Vehicle Casualty Extraction: Training Needs and Solutions

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ABSTRACT

Attacks on vehicles through the use of improvised explosive devices (IEDs) and the incidence of vehicle rollovers have significantly increased over the past few years. It is important to quickly extract casualties from vehicles that have been targeted by these devices. The approach to extracting a casualty from a vehicle varies based on the condition and position of the vehicle, the expected injuries of the casualties inside, the position of the enemy and status of enemy fire, and the type of vehicle casualties are being extracted from. Given that the combination of these variables and many others make each vehicle extraction unique, it is essential to provide a variety of training conditions within which Combat Medics and Combat Lifesavers can practice the extraction task in order to help them develop strategies to make the best decisions possible and increase the survivability of causalities and the extraction team.

This paper describes the process and results of an effort to develop requirements for a reconfigurable vehicle casualty extraction training system that safely allows trainees to practice the knowledge, skills, and abilities needed to perform casualty extraction under a variety of realistic conditions. First, a task analysis and training needs is outlined that was used to define the extraction process and identify potential inefficiencies associated with current methods used to conduct training on this complex task. Next, a process is outlined that was used to extract the critical cues and functional requirements that are essential to integrate within the training system to target each critical extraction subtask. Finally, the design of the Vehicle Extraction (V-Xtract) training simulator that is currently being developed to meet these needs is presented. The V-Xtract system provides a safe, realistic, highly configurable environment that can efficiently present a variety of training conditions to trainees, objectively evaluate their performance, and provide guidance on how to progress future training based on past performance on targeted training objectives.

ABOUT THE AUTHORS

David Jones is a Senior Research Associate at Design Interactive Inc., with extensive experience in performing field-based task analyses and training needs analyses in complex domains and designing training and technology solutions to fill gaps found therein. He has developed training guidance for the Navy's Virtual Technologies and Environments program and developed advanced technology integration solutions for DARPA's Augmented Cognition program. He is currently leading an effort to develop a configurable training environment to train Combat Medics and Combat Lifesavers on the applied knowledge and skills required to perform casualty extraction from vehicles. David is also currently leading an effort to develop training system requirements and design solutions for a system that targets essential training needs and special constraints associated with working within the Mine Resistant Ambush Protection (MRAP) Heavy Armored Ground Ambulance (HAGA).

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INTRODUCTION

The number of improvised explosive device (IED) strikes and vehicle accidents within the U.S. Military is currently at unprecedented rates (*Roadside Bombs No. 1 Threat*, 2009). This has led to an increased interest in training to ensure that casualties are extracted from disabled vehicles without exacerbating existing injuries. A number of variables, such as the position of the vehicle and passengers, the types of injuries incurred, offensive actions taken by the enemy, and potential entry points, complicate the extraction task and require variations in how extraction is performed. Given this, it is crucial that extraction be extensively trained as it may increase the survival rate for both the casualties themselves and the extraction team.

One of the primary goals of simulation training is to provide the opportunity for trainees to practice skills to be learned in an efficient and safe environment. Simulation training also creates realistic training opportunities that would otherwise be impossible to re-create in a safe and realistic manner. These opportunities include the need to train under contextually relevant, high threat, conditions such as those present during war fighting. In the domain of casualty extraction, contextual conditions often present additional challenges not present during extraction under civilian or non-war fighting conditions. For example, civilian rescue efforts emphasize the need to stabilize casualties promptly; yet, the continuous enemy threat present in a war-fighting context provides an additional obstacle to the incident's particular extraction challenges.

Vehicle casualty extraction is a particularly challenging training simulation need. Current approaches usually involve working or disabled vehicles that require dismantling during the exercise, and therefore can only be used for simulation once, or those that do not realistically replicate the conditions present during extrication (e.g., jammed doors, collapsed seats). Reusable simulators for casualty extraction training that are capable of reproducing the necessary cues to instill the targeted training knowledge, skills, and abilities (KSAs) for this domain have not yet been designed. Currently, casualty extraction and extrication methods are trained utilizing disabled vehicles that either can be reused, but that lack the realism to train all the tasks, or are destroyed in the process of the training, resulting in one-time use and high levels of recurring cost. The task of training extraction is further complicated by the need to simulate the combat context during training.

This paper presents an effort to develop requirements for a simulation system to support training combat medics and combat lifesavers on the task of extracting casualties from vehicles. First, the process that was followed to create and validate the system requirements is outlined. Next, the results of a training needs analysis are presented. Finally, a conceptual design is described that aims to satisfy the unmet needs of the training community as identified through the needs analysis.

ANALYSIS PROCESS

In order to develop requirements for a vehicle extraction training system, a contextual task analysis was carried out to define the tasks that were critical to perform during casualty extraction. Following this analysis, a training needs analysis was carried out to determine how each of these tasks are currently trained in the combat lifesaver (CLS) and combat medic advanced skills (CMAST) courses. Finally, the training needs were translated into functional requirements and prioritized.

The first stage of the contextual task analysis consisted of a review of military documentation related to medic and combat life-saver training that included the Combat Medic Advanced Skills Training student reference (Department of Combat Medic Training, 2005), the Combat Lifesaver course student self-study guide (U.S. Army Medical Department Center and School, Edition B), and the Tactical Combat Casualty Care Handbook (Center for Army Lessons Learned, 2006). This portion of the review provided a detailed description of the medical procedures performed by combat medics and combat lifesavers. A review of military vehicle, convoy operations, and MEDEVAC literature was then conducted to obtain an outline of the tasks and procedures that are performed when a vehicle is attacked. As part of this evaluation, the Medical Evacuations in a Theater of Operations TTP Field Manual (U.S. Army Medical Department Center and School, 2000), Convoy Leader Handbook (Military Professional Resources, Inc., 2003), and various vehicle safety documents (e.g., U.S. Army TACOM, 2006) were reviewed. Upon completion of this literature review, instructors for the CLS and CMAST courses were interviewed in order to obtain a deeper understanding of the tasks and training objectives that were essential to target with the training system.

A training needs analysis was carried out with instructors at the Army National Guard Medical Battalion Training Site during a CMAST training event. During this event, students and instructors were observed during the interactive lane training phase. After observation of how students were currently trained to perform the extraction task, follow-up interviews were conducted in order to clarify the most critical training needs of a vehicle extraction training system.

Once training objectives and training needs were outlined, they were then used to drive the development of functional requirements for a vehicle extraction training system. The functional requirements were designed to outline the functions of the system that must be met in order to address the training needs as opposed to a particular method to meet that function (e.g. what needs to be represented as opposed to how to represent it). Developing requirements at this level allows system developers to explore multiple methods to meet the needs of the training community.

ANALYSIS RESULTS

The results of the analysis outlined above allowed researchers to outline the vehicle extraction task and critical training objectives as well as the critical functionality required to meet those needs. The sections below outline the results of each phase of this effort.

Task Analysis Results

The insights gained from this investigation suggest that the vehicle extraction task is performed in five primary stages: planning the extraction/evaluating the scene, gaining entry to the vehicle, prepping the casualty for extraction, exiting the vehicle, and providing care once extracted. In order to design the V-Xtract system, the first four stages were the focus for developing more detailed requirements. Table 1 outlines these critical stages and their associated subtasks.

Table 1. Critical Extraction Stages and Tasks

Stage 1: Planning the extraction/evaluating the scene
Task 1.1: Searching for enemy presence/ providing cover fire
Task 1.2- Searching for IED presence
Task 1.3- Evaluating the position/stability of the vehicle/moving to initial access point
Task 1.4- Determining potential casualty injuries
Stage 2: Gaining Entry to the Vehicle
Task 2.1- Determine if primary doors can be opened
Task 2.2- Disengage combat locks
Task 2.3- Open door
Stage 3: Prepping the Casualty for Extraction
Task 3.1- Release casualty from anything preventing extraction
Task 3.2- Evaluate casualty state and triage
Task 3.3- Treat life threatening injuries
Task 3.4- Provide neck support
Stage 4: Exiting the vehicle
Task 4.1- Attach extraction device
Task 4.2- Selecting door to exit
Task 4.3- Exiting the vehicle

The first stage of the extraction process is the **planning stage.** Prior to extracting a casualty from a vehicle, it is essential to evaluate and secure the scene and plan the extraction to ensure that more injuries are not sustained to the casualty or team during the extraction process. Because many of the situations that require extraction are caused by IEDs and ambushes, this stage of the task requires the team to look for evidence of additional IEDs, any hostile presence, or anything else that may pose a danger to the team. The evaluation then turns to determining the most efficient and safest way to get into the vehicle in order to aid the casualty.

Once the extraction team moves to the vehicle they must **gain entry** prior to extracting the casualty. Although this is generally not a difficult task when doors are not jammed or combat locks activated, when these conditions arise additional steps must be taken to access the casualty. During this process it is critical to continue to be cognizant of enemy threats in the environment and provide cover fire when needed. Once the extraction team gains access to the vehicle, they must evaluate the casualties and triage (if multiple casualties are present), treat life threatening injuries, and release the casualty from anything preventing extraction in order to **prepare the casualty for extraction**. The amount of time that is spent stabilizing casualties within the vehicle versus after extraction is dependent upon a number of conditions that change the urgency of the situation (e.g. enemy fire, fires within the vehicle).

Once life threatening injuries are addressed, casualties can be extracted in order to care for additional injuries. To support this task, extraction devices are sometimes placed on the casualty. The extraction devices can range from belts to specially designed straps. Once they are in place (if used), the team **exits the vehicle** with the casualty, moving them to a safer location to address and stabilize other injuries.

The evaluation further decomposed each task within Table 1 into the specific training KSAs that are essential to target within each task, the critical cues and capabilities that are essential to perform the tasks, and metrics that can be used to measure performance on each task. The training KSAs that were outlined for each task included the following:

- Procedural- The trainee's knowledge of what the fundamental procedures are and how they are performed.
- Perceptual- The trainee's ability to recognize relevant cues in the environment.
- Decision-making- The trainee's ability to evaluate the significance of the cues he detects in the environment and how he responds to them in terms of the effectiveness of the decisions he makes.
- Team Coordination- The physically observable team actions (e.g. effectiveness, fluidity, efficiency).
- Communications- The observation of team performance behaviors through communications (e.g. information exchange, supporting behaviors, initiative, and format of communications, if necessary). In the case of this task, it refers to the whether the trainees communicate at appropriate times, to the appropriate people, with an appropriate message, and transmitted in the appropriate mode. In very few cases are exact words or phrases considered to be necessary as these are normally determined as part of the unit level standard operating procedures.
- Physical Tool Manipulation- How well trainees use all of the tools at their disposal.

Training Needs Analysis Results

The analysis of the current approach to training the extraction task showed that although the process of vehicle extraction is covered in the classroom environment, only a small portion of the skills required to perform the task are practiced during practical applications. During the classes observed, the trainees practiced planning the approach to an overturned junked and gutted HMMWV. During the extraction exercise, all doors were easily opened to gain entry and trainees pulled the casualty within the vehicle to a more covered location. Variations to the process of extraction were practiced through the use of 'junkyard' vehicles to reproduce potential restrictions to extraction that might be experienced in the field. Drawbacks associated with this method include:

- Lack of variation- Once vehicles are put into place they are rarely if ever moved to create variation in training due to the weight of the vehicles.
- Inability to evaluate trainee performance- Current training and evaluation procedures require instructors to rely on a visual evaluation of trainee performance in order to determine their competency level. Because there is very little space inside of the vehicle, instructors cannot see any stabilization care that is provided to casualties within the vehicle, requiring trainees to complete the extraction prior to performing any stabilization if they are to be evaluated on these tasks.
- Potential safety hazards- Junkyard vehicles typically have sharp corners and can be unstable. This inherent instability leads instructors to place them in the most stable positions and leave them there during training. Regardless, there is still the potential for trainee or instructor injury.
- Recurring costs- During the extraction process, some components of the vehicle get cut or bent in order to get the casualty out as quickly as possible (e.g. seatbelts). Once there is too much damage on a vehicle for it to be useful for training it must be replaced with a new vehicle.

Based on the review of the current training and interviews with instructors, the following three critical training gaps need to be addressed with supporting technology:

- Performance evaluation support
- Training management support
- Reconfigurable and reusable vehicle

Functional Requirements

Although functional requirements were also outlined for the performance evaluation tool and training management tool, the requirements presented here are focused on the functional requirements for a reconfigurable and reusable extraction trainer vehicle. Table 2 provides a prioritized list of the functionalities that are required to target the training objectives and tasks associated with vehicle extraction. This table separates the functionality into three tiers of requirements based on the importance of each type of functionality and how often instructors are expected to utilize the functionality. The following is a summary of the functionality that falls within the first two tiers of criticality:

Vehicle Shell and Simulation Support- The core component of the system should be a reconfigurable simulator shell that is representative of a vehicle that trainees would extract from in theater. The system must have the capability to be positioned and stabilized on four wheels, on either side, or on the roof.

Cameras/Recording Capability- Due to the limited amount of space inside of the vehicle, it is difficult for instructors to observe trainees while performing tasks after entry. To provide them with the capability to observe and evaluate performance microphones and video cameras should be integrated into the vehicle at multiple key locations.

Enemy Fire Audio- In order to provide trainees with operationally relevant conditions during training, it is necessary to allow for the presence of enemy fire and for the configuration of such fire from different directions and for changes in direction throughout the training exercise. This will allow for training of the decision making required for reassessment of the exit side of a vehicle, after having entered the vehicle. To support this need a spatialized audio system is essential.

Movable Ammo Boxes/ Storage Containers- Containers such as ammo boxes get shuffled and jammed into positions that obstruct the available space to perform extraction tasks when vehicles roll over. It is important to train on how to work around these obstacles and adjust extraction plans based on their presence within the vehicle. It is essential that ammo boxes and containers can be moved and locked into place throughout the vehicle.

Table 2. Prioritized Functionality List

	Importance/ Urgency	Expected Utilization	Cost*
Simulator Shell[2]	10	10	H
Simulator Support[2]	10	10	H
Cameras/ Recording Capabilities	10	10	M
Enemy Fire Audio	9	10	L
Movable Ammo Boxes / Storage Containers	9	10	L
Restraint Systems	9	10	L
Combat Locks Operation	9	10	L-M
Weather Resistance Requirements	9	9	L
Vehicle Positioning/ Rotation	8	10	H
Communication Systems	8	9	L
Fire Representation	8	8	L
Vehicle Stress / Immersion Cues	7	10	L-M
Gunner Hatch / Roof hatches	7	7	M
Vehicle Trapping Functionality	7	6	L
Exterior Vehicle Skins (Decals)	6	10	L
Door Operation Simulation	6	7	L
Lighting	6	5	L
Visual Enemy Fire Representation	6	5	L-M
Repositionable Dividers	5	7	L
Vehicle Instability	4	4	M-H
Vehicle Seating & Position	4	3	L
Door Prying Capability	3	5	L-M
D-Ring Release Capability	3	2	M-H
Exterior Vehicle Skins (Panels)	2	3	M
Fire Suppression	2	1	
MILES Responsive Enemy Fire	2	1	H
Vehicle Headsets	1	2	L

* Low cost: <$500; Medium cost: $500-$5000; High cost: >$5000

Restraint Systems- Overcoming restraint systems is a critical component of the rescuer's efforts. Seatbelts allow trainees the ability to train to overcome challenges faced during operational conditions such as jammed buckles or hard to reach buckles that require that the seat belt be cut in order to extract the casualty. Two types of restraint configurations should be provided: five point and chest-lap belt. Toggling between the two types of restraints should be allowed as needed. The belts should offer the capability to be cut or simulate cutting and they shall incorporate a reusable mechanism that allows quick reuse if they are cut.

Combat Lock Operations- The vehicle must contain combat locks that behave like the real combat locks in an operational vehicle as this is a key component of the task trainees will have to overcome in an operational environment. The visual form and steps required to deactivate the locks should resemble the real combat locks currently found on the HMMWV.

Weather Resistance Requirements- It is expected that the vehicle and all components will be stored outside and allow for training under all weather conditions. Further, the use of simulated blood and other bodily fluids deemed necessary to the training would require that the interior of the vehicle can be sprayed off. This capability requires that all components are designed to resist the effects of weather.

Vehicle Positioning/Rotation- In order to provide a variety of training conditions it should be possible to position the vehicle along two axes (roll and yaw). This allows for a variety of vehicle positions to represent the possible vehicle resting situations. The vehicle shall be capable of being adjusted into positions such that it can face in any direction along the yaw axis (360 degrees) and rotated along its roll axis at four discrete positions (normal driving position, upside down (top down), or resting on its left or right sides) and locked into place at these positions.

Communication Systems- Communication stacks can be present between the two front seats in the vehicle. This is an obstacle that must be avoided when present and can provide the trainee with updates of the situation outside of the vehicle. Communication gear must be removable or able to be locked into place and should be operational with real-time updates of the outside situation or a recorded scenario of communications.

Fire Representation- During extraction, the presence of fire creates a sense of haste to the operation as well as causing the task to become more difficult due to visual occlusion. The visual appearance and smell of smoke and burning plastic/metal should be reproduced both inside and outside of the vehicle.

Vehicle Stress/Immersion Cues- In addition to the smell of smoke, the smell of various types of ordnances, gas, and other chemicals being carried will create a more immersive environment and allow the trainee to train under a condition that is expected in the real world. To support this, the training system shall contain an odor simulator that will produce various odors and include a quiet ventilation system that restricts the smells (and any smoke produced) to the inside of the vehicle.

Gunners Hatch/Roof Hatches: In addition to allowing the capability to practice extraction through each of the doors and vehicle exits, it will also be possible to practice this task using the gunner and access hatches that are present in some of the military vehicles in use today (e.g., MRAP). Each of these hatches will be capable of being set to a “Not Present” position (inaccessible and not visually present) and open to provide training variation.

Vehicle Trapping Functionality- It is necessary to simulate the trapping of casualties by components within the vehicle (i.e., steering column, seats), to allow training on the techniques and procedures used when extracting casualties trapped by these components. To meet this need, it should be possible to simulate damage on the interior of the vehicle that results in the trapping of casualties’ bodies.

Exterior Vehicle Skins (Decals)- In order to allow trainees to practice missions under a variety of conditions it is essential to present different forms of damage to them to react to. Decals can be used to represent a damaged state at the following sectors of the vehicle: front left and right quarters, rear left and right sides, center left and right sides, and roof panel. All decals should be removable and repositionable.

Door Operation Simulation- It shall be possible to simulate different types/weights of doors as well as responses to environmental forces (i.e., wind) while ensuring that trainees are not seriously injured by a slamming door. The door mechanism should prevent the door from injuring the trainee. The door mechanism should allow for different weights/characteristics of doors to be simulated without adding to the weight to the door. It shall also be possible to add panels to make the door look accurate in regards to the simulated characteristics (i.e., up-armored panels.)

Lighting- Various colored lighting (red and white) is used within vehicles under low light conditions. It is important to provide these lights to add to the realism of training in low light conditions. In addition, by providing soft blue lighting in the vehicle, night conditions can be simulated. Lighting will be integrated into both the front and rear compartments of the vehicle that can be controlled via a wireless controller.

Visual Enemy Fire Representation- Although audio is the primary means used to determine that shots are being fired and where they are being fired from, visual representations of rounds hitting a vehicle can provide critical information. The visual representation of a round fired at the vehicle should be present and controlled remotely.

Repositionable Dividers- To allow training on multiple variations of vehicles, it is necessary to add and move divider panels to adjust the space that is available and accessibility between the front and rear cabin of the vehicle. To meet this need the system shall have removable panels that can be fastened into position to adjust the space within the compartments of the vehicle.

In addition to outlining the requirements presented above, the following aspects of the functionality were also defined:

- **Purpose**- The underlying reason that the functionality is required within the vehicle.
- **Functionality**- The high level functionality that is to be designed.
- **Assumptions and Constraints**- Any conditions or limitations that are expected within the training environment or that should otherwise be placed on the design of the functionality.
- **Design Parameters**- The requirements that the functionality must meet.
- **Non-functional Requirements**- Requirements associated with aspects of the design that aren't essential to operation (e.g., color).
- **Example**- One or multiple potential uses for the functionality.
- **Safety Concerns**- Any aspects of the system that could affect overall system safety.

Targeted Solution

In order to meet the needs outlined in this document, a reconfigurable vehicle extraction training system is being designed. Although the Virtual Casualty EXTRACTion Training System (V-Xtract) is being designed to include the performance evaluation and training management support capability deemed critical by the training needs analysis, the following are descriptions of examples of the functionality that is being designed into the reconfigurable vehicle system component to meet training needs.

Reconfigurable/Repositionable Vehicle Format

As one of the core deficiencies with the current approach to training lies within the inability to adjust training scenarios that are represented by the vehicle, V-Xtract includes a reconfigurable/repositionable vehicle that utilizes a lightweight vehicle shell that can be pushed and towed into position, rotated to stand on all four wheels, on either side, or the roof, and stabilized. Figure 1 demonstrates how the rotational component will connect to the vehicle frame to allow for stabilized and safe training in any of these vehicle positions. By allowing the system to be rotated and moved into position by one or two instructors, manning requirements for the training facility are not increased.

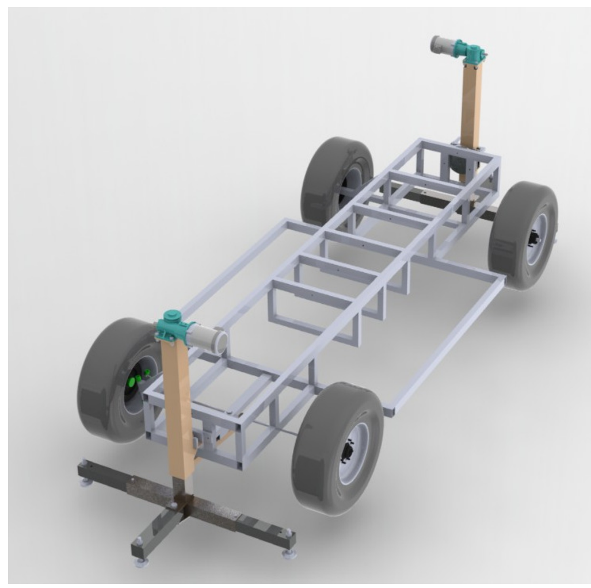

Figure 1. Rotational/Stability System

Reconfigurable Roof and Door Access

Because instructors were interested in **training extractions from a variety of vehicles**, methods to simulate a variety of vehicle formats have been developed. Although the exterior form of the vehicle will look like a HMMWV shell, the doors and roof access will be configurable to represent different vehicles. For example, the door hinges will be adjustable to simulate the weight of normal doors or the weight of uparmored doors. Likewise, the roof will have a single access point that can be adjusted to represent a gunner's hatch with or without the GPK installed, a MRAP exit hatch, or no roof access at all (see Figure 2).

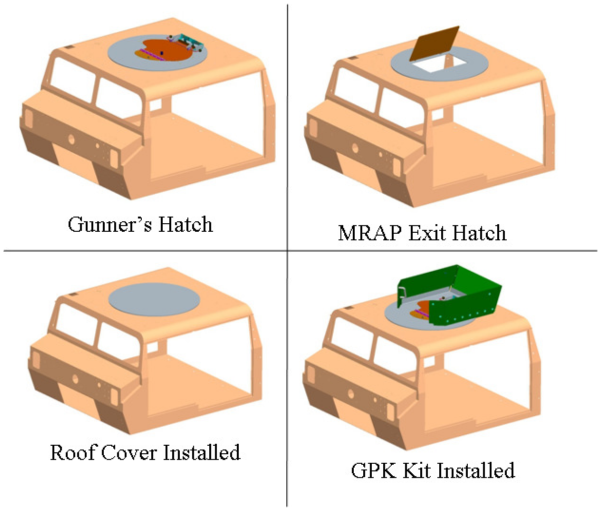

Figure 2. Reconfigurable Roof Hatch Design

Reconfigurable/Reusable Seat Restraints

The interior of the vehicle is also being designed to meet the critical need of **creating training variation**. An example of the flexibility designed into the system that supports this need as well as the need to **reduce recurring system use cost** is the restraint system design. As Figure 3 shows, the seat restraint system is designed with a buckle system that connects the belt system to the seat. This approach allows a single instructor to quickly change between a 5 point harness to a chest and lap belt system between scenarios. In addition, to reduce the recurring cost of the system, the belts are being designed with sections of the belt that can be cut and quickly replaced. By developing this system with replaceable 'cutable' sections, the amount of seatbelt that must be replaced between scenarios is reduced, reducing the recurring cost of the system.

Figure 3. Reconfigurable Seat Restraint Design

Although these examples show a limited number of the functionalities that are designed into the V-Xtract system to meet the functional requirements and training needs, they demonstrate the need for a thorough understanding of the problem space to drive simulation and training development.

Conclusion and Future Development

This paper outlines an approach for developing functional requirements for simulation and training systems. The approach goes beyond the traditional task analysis by merging the results with a training needs analysis and working closely with the target training population to determine where training gaps exist and what their high priority needs are. Although the process presented is scoped in the domain of developing a physical training system to train casualty extraction from vehicles, the approach is applicable across a variety of domains. Each stage of the process extracts information that is not gleaned directly from the other stages and ultimately leads to thorough guidelines that can be presented to system designers to drive concept development.

The V-Xtract training system presented in this example is currently being developed in a two-stage approach. Using the prioritization presented in Table 2, a Tier I system is being tested and validated that integrates the highest priority functionalities. Concept designs for the Tier II functionality are currently being developed based on the functional requirements outlined herein and development of that functionality will be integrated into the system and evaluated with instructors in the following year.

ACKNOWLEDGEMENTS

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