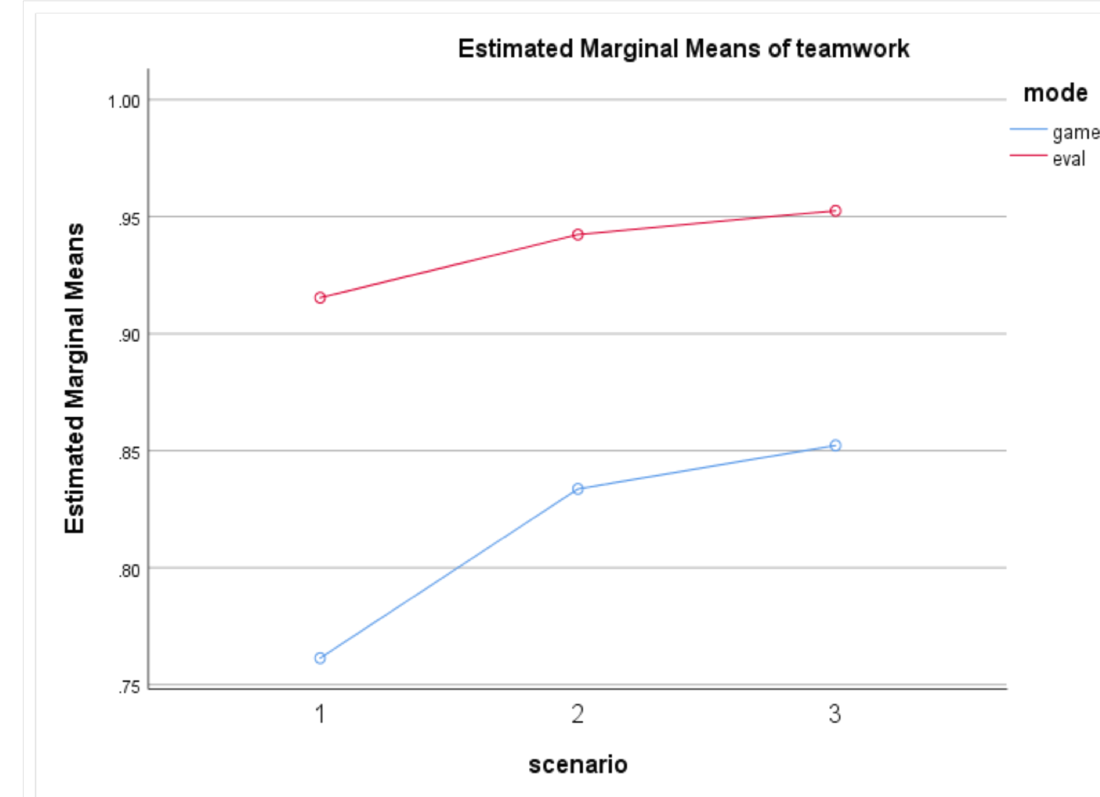


Figure 2. Performance based on BayesNet probabilities across three scenarios in Game-Play mode and Evaluation mode.

We conducted an interim analysis of the BayesNet probabiliti
completed cases (n=31 Evaluation mode and n=29 Game-Pla
significant increase in the BayesNet scores across all teamwo
Communication, Resource Management, Situation Monitoring
teamwork composite (equally weighted combination of the fiv
to Scenario 3 in both Game-Play mode and Evaluation mode
significantly outperformed participants in Game-Play mode ac
Scenario 1) (p<.001); however, the performance improvemen
greater in Game-Play mode (F=35.98, p<.001 versus F=9.14
significant difference between the modes in reported usability
teamwork (p=.53), however those in the evaluation mode fou
to navigate (p<.001) (Figure 3).

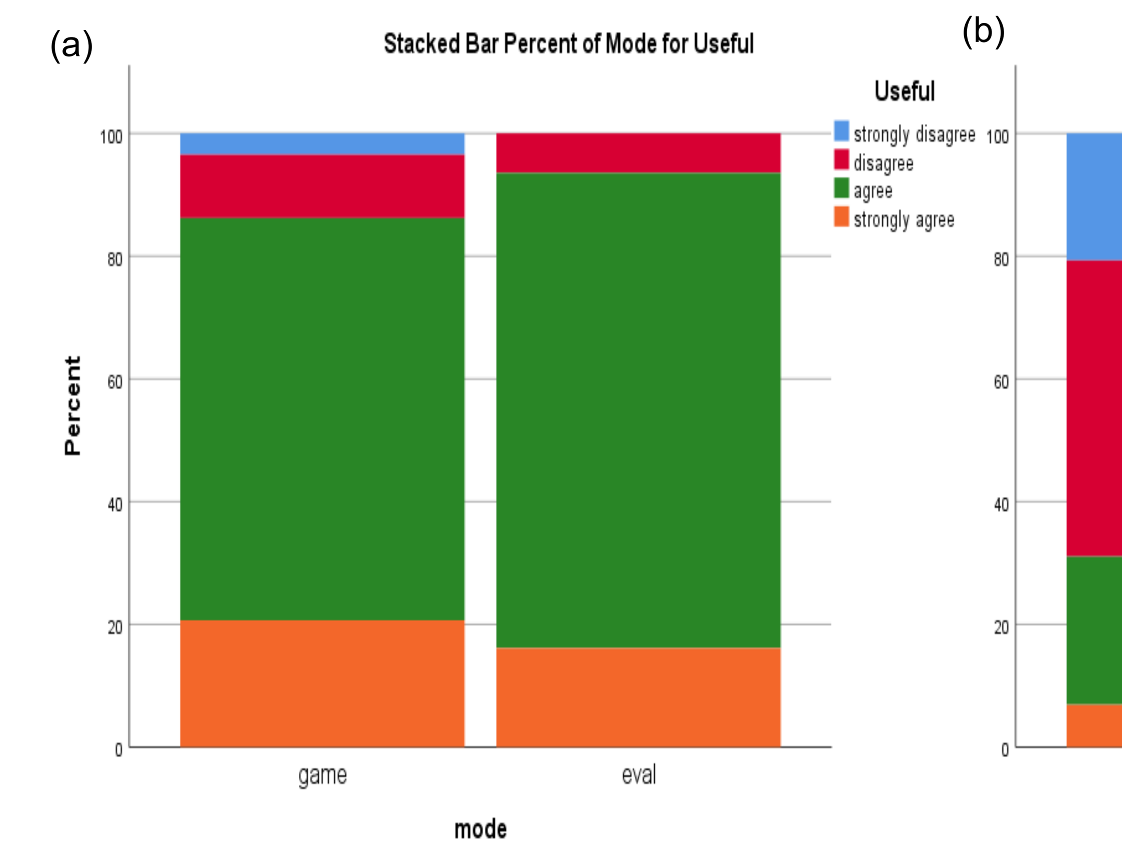


Figure 3. Post-survey responses. (a) Ease of usability. Difference
square: p=.53. Means: Game-play mode = 3.03, evaluation mode
Ease of user interface. Difference between modes is significant: C
Game-play mode = 2.17, evaluation mode = 3.48; t-test= 7.32, p<

# DISCUSSIO

Our interim results suggest that both modes offer performanc
Furthermore, we demonstrated a statistically greater differenc
within Game-Play mode in comparison to Evaluation mode. H
performed Game-Play participants at all times. These results
differences in how these two modes are designed and experie
as a baseline value of BayesNet scores the difference betwe
not reflect differences in KSAs of the participants but rather th
and/or the effectiveness of the evaluation process in differenti
we cannot definitively state that the increased performance ga
improved edification of the participant and not increased fami
reflective of the differences in the evaluation process. To bette
gains further research should be done; specifically a cross-ov
could help in this evaluation.

Overall, the survey data suggests that game participants enjo
serious game. The greatest obstacle to satisfaction appeared
Game-Play mode); further development of the game into a vir
may lead to improved participant satisfaction, and perhaps pe
serious game offers a unique and easily accessible method o
to a broad cohort of healthcare and military personnel.

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**Game Play Mode - Scenario 1 Script**

Scenario 1: Trauma – MVA

11 Pauses/Assessable Moments

Player actions and their descriptions

| **Action** | **Description** |
|---|---|
| Request introduction | Player requests introductions including name and occupation from team members and anyone new who hasn't introduced themselves |
| Request information | Player requests needed information to improve their situation awareness |
| Provide introduction | Player provides complete introduction with name and occupation initially to team and to anyone who enters the room |
| Provide information | Player provides needed information to non-player characters (NPCs) |
| Provide encouragement | Player gives positive encouragement to individual, team, and/or to patient |
| Provide closed-loop communication | Player acknowledges and/or repeats back information provided by an NPC |
| Provide feedback | Player responds to NPC's question or action with affirmative or negative response |
| Establish readiness | Player checks in with NPCs on their level of preparation for the event |
| Encourage feedback | Player encourages NPCs to speak up and give feedback |
| Debrief team | Player gathers the team at conclusion of event to discuss what went well and what could be improved |
| Call team huddle | Player gathers the team to get them all on the same page midway through event, update plan as necessary, reassign roles if necessary, answer questions |
| Brief team | Player gathers the team together to get them all on the same page, assigning roles, tasks, encouraging team to speak up |
| Assume lead | Player communicates to team members or new people arriving on scene that she/he will be assuming the role as Leader |
| Assign task/role | Player assigns medical task or role to the appropriate NPC who is best suited |
| Ask for assistance | Player asks or calls for help from existing team or consultation |
| Provide assistance | Provides help to other team members |
| Express concern | Player brings up a concern about the patient's condition which wouldn't require a full huddle |

Cast of Characters:
1. ED-Resident (Roxy) - right side of patient bed (patient's right)
2. Trauma-Resident (Jamal) - left side of patient bed
3. RN 1 (lines) (Marilyn) - on right side of bed
4. RN 2 (meds) (Ben) - on left side of bed
5. RN 3 (scribe) (Susan) - by the computer
6. Respiratory therapist (Xan) - at the head of the bed
7. Trauma Attending (Areti) - on the right of the bed [so facing the default camera view]

Miguel (radiology technician), Ken (paramedic), Shezad (patient) and Penny (orthopedic resident) will come in later.

Player Character (PC) = ED attending, Fatma

# Setup

Fade in: Pager screen that says, "Critical trauma arriving in 8 min. by ambulance 32 y.o. in MVA. GCS 15." (fade out, fade in to trauma bay)

Already in trauma bay:

ED-Attending (Fatma)
ED-Resident (Roxy)
Trauma-Resident (Jamal)
RN 1 (lines) (Marilyn)
RN 2 (meds) (Ben)
RN 3 (scribe) (Susan)
Respiratory therapist (Xan)
Trauma Attending (Areti)

[popup: This scenario takes place in the Emergency Department. You are Dr. Fatma Kassamali, an E.D. physician. You are in an unfamiliar hospital but are expected to take the role of the leader for the upcoming situation.]

# PC to do introductions and assumeLead

### Assessment#1 Provide Introduction [popup] (Button name: Introduce Yourself)

DefaultDialogue>I'm Dr. Fatma Kassamali, the ED attending, I go by Fatma. (0.95) | I'm Dr. Fatma Kassamali.(0.65) | I'm the ED attending. (0.65) | I'm Fatma. (0.05)

Response>Jamal: Hi, Fatma! | Jamal: Hi, Dr. Kassamali. | Jamal: You're Fatma, right? | Jamal: You're the ED attending, right?
[if not addressed: Jamal: Hi, who are you?]

**Assessment #2 Request Introduction [popup] (Button name: Request Introduction)**

DefaultDialogue>Who do we have in the room today? Your name and role please. (0.95)| Who's here and who's missing? (0.65)| I see we have the usual suspects. I'd like to hear from each of you. (0.35)| What's up? (0.05)

Response>Roxy: Let's all introduce ourselves? | Roxy: We should tell you who's here. | Roxy: We have names, you know. | Roxy: I think we should begin by introducing ourselves.
Fatma: Great. Who do we have in the room today?

[if not addressed: Roxy: Fatma, do you know who is on the team?]
ED-Resident: I'm Roxy, and I'm the E.D. Resident.

Trauma-Resident: I'm Jamal, Trauma resident.

RN 1 (lines): I'm Marilyn, E.D. nurse.

RN 2 (meds): I'm Ben, and I'm an E.D. nurse.

RN 3 (scribe): I'm Susan, E.D. nurse, and I'll be the scribe today.

Respiratory therapist: I'm Xan, respiratory therapist.

Trauma Attending: Hi, I'm Areti, the Trauma Attending. I go by Areti.

**Assessment#3 Assume Leadership (timeout) (Button name: Assume Leadership)**

DefaultDialogue>I'll be running this trauma. (0.95) |Areti and I are the attendings today. (0.05). | I guess I should take the lead here.(0.65) | Everyone here seems experienced. Let me know if you need direction. (0.05)

Response>Susan: Understood, you'll be running this Trauma. | Susan: Ok you are in charge.| Susan: That would be great. | Susan: Yes we know. You'll be in charge.
[if not addressed: Susan: Who is in charge here?]

# PC to call for briefing

**Assessment#4 Brief Team [popup]**

DefaultDialogue>Hey team, let's brief! (0.95) | I think we should talk about this a little. (0.65) | Get over here so we can talk. (0.35)| Let's not waste time talking--let's just get started. (0.05)

Response>Marilyn: Okay, let's brief. | Marilyn: Okay, let's talk. | Marilyn: Okay, we'll talk. No need to be pushy. | Marilyn: I disagree. I think we need to brief first.

# Briefing

Fatma: (to room) Okay, let's brief. What do we have?

RN1 (Marilyn): Rescue is 8 minutes away with a 32 y/o male status post MVA (motor vehicle accident). Patient has C-collar in place, abdominal bruising and an obvious deformity to the right thigh.

Fatma: Thanks, everyone. Listen up--Xan, you're on the airway. Let Jamal or Roxy know if you need assistance. Be aware of c-spine precautions.

Xan: Got it.

Fatma: Roxy or Jamal, who's assessing breath sounds?

Jamal: I'm assessing breath sounds. I'll listen to heart tones too.

**Assessment #5 Provide ClosedLoopCommunication (Button name: "Confirm Information")** [dialogue options to pop up automatically--no timeout]

DefaultDialogue: Okay, Jamal, you'll do breath sounds and heart tones. (0.95) | Great, Jamal, Thanks. (0.65) | Jamal, can you take on more? (0.35) |What else do we need to take care of? (0.05)

Response: Jamal: No response| Jamal: No response| Jamal: I don't think so--perhaps Roxy can.| Roxy: What about the FAST exam?

[if not addressed: Roxy: What about the FAST exam?]

Fatma: Roxy, I want you to be on the patient's right and assess for proximal and distal pulses in all extremities. You'll also be taking care of the FAST exam today-- he has abdominal bruising, so we'll need to be watchful.

Roxy: I'll assess for pulses and do the FAST exam.

Fatma: Because of the thigh deformity, we'll need to alert the radiology technician in anticipation of needing an x-ray or CT. Let's also get ortho.  Marilyn, could you page a radiology technician and the ortho resident for me?

Marilyn: I'll page a radiology technician and the ortho resident.

Fatma: Thanks, Marilyn. Susan, I heard you say you'll be the scribe today. Marilyn and Ben, how about you?

Marilyn: I'll do lines today.

Ben: I'll be on meds & monitors today.

Fatma: Great, Marilyn's on lines and Ben is on meds. Marilyn,  standard trauma labs including type and cross. Okay, we have a plan in place. If anything changes, we can huddle to reassess, but here's what we know: We have a 32 year old male MVA, GCS 15 with C-collar in place, abdominal bruising and an obvious deformity to the left thigh. We'll need an X-ray, orthopedics and possibly inform the operating room.

# Encourage Feedback

Fatma: Okay, we have a plan in place. Have I forgotten to mention anything?

Marilyn: No

**Assessment #6 Encourage Speaking Up (timeout)**

Dialogue>Please speak up if you have any concerns during the trauma. (0.95) | You need to tell me if you think something is wrong. (0.65) | It's your responsibility to catch any mistakes during the trauma. (0.35) | I expect you to speak up-- I don't want to get blamed if something goes wrong. (0.05)

Responses>
Ben: Thanks, Fatma. We'll be sure to speak up. |
Ben: Okay. |
Ben: [no response]
Roxy: I think everyone should speak up if they have questions or concerns.
[if not addressed: Ben: What if we're worried about something during the trauma?]

Fatma: Good. Please also let me know if you need help.

**Assessment#7 Establish Readiness (timeout)**

Dialogue>Now please check your equipment and get ready for the patient's arrival. (0.95)| Please make yourselves busy. (0.65) |I hope you're all ready. (0.35)| Many hands make light work. (0.05)
[if not addressed: Marilyn->Fatma:"Are we done briefing now?]

# Marilyn Calls Miguel

[Marilyn walks over to phone on the wall to page the ortho resident and radiology tech, then prepares lines.]

# Miguel interaction (RT) 1

[Radiology Tech Miguel, arrives.]

Miguel (to room): Hi, I'm Miguel, the radiology tech.

Fatma: Hi Miguel, I'm Fatma, the ED attending leading this trauma. We have an MVA with a right thigh deformity and abdominal bruising. We anticipate needing multiple X-ray studies.

Miguel: Got it.

Popup: All team members prepare for patient arrival.

# Patient and paramedic arrive on scene

[Paramedic Ken wheels patient on gurney into ED room and gives report.]

Paramedic: (to room) I'm Ken Rescue 4. This is Shezad. He was a restrained driver in a single-car accident, pulse 123, BP 92/52, respiratory rate 24, saturation 99%, in the field, GCS of 15, a right thigh deformity, and abdominal bruising. He has a large bore IV with lactated ringers running and C collar in place No meds given.

Fatma: (to paramedic) Thanks, Ken. We'll take it from here.

[Ken leaves ED room. Show pop-up with the following text:

- Shezad is complaining of right thigh pain. The team completes a primary survey: airway, breath sounds and circulation are normal. He is alert, talking, oriented x 4.
- Secondary survey reveals a deformity of the right thigh and abdominal tenderness and bruising. History is positive for cephalosporin allergy.

# Roxy asks for assistance with FAST

[Show Roxy looking at ultrasound machine.]

Popup: Roxy is doing the FAST scan.

Fatma: Everything OK there, Roxy? You look a little puzzled.

Roxy: I'm looking at the FAST and I'm not sure.  It may be positive?

**Assessment#8 AskForAssistance (timeout) (Button name: Ask for Help)**

Dialogue>Areti, could you help Roxy  interpret the FAST, please? (0.95) | Areti, could you see what Roxy needs? (0.65)|  Could someone help Roxy? (0.35) |Somebody take over for Roxy.(0.05)

Response>Areti: Sure, Fatma. I'll help Roxy with the FAST. |
Areti: I will take a look. |
Jamal: I think Areti could help Roxy. |
Areti: I'll do it, Fatma.

[If not addressed: Roxy: Fatma, I need help with the FAST]

# Order Films

[Areti moves next to Roxy, examines FAST]

Popup: Areti helps Roxy interpret the FAST scan.

Areti: FAST is negative.

Fatma to Miguel: Let's get C-spine, chest, and right femur films. Once ortho sees the patient we can go to CT.

Fatma: Susan, can you order the studies?

Susan: Ordering c-spine, chest, and right femur films right now.

# Penny Interaction 1

Penny (ortho resident) arrives: Hi everybody. I'm Penny, the ortho resident.

Fatma (to Penny): Hi Penny, I'm Fatma, ED attending leading this trauma.

**Assessment #9 Call Huddle (timeout) (Button name: Call for Huddle)**

Prompt: Penny "It would help if someone could update me on the situation"

Dialogue>Head's up, everyone. The Orthopedics resident is here. Let's huddle. (0.95)| We should probably discuss the plan. (0.65) | We have to figure out what to do next. (0.35) | Let's not waste time talking. Let's just get started. (0.05)

Response>Areti: Okay, let's huddle. | Areti: Okay, let's talk. | Areti: Okay, let's huddle and figure that out. | Areti: I disagree. I think we need to huddle first.
[if not addressed: Areti: Fatma, what is the plan of action?]

# Penny Interaction 2

[Everyone faces Fatma and Penny.]

Fatma (to room): Here's the situation: 32 year old male, Shezad, with right thigh deformity. Background: motor vehicle accident victim, no loss of consciousness, negative FAST. Assessment: Probable right femur fracture. The radiology prelim report is in. No cervical spine disease, normal chest X-ray. Penny, what do you think of the femur X-ray?

Penny: Yes, he'll need to go to the operating room but we need a CT first. Can we give him a gram of Ancef after CT as a pre-op med?

Fatma: Ben, please prepare one gram of Ancef.

Susan: Fatma, the patient is allergic to cephalosporins.

**Assessment #10 Provide Feedback, (timeout)**

Prompt: Susan: Fatma, did you hear me?

Dialogue> Thanks, Susan. Your speaking up just prevented an allergic reaction. (0.95)|Thanks. I appreciate your speaking up.(0.65) |Thanks, good catch.(0.35)|Okay. (0.05)

[if not addressed: Susan: Fatma, did you hear me say that the patient is allergic to cephalosporins?]

# Penny Interaction 3

Fatma: Is Vancomycin acceptable?

Penny: Yes, let's start Vancomycin, one gram, now and administer over one hour.

Ben: OK, I will start one gram of Vancomycin over an hour right now.

[visible on monitor as asset: Vitals: HR 104, BP 102/60, RR 16, SpO2 99%]

Fatma (to Penny): Do you plan to admit him to the orthopedics service for surgery?

Penny: We'll need a CT of that leg first.

Fatma: Great. We'll keep him in the ER and manage his pain until a bed becomes available or he goes to surgery.

[Penny walks closer to face Shezad.]

Penny (to Shezad): Hi Shezad, I'm Penny, the orthopedics resident. You've broken your leg in a couple of places and will need surgery to repair it. We're going to get a CT scan now. This will give us more information so that we can make a plan for surgery. What questions do you have?

Shezad: Please give me something for the pain!!

Popup: Shezad receives morphine for pain and is taken to CT. Scan shows no vascular injury and he is on the way to the OR with ortho. The team members start to leave for their next case.

# PC to call for debrief

[Everyone in same position in room except patient and Penny - Shezad, bed and Penny are no longer in room. ]

**Assessment #11 Debrief Team (timeout) (Button name: Debrief Team)**
DefaultDialogue>Hey, team, would you all have about 5 minutes for a short debrief? (0.95)| Let's take 5 minutes to debrief. (0.65)| Let's take five minutes to chat. (0.35)| We need to talk.(0.05)
Response>Areti: Great, let's debrief the case. | Areti: I have 5 minutes to debrief. | Areti: I have 5 minutes to chat. | Areti: I suppose you would like to debrief the case.
[if not addressed: Xan: I think we are about done here, unless there is something else to do. Do you need me anymore, Fatma?]

# Debrief

(Everyone turns to face Fatma.)

Fatma: Thanks everybody. I'll be respectful of your time. First, before we discuss the facts of the case, your reactions?

Marilyn: We were very efficient, but I was concerned that we almost overlooked the patient's med allergy, then Susan reacted quickly and spoke up so the patient's care was not compromised. Great catch, Susan!

Ben: Yes, I'm glad you spoke up because I don't think I heard that information about his allergy.

Areti: That was a great example of cross monitoring and speaking up!

Susan: Thanks for listening to me.

Fatma: Yes, thank you Susan. I really appreciated you paying attention and calling out that concern. I think our team did a great job of supporting one another. What else did we do well in this case?

Roxy: I thought the briefing helped us prepare for the patient. Also, I thought you had great situation awareness when you noticed that I needed help with the FAST. Thanks, Areti, for your help.

Fatma: What do you think we could do better? I'll start by saying that next time, I'll check-back on critical information like the medication allergy. Thank you for your hard work today!

Popup: Team continues its debrief...

Popup: End of Scenario

(Fade out as the discussion continues)

--END--

**Example of User Interface for Game Play Mode-Scenario 1**

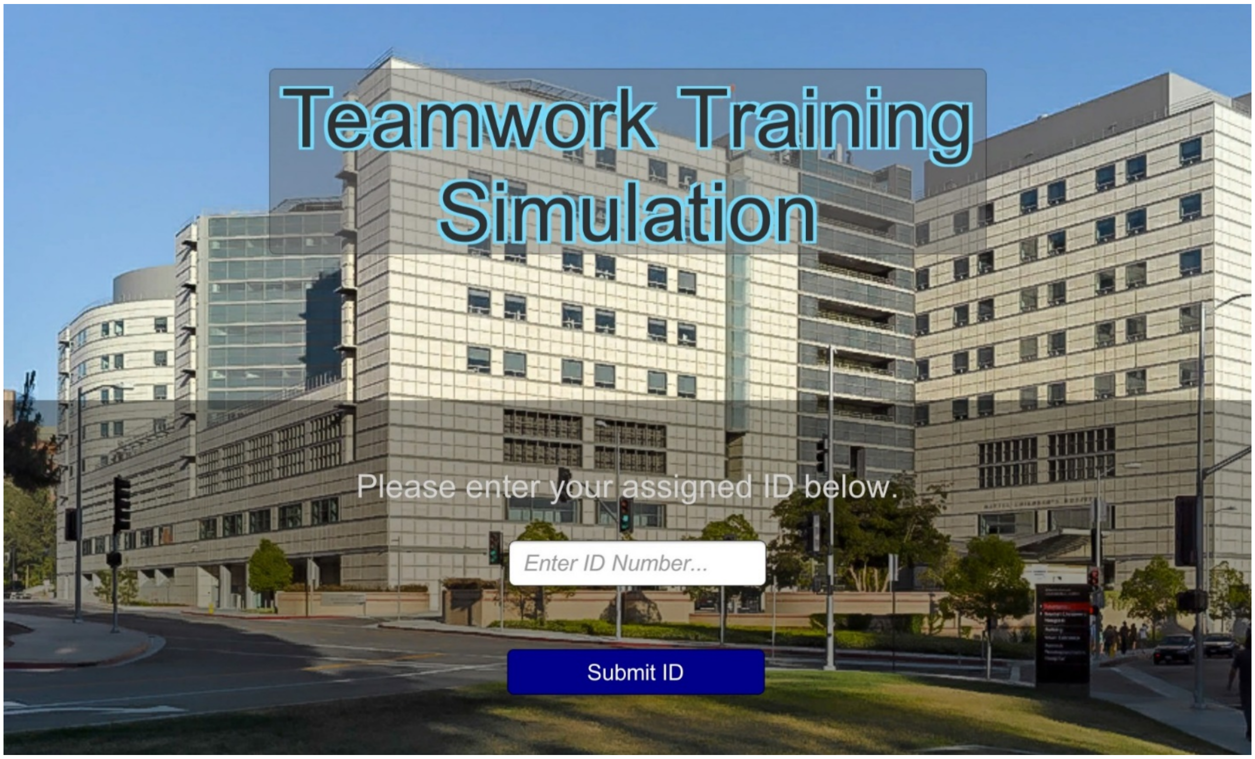

**Figure 1.** Simulation Login Screen

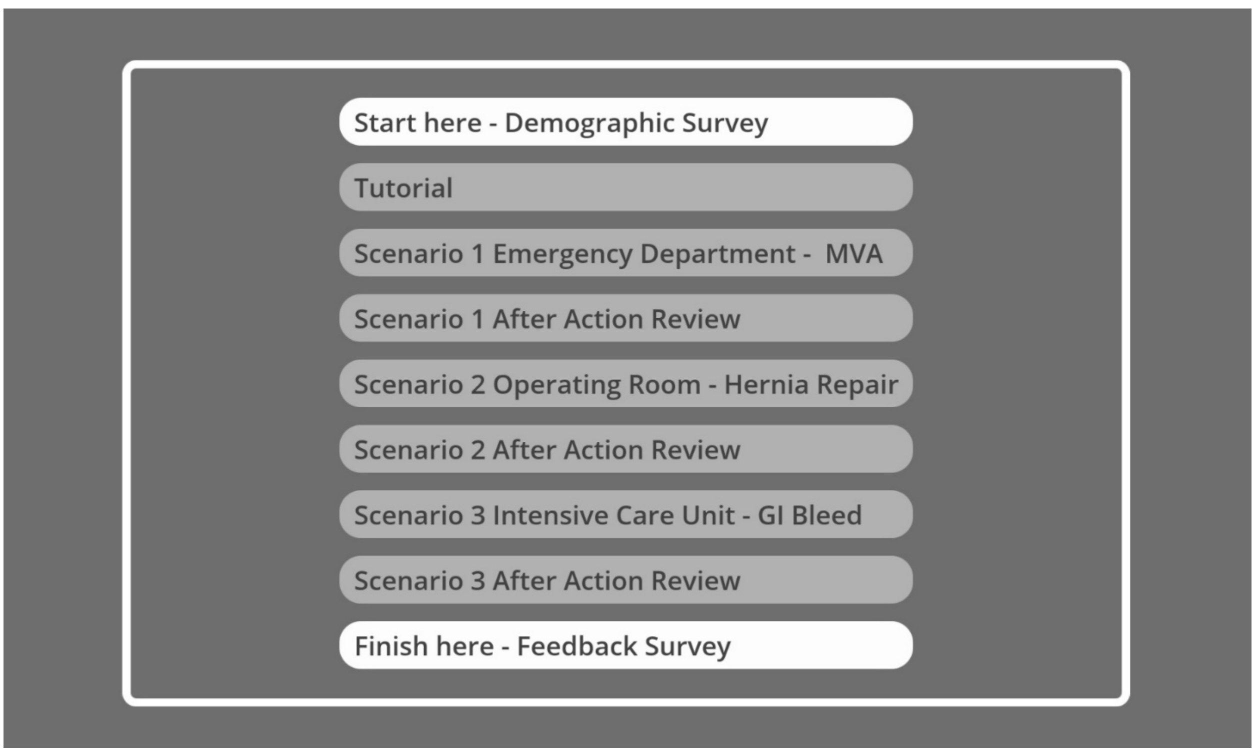

**Figure 2.** Main Menu Screen

Sample of Tutorial Slides for Game Play Mode:

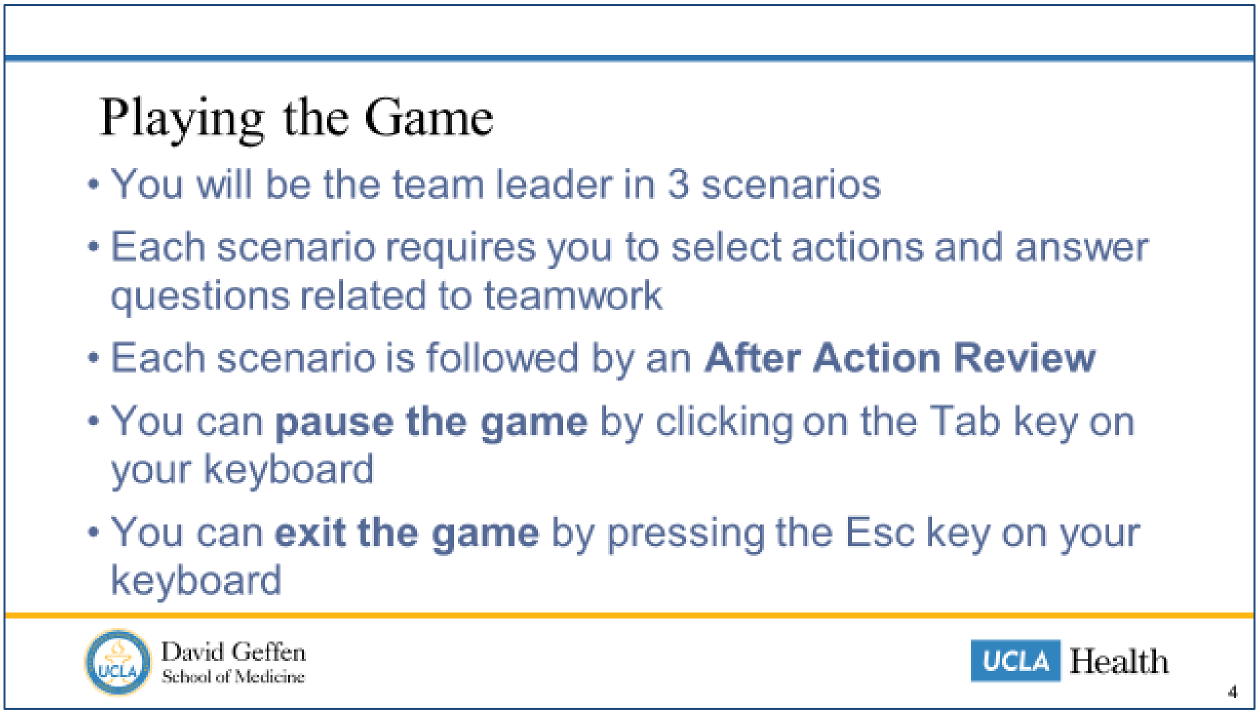


**Figure 3.** Overview of what to expect when playing the game


**Figure 4.** Overview of how to navigate Game Play interface


**Figure 5.** Overview of what "action required" prompt indicates

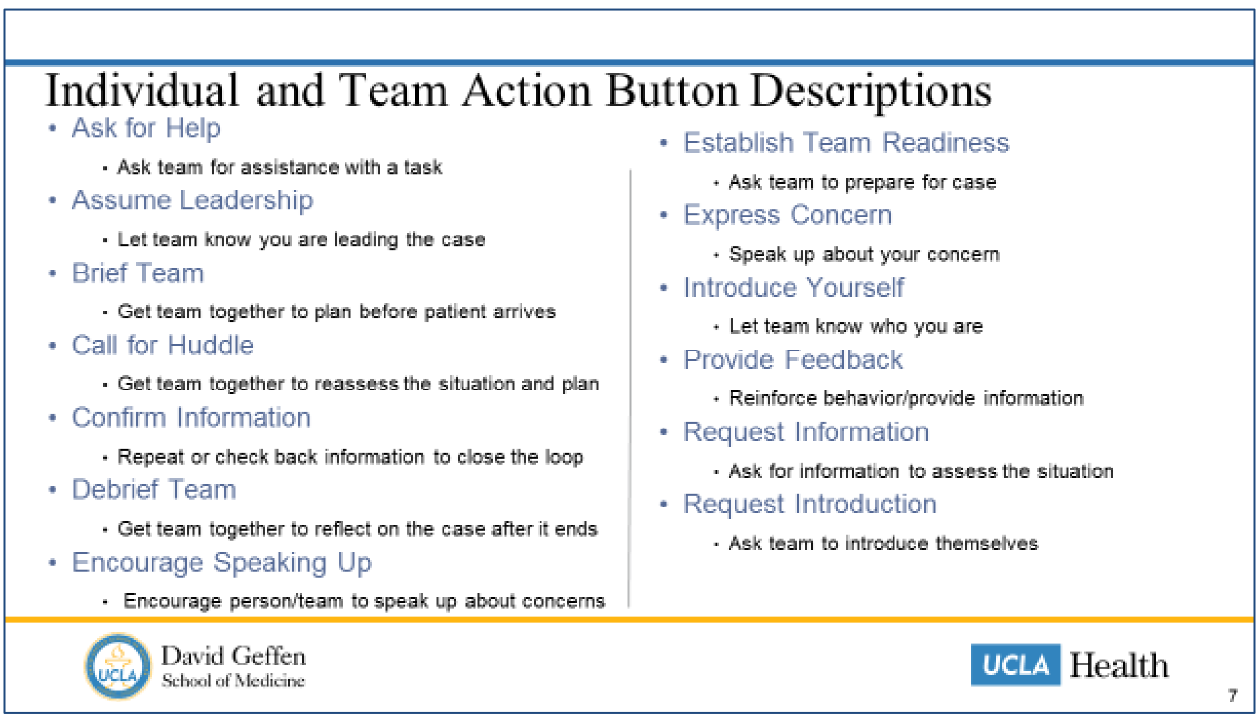


**Figure 6.** Action button descriptions

Screenshots of Scenario 1 Game Play Mode Interface:


**Figure 7.** Player character (PC) dialogue & individual team member action buttons


**Figure 8.** "Action required" prompt & available team action buttons

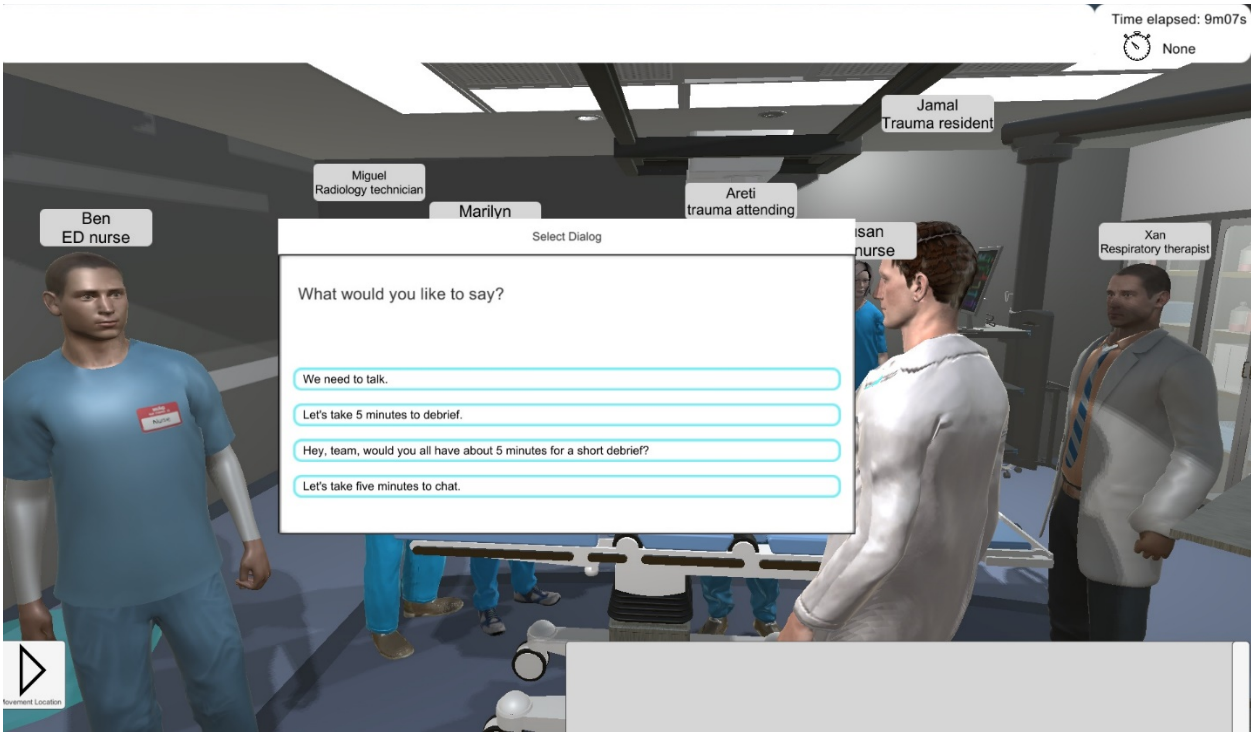


**Figure 9.** Player character (PC) dialogue options

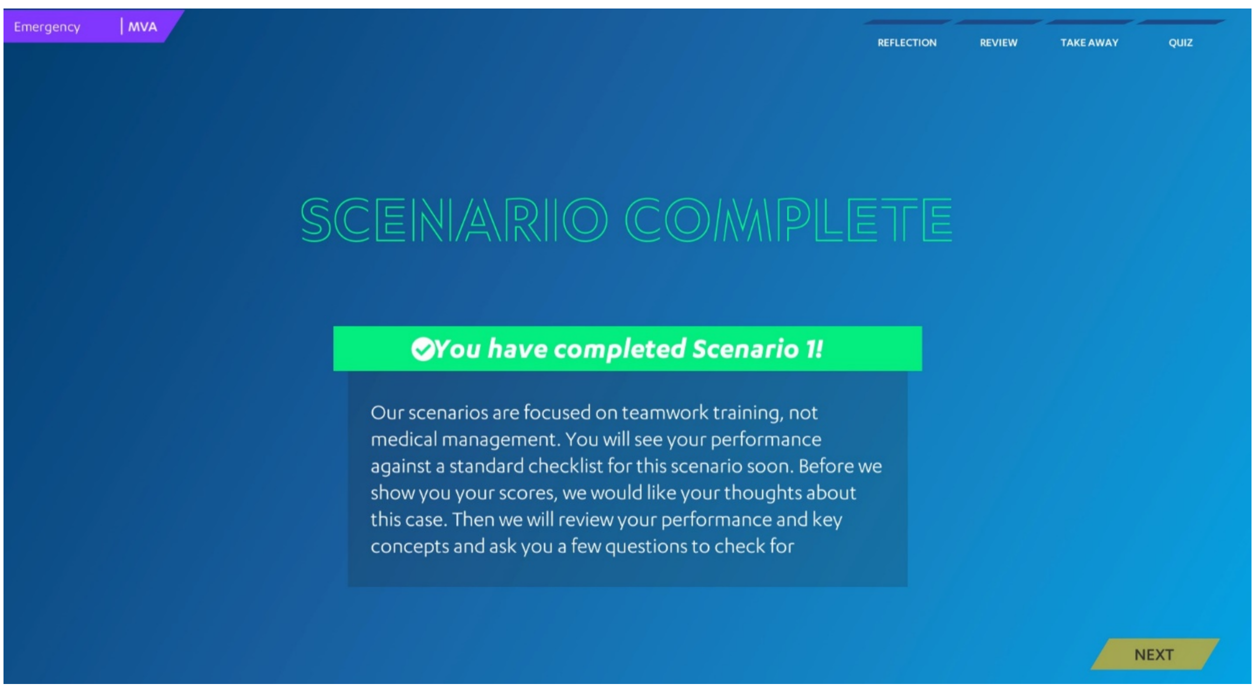


**Figure 10.** After Action Review (AAR) Scenario Complete Screen

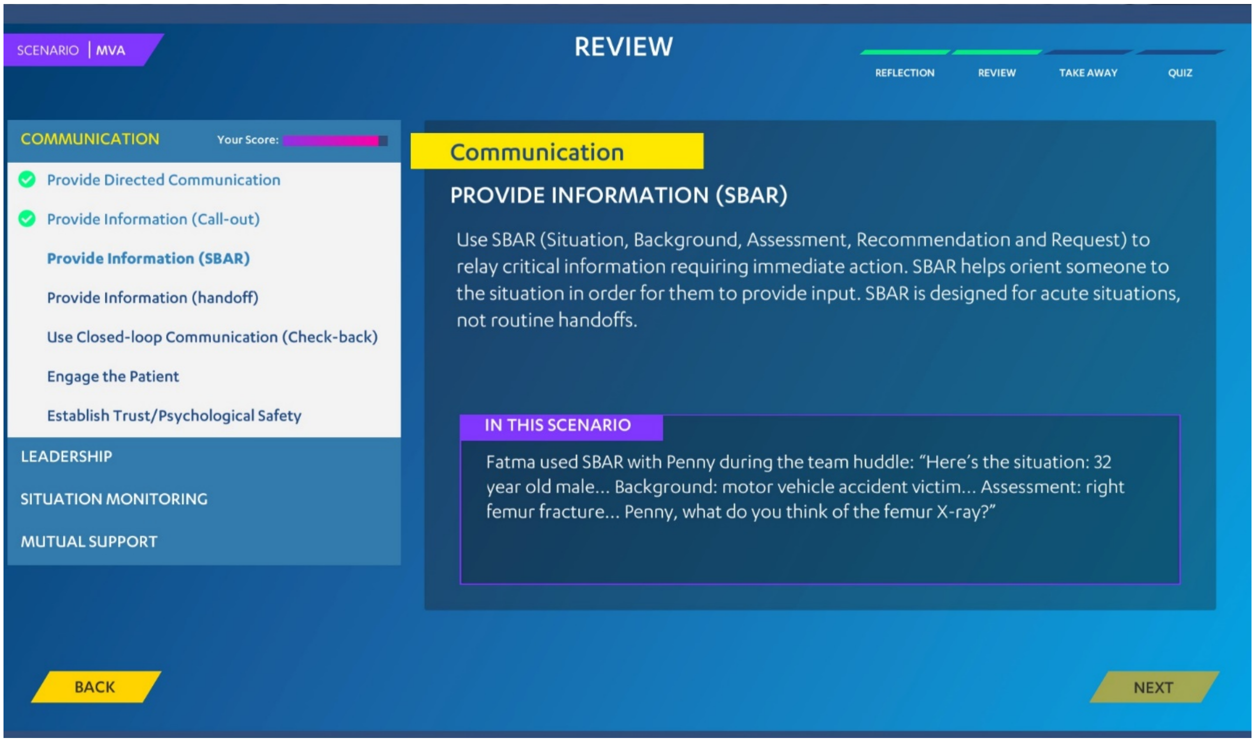


**Figure 11.** AAR teamwork concept review