Abstract
Training warfighters requires the establishment, enhancement, and assessment of decision making (DM) skills at various levels. This review seeks to identify DM training technologies at the tactical and operational levels of war. Simulation based training (SBT) provides learning experiences for improved cognitive abilities and retention of complex skills. Here, seven SBTs will be evaluated for their situational awareness (SA) training abilities for decision making. Valuation of the included SBTs examine the modifiability (scenario customization), data availability (physiological and behavioral), assessment methods (feedback and after action reviews), validity (team training), and fidelity (2D or 3D environments) for tactical and operational warfighter training.

Keywords
Simulation training, decision making, levels of war, tactical, operational, feedback, team training, warfighter, NDM, Naturalistic Decision Making, SA, Situational Awareness, leadership training, situational fidelity, cognitive realism, physiological data, behavioral data, cognitive data, 3D, Steel Beast Professional, Full Spectrum Command, Rapid Decision Trainer, SimFX, DC Train, VirtuTrace, EST 2000.

Introduction
Complex skills required for various civilian and military professions (e.g., soldiers, firefighters, police officers, nurses, and pilots) cannot be learned and mastered via books and lectures alone. Skills, such as decision making (DM) often require a substantial amount of training and practice (Peeters, Van Den Bosch, Meyer, & Neerincx, 2014). Simulation based training (SBT) can enhance such skills, allowing trainees the opportunity to develop decision-making skills needed to perform in harsh and complex environments (Astwood et al., 2008). In comparison with on-the-job training, simulated environments can 1) alleviate risk and danger involved by confining them within a safe environment, and 2) increase the complexity of the learning task while offering enhanced support throughout the course of training (Bohil, Alicea, & Biocca, 2011).

Research for decision making training garners interest from different branches of the military (e.g. Marines, Air Force, Army) for a variety of training goals such as leadership, communication, or crisis management (Zsambok & Klien 2014). However, in modeling military decision making for optimal training and performance, challenges become evident when faced with the task of applying DM for SBT selection.
In an attempt to address these challenges, this literature review aims to evaluate DM training via SBT by addressing their level of war training, existing research pertaining to decision making training abilities, and their embedded training characteristics. Additional evaluation was conducted to correlate characteristics of SBTs that have research providing evidence in support of successful decision making training. A comparison of research and commonly referenced simulator characteristics assisted in the provision of recommendations and considerations for the identification of relevant criteria for warfighter DM training.

Background

Warfighting’s demands on DM
Decisions are inherently bound by context. Consequently, to understand what unique SBT needs are placed on systems to address warfighter DM, we must start with a working understanding of the population itself and the phenomenon under study.

“Warfighter” describes personnel under the employ of the United States Military. Just as understanding the cognitive and behavior demands of any person requires some understanding of the tasks in which that person engages, understanding the responsibilities and tasks for training warfighters requires an understanding of warfare. The U.S. Joint Chief of Staff (2002) categorizes war into three levels: 1) tactical, 2) operational, and 3) strategic. The tactical level of war requires training for decisions that directly influence activities on the battlefield (Covell, 1996). In this review, SBTs categorized as those that train for tactical levels of war focus on combat elements such as shooting accuracy or SBTs that put the trainee in “boots on the ground” scenarios to accomplish combat objectives. Tactical decision making training SBTs are effective for individual and team training, require high levels of environmental awareness, and seek to enhance physical and perceptual cognitive skills (Schmorrow, 1998). Training for the operational level of war aims for decision making concerning the implementation and execution of operational campaigns to accomplish strategic goals. The operational level of war involves understanding tactical capabilities and resources as well as communicating with superiors and subordinates (U.S. Joint Chief of Staff, 2002). Oftentimes, operational warfare requires leaders to use tactical understanding to communicate and command for crisis mitigation or ensure the success of strategic visions (Covell, 1996; Sniezek et al., 2002).

Researchers in DM have attended, primarily, to the challenges of tactical and operational behaviors, working to untangle the role of human intelligence, biases, and cognitive vulnerabilities in complex and dynamic contexts. In 1989, military and commercial interest concerning decision makers’ evaluation and response to scenarios in natural (rather than laboratory) settings sparked a wave of reformed DM research. Acknowledging that DM is more than contextual choices, but also affected by experiences of the decision-maker, Naturalistic Decision Making (NDM) moved from measuring novice decision makers’ use of options to examining expert decision makers’ feedback and experience based process within an environment (Zsambok & Klein, 2014). NDM researchers structured studies with Army small unit leaders, Navy commanders, along with other occupations which require decision making in novel, information rich environments. Results indicated experts used preexisting schemas to
comprehend for existing situations. Experienced decision makers’ ability to categorize a novel situation based on previous experience helped them to quickly infer the course of action required to influence a course of events (Klein, 2008).

An ancillary to NDM, situational awareness or situational assessment (SA) involves understanding how processing the environment influences the ability to see the short and long term consequences of decisions (Cuevas, 2000). SA seems to happen instantaneously, however the strength in SA foundation skills increases with experience (Randel, Pugh, & Reed, 1996). Defined by three levels, SA involves 1) perceiving the elements in the environment, 2) comprehending the current situation, and 3) projecting the future status of the situation (Loukkala & Virrantaus, 2014). This review will evaluate SBTs’ DM training capabilities in terms of environmental presentation for the SA required to perceive the environment and comprehend situations, and the presentation of choice of action.

Although operational and tactical decision making are fundamentally similar, nuances regarding the roles of trainees requires consideration for training. Both levels of war require training for all three stages of SA. However, the difference in tasks required of operational and tactical warfighters may cause shifts between the three stages of SA training.

With operational decision makers in directional roles, the stimuli must correspond with the training objectives. That is, operational leaders must learn how to use limited resources and find direction in unclear situations (Covell, 1996). Optimal operational training places importance on scenario comprehension (level 2) and future status projection (level 3) of SA.

Tactical warfighters set aside analytical thought to make quick judgments on the battlefield based on previous experiences. If the battlefield presents a truly novel situation, then the tactical warfighter will acquire more information through the environment or communicating with teammates, subordinates, or superiors in order to obtain or maintain power over enemy combatants (Milano, 1991). Tactical training emphasizes SA perception (level 1) and comprehension (level 2).

In the scope of DM and applying DM models to a selection of SBTs, the present work aims to study the influence of input on the decision making process of a trainee.

Methodology

Design
A systematic literature review focused on DM skills training specific to the military. To contextualize SBT considerations, the following section reviews DM theories and approaches as they apply to warfighter training.

Search Methods
ProQuest, Ebscohost, and Defense Technical Information Center provided empirical research and articles of commonly used and analyzed simulation training technologies. Simulators with the largest amount of recent (within 5 years) research associated within the decision making domain were considered for review of embedded training characteristics.
Search Outcomes
The researchers located 523 references reporting studies on decision making simulators. Primary and secondary studies were included upon meeting selection. A full review of 62 papers and consideration of 29 simulators led to the inclusion of 7 decision making simulators. All simulators contained empirical research regarding decision making in at least one of these scopes: perceptual skills, situational awareness (SA), or Naturalistic Decision Making (NDM); additionally, simulators must have evaluated at least two of the characteristics in reference to the aforementioned decision making domain.

Comparative articles (i.e., articles that compared or contrasted multiple SBTs) provided limited insight regarding the challenges of fitting SBT solutions to DM training needs. These comparative studies were limited by two factors. First, the number of SBTs under consideration was limited to no more than 3 systems. Second, the authors restricted comparisons to systems used within isolated domains. For example, Sniezek, Wilkins, Wadlington, and Baumann (2002) offered a comparison between three CBT DM simulators used for military “boots on the ground” training.

Though the limited-number and limited-domain studies provide some insight regarding the features and efficacy of DM SBT solutions, they may contribute to certain restrictions. Due to this immediate gap, we continued to research DM trainers across domains. Criteria such as research and data supporting DM training efficiency and effectiveness limited the inclusion of trainers. Additionally, the SBTs contained at least two of the following characteristics deemed imperative to SBT evaluation: (1) scenario customization capability; (2) ability to capture behavioral data; (4) ability to capture physiological data; (5) feedback capabilities; (6) team training; and (7) 3D environment—all to elicit best practices/recommendations, design considerations, and gaps/limitations across trainers.

Aim
Evaluating operational and tactical decision trainers requires a regard for the training potential of an SBT in reference to two different types of DM skills: technical (tactical) skills and non-technical (assessment) skills. The assessment of empirical research on effective decision making training tools, technologies, and techniques aided in the provision of recommendations, and design considerations.

The following research questions were addressed:
• Is there support for effective DM training in SBTs?
• What are the qualities of the effective SBTs that created relevant training scenarios?
• What are the embedded characteristics of the effective DM training simulators?
• What are the distinctive techniques associated with successful DM training?
• Can these scenario qualities, embedded characteristics, and training techniques be generalized across different levels of modern warfare?
• How can this knowledge help to guide the selection process of SBTs for decision making?
Decision Making (DM) SBT Characteristics

SBTs provide opportunities to manipulate trainees’ environments and use various instructional strategies for successful decision making training. There are many different ways a simulator can be evaluated. This review will assess tactical and operational SBTs based on four of Oswald’s (1993) characteristics for the evaluation of simulator effectiveness. Table 1 summarizes the characteristics.

Table 1: Simulation Based Training (SBT) Characteristics Summaries

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario Customization</td>
<td>The ability to modify, customize, and edit a scenario in order to address specific trainee goals or specific training tasks</td>
</tr>
<tr>
<td>Capture Behavioral Data</td>
<td>Tracks trainees’ input during the training scenario as evaluative data points</td>
</tr>
<tr>
<td>Capture Physiological Data</td>
<td>An SBT is equipped to record trainees’ arousal levels</td>
</tr>
<tr>
<td>Feedback</td>
<td>Guidance provided to the trainee during the training scenario</td>
</tr>
<tr>
<td>Team Training</td>
<td>An SBT provides simultaneous training or multiplayer capabilities in order for trainees to work together to achieve a common training objective</td>
</tr>
<tr>
<td>3D Environment</td>
<td>High fidelity virtual environment</td>
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Based on Oswald’s Characteristics of Simulator Effectiveness (1993, p.163).

Scenario Customization

Scenario customization is a characteristic that aligns with Oswald’s construct of “Modifiability” (1993, p.163). For the purpose of this review, a distinction will be made between scenario customization and scenario editing. Scenario customization is the degree to which a simulation can be adjusted or changed. A highly customizable SBT can introduce novel features into a training environment or has scenario authorship capabilities; thus, a custom training environment and elements within the environment can be created to meet specific training objectives. Scenario customization offers a broad range of the type and amount, and level of stimuli within a variety of environments. While scenario customization is used to address specific training needs, scenario editing is used to meet training needs. Used frequently for collective tactical trainers, scenario editing offers limited modifiability, usually pertaining to an adjustment of a predetermined range of environmental features and the rate of stimuli.

Kaber, Riley, Endsley, Sheik-Nainar, Tao, & Lampton, (2013) measured dismounted infantry soldiers’ situational awareness (SA) in virtual environments. Trainers tracked differences in SA performance between platoon leaders in flexible virtual training scenarios. The ability to select elements within the training scenario denotes customized training objectives for variation in SA training for combat experiences. Kaber et al. (2013), illustrated that experience among...
participants resulted in significant differences in performance in terms of SA and communication. These results highlight the necessity for training across skill and experience levels in dismounted infantry units. Evidence exists in support of modifiability increasing SA training efficiency for perception, comprehension, and projection skills (Kaber et al., 2013). However, this instance of scenario modification is limited to operational training in order to plan and explain tactical decisions, as well as individualize training to incorporate specific training objectives or customize training scenarios with various skill sets. Scenario modification may not be necessary for some tactical SBTs, such as those used for collectively training lower levels of SA, such as in the EST2000 or the Rapid Decision Trainer (RDT).

**Capture Behavioral Data**
Capturing behavioral and physiological data aligns with Oswalt’s (1993, p.163) characteristic of “Assessability.” Virtual reality and computer based simulation systems offer the opportunity to capture interactive behavioral data. SBTs provide an ideal medium for training decision making. The ability to track poor choices provides opportunity to evaluate the performance of the trainee as well as the efficiency of the training stimuli. Capturing behavioral data for decision-making training is important because trainers can have evidence-based support of their assessment of the process and product of warfighters’ training.

**Capture Physiological Data**
Training for warfighter decision making aims for judgement based decisions rather than emotionally based decisions (Keren et al., 2013a). Physiological data illustrate the efficacy of stress management skills training (SMT) in participants subjected to a warfighting scenario in a 3-D environment (Bernier, Bouchard, Robillard, Morin, & Forget, 2011). Capturing physiological data in SBTs is valuable for showing the level of success in trainees’ emotional regulation training. Capturing physiological data also helps trainers to objectively see if the SBT is sufficiently eliciting the level of arousal required for adequate training (Bernier et al., 2011). To ensure active practice for DM training, the SBT must elicit emotions which compromise a warfighters’ decision making.

**Feedback**
Feedback can be a feature which also can be judged according to Oswalt’s (1993, p. 163) categorization of “Assessability.” In this review, simulators will be evaluated on whether or not they offer feedback as an embedded feature.

For the purpose of this review, After Action Reviews (AARs) and feedback will be distinguished by the timing of the trainer intervention. AARs occur after the training scenario has been completed. Feedback occurs in real time; the trainee receives guidance during the scenario. Feedback capabilities within a simulator are to either provide guidance or to ask probing questions to the trainee to enhance situational awareness for higher training value (Kaber et al., 2013). The use and type of feedback can vary depending on the type of decision making training. Feedback has been shown to increase motivation, reduce performance uncertainties, and help a trainee correct mistakes (Billings, 2012).

**Tactical trainers:** Goldberg and Cannon-Bowers (2015) used the Tactical Combat Casualty Care Simulation to test the effect of feedback on tactical performance. An intelligent tutor embedded within the training simulation assisted the trainee through basic tactical, technical and clinical
skills. Ultimately, feedback increased performance in tactical training (Goldberg and Cannon-Bowers, 2015).

Operational trainers: The use of feedback in operational trainers is seen as a critical element in training for SA (Kaber et al., 2013). However, the level and type of feedback varies depending on the type of decision making task as well as the experience of the trainee. Different levels of expertise require different types of feedback.

Feedback that focuses on lower level tasks are best suited for the obtainment of decision making skills. As the trainee’s skill increases, feedback regarding the task performance is most appropriate (Sniezek et al., 2002).

Team Training
Team training can be evaluated using Oswalt’s (1993, p.163) characteristic of “Validity”. For certain tactical and operational warfighter training scenarios, effective communication and leadership are critical outcomes. Team training requires decision making in the midst of differing roles, expectations, and experiences. Team situational awareness requires consideration of awareness on both an individual and team level (Cuevas, 2011).

Team training increases a SBT’s validity if warfighter decision making occurs on a tactical level as a member of a team, or on an operational level as a strategist.

Team training for tactical decision making results in fast, efficient decision making as well as increased confidence and improved communication skills (Crichton, 2000). Tactical team decision training focuses on the trainee’s awareness of their role in the team, and the resources available (equipment).

Situational awareness for team training at an operational level requires the leader to perform in reference to the task, environment, equipment, maintenance of shared team situational awareness, and prediction of decision outcomes (Matthews, Strater & Endsley, 2004; Salas, Cannon-Bowers, & Johnston, 1997).

3D Environment
Assessing SBTs using Oswalt’s (1993, p.163) characteristic of “Fidelity, Resolution, or Level of Detail,” it is noted that high fidelity terrain renderings are an essential quality for tactical training simulations.

In a study conducted by Ashraf, Collins, Whelan, O'Sullivan and Balfe (2015), a 3-D environment resulted in participants becoming proficient at performing surgical tasks more quickly than participants trained in a 2-D environment. Although the tasks involved with the surgical skill training are dissimilar to the warfighter decision making training, Ashraf and colleagues’ study supports the notion of environmental fidelity enhancing training. However, the environmental fidelity requirements for the acquisition of rote perceptible skills (such as surgical task training) differs from the requirements for operational DM training.

Task distinction and 3D environment representation led Tittle, Woods, Roesler, Howard, and Phillips, (2001) to propose that a poorly designed 3D training scenario creates lower training efficiency than a 2D environment. However, 3D displays are superior to 2D displays for training to distinguish object properties or simulating real-world environments that trainees must navigate.
(Tittle, Woods, Roesler, Howard, & Phillips, 2001). Figure 1 illustrates navigation in a 3D training environment in one of the featured virtual reality (VR) simulators, VirtuTrace.

![Figure 1. Trainee navigating a smoky home in the VR simulator, VirtuTrace. Image used with permission from N. Keren.](image)

Ultimately, simulators must present information and events appropriate for the level of SA required for training. An appropriate level of SA results in training scenarios that influence a trainee’s perceptions and actions.

**Simulation Platforms for Decision Making Training**
The evaluated technologies have been categorized into two main groups: 1) computer-based decision-making simulations, and 2) virtual training environments. Both groups provide environments in which users can move around and/or use additional physical peripheral devices. The following simulators were included because their training capacities were supported by data-driven sources and referenced to characteristics established earlier in the review. Excluded simulators were either not data driven or data supported, or did not include commonly used tools.

**Computer-Based Decision Making Simulations**
Many forms of computer-based trainers (CBTs) facilitate learning (Sniezek et al., 2002) and are employed to address insufficiencies associated with conventional training (i.e., time for training, cost, and training transfer). This section contains detailed summaries of several relevant CBTs currently used for SA development and training for warfighter decision making. From the literature, we can leverage current system design, tools, and considerations for choosing decision-making SBTs.
Steel Beast Professional
Steel Beast Professional (SB Pro) trains modern armored warfare scenarios at the company team level and below. SB Pros are tactical tank simulators used for combined arms training. Simulation training for combined arms tactics requires team decision making for maneuvering armored vehicles as well as choice of artillery. A realistic 3D environment provides an environment for optimal SA tactical training. SB Pro trainees navigate terrain within a theater of operation to accomplish tactical objectives and distinguish the location of camouflaged enemies. Customizable scenarios, roles, and maps create an innumerable variety of missions and scenarios to enhance training on the team or individual level (Shoemaker, 2003).

Figure 2. SB Pro urban environment. Image used with permission from N. Hinrichsen.

Conducted over a network with combinations of cooperative and competitive styles of play, missions and scenarios include multi-players in a single tank, multiple tanks, and helicopters. As combined arms tactical trainers, SB Pro enables team training for the lower ranks (House, 1985).

SB Pro trainees receive minimal instructor feedback and guidance during training, increasing the lack of situational clarity required for NDM training. This results in trainees relying on communication with teammates during the training scenario. The creation of shared mental models through narration amongst teammates enhances team SA (Durso & Gronlund, 1999). Figures 3 and 4 show the environmental level of detail for different trainee roles in a team training scenario.
SB Pro records the speed that a user acquires and hits set targets, how many targets the user hits, and how many shots are taken, providing data for AARs (Shoemaker, 2003).

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**Full Spectrum Command (FSC)**

This computer-based simulation models the command and control of a U.S. Army light infantry company in military operations in urban terrain (MOUT) environments. As a company commander, trainees engage in scenarios designed to develop operational skills; such as incorporation of both tactics and strategy, and resource management.

Situated in Eastern Europe, scenarios incorporate asymmetric threats and are focused on peacekeeping. The player in FSC initiates action and begins observing and responding to emerging issues portrayed in a simulated battlefield. Responses to emerging battlefield conditions occur in real time. For leadership training, the maintenance of SA and effective real-time decision making are imperative to unit success (Johnson, Pleban, & Tucker, 2009).

 Portions of behavioral data from the missions are available for replay (Beal & Christ, 2004). FSC’s behavioral data capture, and feedback provided valuable decision making training experiences for both officers and students (Beal & Christ, 2004).

**Rapid Decision-Trainer (RDT)**

Developed by the Infantry Officer Basic Course (IOBC), the Rapid Decision Trainer (RDT) is a first person, tactical trainer for platoon leaders to train for live fire exercises (LFXs). RTD provides lieutenants with the opportunity to serve as a platoon leader for the specific training objectives of rehearsal of combat activities, and training for live-fire exercises (LFX). RDT contains an assessment engine to provide an evaluation of performance during key decision making points (Pike, Anschuetz, Jones, & Wansbury, 2005). RDT offers feedback capabilities and captures behavioral data. Previous research found a positive impact between training and performance during real LFXs (Beal & Christ 2005; Pike et al., 2005).

For optimal training, NDM training requires poorly defined goals. However, Beal’s (2005) research showed that games oriented towards specific goals received high ratings of perceived efficacy. This does not coincide with NDM training which values uncertainty in both problem structure and the environment (Randel et al., 1996). Infantry leader reported increase training value when qualified instructors were present to offer feedback during mission execution and detailed after action reviews following training exercises, as opposed to using the game as a stand-alone trainer.

Performance tracking has been shown to be an important element for trainers that are developed and adapted to address explicit training needs (Beal, 2005). To aid instructors' efforts to assess the lieutenants' RDT performance, the game automatically tracks the critical tasks that lieutenants initiate during their missions, and then provides instructors with results of lieutenants' task performance during an assessment phase at the conclusion of each mission (Beal, 2005). However in Beal’s (2005) report, although the use of specific events and tasks embedded in the trainer allowed for easy assessment at critical points in performance, instructors noted a weakness in RDT’s lack of modifiability.
RDT was included in the review to demonstrate differences in design considerations for a basic

tactical trainer for the first level of SA (perception). Although RDT offers realistic 3D battlefield

environment, which presented events and actions that were adequate for training (Beal and

Christ, 2005), leaders reported that for this type of tactical trainer, training value does not

increase with higher level of graphical detail (Beal, 2005). This subjective report did not coincide

with Ashraf et al. (2015) who recently suggested that high fidelity is required for tactical

training. This could be because RDT does not train for tactical decision making, but rather

training for perceptual cognitive skills associated with decision making. The RDT provides a

good example of a tactical trainer that works on the first level of SA and will be a good basis for

comparison with higher-level SA SBTs later in the review.

**SimFX**

Designed to evaluate training potential of computer based simulations of dismounted infantry

operations (Archer, Brockett, McDermott, Warwick, & Christ, 2006; Beal & Christ, 2004, 2005;

Beal, 2005; Centric, Beal & Christ, 2005) Simulated Field Exercise (SimFX) uses cognitive

realism for training rapid DM of small unit leaders in contemporary operational environments

(COE).

SimFX uses cognitive realism training, replacing high fidelity desktop simulators with low

fidelity, text-based simulation. Rather than attempting immersive virtual environments, this

outcome-driven simulation engages trainees with branching story-lines. Trainees engage in the

simulation by selecting choices presented in dialogue box series. Successive dialogue boxes

(scenarios and choices) are designed in real time by an author.

The simulation trains for decision making to accomplish operations in a low-fidelity 2-D

environment. A trainer builds and modifies scenarios to present the trainee with a series of

dialogue boxes containing key decision points designed towards a training objective (Archer et

al., 2006). The decision dialog window and a map display show the current situation the player

must react to and provides a set of alternative courses of actions to take.

SimFX uses deliberate practice to enhance SA, which repeatedly presents players with a stand-

alone decision, while offering different information accompanying each decision made. SimFX

offers feedback along the way, with an explanation of relevant cues used (Archer et al., 2006). Ideal

for SA awareness training, Sim FX’s recordable and replayable features along with real
time training capabilities ensures immediate process-oriented feedback (Johnson et al., 2009).

SimFX research emphasized the need to incorporate scenarios able to fluctuate in complexity.

Fluctuation in levels of complexity is a characteristic imperative in ensuring proper development

decision making across all experience levels.

Johnson, Pleban, and Tucker (2009) examined SimFX’s effect on SA and adaptive DM and

concluded that there are positive training effects of SimFX on small unit leaders’ situational

awareness. Moreover, the study found training strategies using formative feedback following

each decision improved participants’ decision making (compared to the control group, no

formative feedback) (Johnson et al., 2009). The use of a low fidelity trainer illustrated an

alternative approach to DM training through scenario authoring and the incorporation of subtle
cues. This approach successfully enhanced SA for decision making through cognitive realism rather than environmental realism (Beal, 2007).

**DC-Train**
In the role of a Damage Control Assistant (DCA) for a ship, trainees coordinate crisis management efforts at the operational level, which involves situational awareness for leading crews, allocating resources and formulating plans to address the crisis (Bulitko & Wilkins, 1999).

Although experts perform more quickly and accurately in situational assessment than novices, managing crisis situations is a challenge as both novices and experts often experience difficulty making decisions due to ambiguous environments and unknown conditions (Sneizek et al., 2002).

Using SBTs for maintenance of skill for experts and acquisition for novices requires different training scenarios (Sniezek et al., 2002). DC-Train comes equipped with a scenario generator module for the specification of crisis scenarios by both instructor and student (Grois, Hsu, Voloshin & Wilkins, 1998; Sneizek et al., 2002). Adjusting scenarios for NDM training in crisis situations is important for adjusting training experiences for a range of trainees. Experts require less time to assess the situation and experience less stress than a novice when challenged with a crisis situation (Lipshitz & Strauss, 1997). Adjusting scenarios based on the expertise of a trainee allows for better rounded training for operational decisions.

Additionally, DC-Train is equipped with a feedback and AAR system. The feedback system offers prompt and specific communication with the trainee and judges the “correctness” of a trainee’s decision given the presented alternatives. Sneizek and colleagues (2002) tested DC-Train through the assessment of trainees (via ratings) of subjective difficulty, subjective time pressure, and expended effort. Results from empirical evaluations of training effectiveness indicated DC Train provides realism and improves decision-making performance. These capabilities address challenges problematic in training crisis decision making skills, allowing the researchers to pull best practices and recommendations for future DM trainers.

**Virtual Reality Simulators**
In order to offer a valid survey of simulators that train DM skills, the review included virtual and immersive environments for military and other domains.

Virtual Reality (VR) has been shown to assist in the development of DM skills under stress and time constraints as well as the enhancement of SA awareness (Lampton, et al., 2006; see also Pleban, Eakin, Salter, & Matthews, 2001; Tichon, Wallis, & Mildred, 2006). The following simulators met the inclusion criteria and provided enough material to elicit practical recommendations for future users, developers, and consumers.

**VirtuTrace**
VirtuTrace trains and evaluates fire fighters’ naturalistic decision making (NDM). VirtuTrace was included in this review because it is a virtual reality trainer that gathers physiological and
behavioral data. Although VirtuTrace is out of the warfighting domain, it was included due to the fact that there has been extensive NDM research, which can aide in the formulation considerations for SBT DM design.

A highlight of VirtuTrace is the amount and nature of trainee data capture during training scenarios which aim to elicit stress using a three-dimensional, eight channel, surround sound system and a motion-based navigation system allowing physical movement virtual scenarios (Keren, et al., 2013b).

Physiological data is collected through blood pressure sensors, heart rate, ECG, cardiac output, respiration rate, and galvanic skin response. A decision matrix presented to the firefighters progresses the training scenario and also provides behavioral data for later review. The behavioral data captured includes the sequence, amount, timing, and final decision of trainees (Keren, 2013b). The behavioral and physiological data is then integrated into a “property map” with the previously collected data generated throughout the simulation to populate an AAR program. The inclusion of physiological data is important not only to see if the scenario is eliciting a response in trainees, but also to show evidence of SA training (Randel et al., 1996).

Figure 5. VirtuTrace decision matrix. Image used with permission from N. Keren.

Behavior data collected during the training scenario pertains to 1) the sequence in which participants acquire information; 2) number of items participants view for every alternative along each dimension; 3) the amount of time elapsed from the time the participant began the task until
their choice; 4) when/how long the information rubric had been reviewed; and 5) the final choice (Vidulich, Stratton, Crabtree, & Wilson, 1994). VirtuTrace includes a “post-session analyzer” with “decision portraits” of the participant (Keren et al., 2013b). This collection of behavioral data is important for analyzing SBTs for DM capacities.

**EST2000**

An instrument for the U.S. Army’s small arms training, the Engagement Skills Training 2000 (EST 2000) is a tactical marksmanship trainer, which aides in soldiers’ preparation for live-fire training and qualification attempts. The current three modes of EST 2000 consist of marksmanship, collective, and shoot/don’t shoot. Collective training scenarios cannot be edited, but environmental settings can be adjusted. For marksmanship training, video-based scenarios can be escalated or deescalated and present multiple outcomes (R. Oliver, personal communication, June 1, 2016).

EST 2000 was included because it is a virtual reality tactical trainer with the aim of training for SA at the perception and comprehension levels. The combination of high environmental fidelity for a low SA level tactical trainer was of interest to the review.

![Figure 6. Marksmanship training for the EST 2000. Image used with permission from R. Oliver.](image-url)
Researchers used the EST 2000 to study the decision-making processes involved in cognitive ability and marksmanship, as well as to test the validity of a friend/foe task (Kelley et al., 2011). Kelley and colleagues (2011) used two scenarios for collection: a friend/foe detection task and the standard marksmanship mode of the EST2000. Reaction time, proportion of targets hit, shot of radius from center mass, and root mean square of aim trace on the EST 2000 were used as outcome variables. Additionally, EST 2000 uses embedded sensors to capture physiological data such as trigger pressure and respiration (vertical motion of the weapon) (R. Oliver, personal communication, June 1, 2016).

There is no link between EST 2000 training for NDM or SA (Kelley et al., 2011). But, perceptual motor skills were found to be a predictor of performance (Kelley at al., 2011).

This could be due to the fact that the EST provides the training for perceptual motor skills rather than training that supports the DM process as whole. The implications for perceptual skill training as a component of SA training will be further investigated in Design Considerations.

**Design Considerations**

The findings leveraged from this review provide considerations for the characteristics of SBTs for operational and tactical DM (Table 2).

### Table 2: Simulation Based Training (SBT) Characteristics Checklist

<table>
<thead>
<tr>
<th>Computer-Based Simulators (CBTs)</th>
<th>Tactical</th>
<th>Operational</th>
<th>Scenario Editor</th>
<th>3D Environment</th>
<th>Team Training</th>
<th>Feedback</th>
<th>Physiological Data</th>
<th>Behavioral Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>SB Pro</td>
<td>X</td>
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<td>FSC</td>
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<td>Virtual Reality (VR) Simulators</td>
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**3D Environments**

Since tactical objectives are linked to the lower levels of SA training, they require a realistic rendering of the environment (Ashraf et al., 2015). In this review, the importance of environmental perception training for tactical SBTs is evident. Therefore, it is recommended that all tactical trainers come equipped with 3D environment representation. However, use of 2D displays are still worth consideration. Tittle, Woods, Roesler, Howard, and Phillips (2001) proposed that 2D displays are valuable for tasks related to shape understanding and relative position judgements (such as maps). In Figures 7 and 8, the graphics of SB Pro illustrate the use of 2D displays and 3D displays within a tactical trainer.
Operational trainers that have 3D environment rendering, such as FSC rely heavily on accurate environmental representation in order to train leaders’ SA to make decisions about emerging
battlefield conditions. They are operational-tactical trainers. The priority of SA training for FSC lies in the first two levels of SA. Trainees train to 1) perceive the environment and then 2) comprehend the current situation. FSC requires trainees to respond to emerging issues on the battlefield in real time. This means that training occurs when mental schemas and experience are used to recognize and categorize battlefield conditions for decision making.

The operational trainers that do not use 3D environments do not incorporate tactical decisions into training. True to the operational level of war, reviews of both SimFX and DC Train cite resource management as an important training objective (Archer et al., 2006; Sniezek et al., 2002). Training effectiveness of SimFX is due to the “cognitive realism” rather than environmental realism required for tactical-based trainers (Pleban et al., 2001). DC-train also uses cognitive realism, opting for constructive simulations of ship damage in response to choices selected by the trainee from a graphical interface. The value of the training environments for these operational trainers is not found in the environmental fidelity, but rather the presentation of choice and options. Choice and option presentation will be considered in this recommendation section as well.

*Scenario Customization*

Both the EST2000 and RDT train for LFXs. Trainees perceive the target and then accomplish the task. The issue of automatic performance tracking brings to light the ambiguous area of where in SA decision making occurs. Training for RDT and EST2000 does not progress past the perception training stage of SA because successful performance in the simulators does not require comprehension of the situation. This means that, training does not need to progress to the stage where trainees must access previously established schemas in order to determine long term goals (Sarter & Woods, 1991). Successful training for the EST2000, RDT and LFXs depends on the ability to perceive the environment and use motor skills to execute actions.
Scenario modification is not required for level 1 (perceptual) SA tactical training. These DM trainers would have scenario editing rather than scenario customization capabilities. However, an important consideration is the effectiveness of tactical training from operational trainers with high fidelity environments and tactical measures of performance.

**Situational Clarity and Clarity of Choice**

The higher SA level the decision requires, the greater complexity or uncertainty required for DM training. Ill-structured problems regarding the task and the environment are key elements for NDM (Orasanu & Connolly, 1993; Zsambok & Klein, 2014). These systems provide the opportunity for immersive practice in perception, comprehension, and projection, so trainees can develop the skills necessary for dealing effectively and efficiently with the whole-task decision-making.

As evident in the higher level operational trainers (DC-Train, SimFX), unclear goals is important training quality for the operational task. For DC-Train, operational decision making in crisis scenarios requires “whole-task decision-making.” Lack of clarity of objectives is required for operational DM training, because operational training requires all three levels of situational awareness to support the DM for planning, orchestration and coordination of tactical events to accomplish objectives (United States Air Force Research and Education College of Aerospace, 1997).
SimFX uses scenario authoring to incorporate the subtle cues into unclear environments. The use of environmental cues is important for training and evaluation. Some success has been found for SA training performance in a realistic battlefield test condition by training naive subjects with only task relevant cues in a reduced-stimulus environment (Kass, Herschler & Companion, 1991). Therefore, the choice presentation should have consideration for the skills and the experience of the trainee through solution differentiation, and the appropriateness and intensity of the environmental stimuli (Doherty & Kurz, 1996; Herbig & Glöckner Klein 2009).

**Multiple Player Training Capabilities**

The criticality of team training for a DM SBT relies on the role of additional trainees in the scenario. However, when training for NDM, it is recommended that training be as complex as possible; this includes the incorporation of multiple players (Elrich, Knerr, Lampton, & McDonald, 1997). It is recommended that all DM SBTs incorporate multiple player or team training capabilities. For tactical trainers, the role of a trainee may be a leader or a team member. For SBTs, which train for tactical leadership, such as the SB Pro, team training is imperative. The SB Pro is a combined arms trainer, meaning that players must cooperate with their various tactical capabilities.

![Figure 10. Collective Training for the EST 2000. Image used with permission from R. Oliver.](image)

Cooperative team training requires that team members must learn how to communicate with one another in poorly defined situations, a cornerstone of shared team SA. A multiplayer option for competing SBT trainee roles is also optimal because virtual agents do not reflect the dynamic actions of a human player. For example, in an evaluation of Full Spectrum Command, the
responses of friendly forces were unrealistic, and therefore impacted leaders’ perceived training value of the FSC simulator (Beal and Christ, 2005).

**Feedback**
For NDM training, SBTs should all have an option for a dynamic range of types of feedback. Feedback efficiency is dependent on the experience of the trainee, the complexity of the decisions, and the amount of distracting stimuli in the training scenario (Kluger & DeNisi, 1996).

This review found that differences in trainee’s level of experience as well as differences in training strategy between tactical and operational scenarios are pertinent in choosing the appropriate type of feedback, though optimal feedback is process oriented rather than product oriented (Balzer, Sulusky, Hammer, Summer, 1992; Sniezek et al., 2002).

Evaluation of training for decision-making in operational crisis situations confirmed that outcome is a poor indicator of performance because a negative outcome may not necessarily reflect on the decision-making of the trainee, but rather the extremeness of the situation (Sniezek et al., 2002). Additionally, the function of feedback for crisis training may work best on the front end, such as advising trainees beforehand to prevent negative practice (Sniezek et al., 2002).

Reports of the efficiency of tactical feedback vary. Some studies cite that feedback can be distracting for highly tactical, task-oriented training (Kluger & DeNisi, 1996). Brewster (2002) found that a main advantage of tactical decision exercises is the ability for trainees to receive feedback on their proposed strategies from their peers. Much like feedback methods for crisis simulations, Brewster highlights that the feedback advantage of tactical decision-making exercises lies in the reception of feedback before the decision-making occurs. More importantly, trainees should brief their proposal of a tactical approach in a training simulation (Brewster, 2002).

To ensure efficacy of feedback in both tactical and strategic decision-making training, a critiquing system must focus on process oriented feedback rather than product oriented feedback (Balzer, et al., 1992, Brewster, 2002; Sniezek et al., 2014). However, variables such as the type of decision training and expertise of the critiquing system (expert or peer), and the level of skill of the trainee are important for consideration when evaluating methods of feedback.

The distinguishability between skill acquisition and skill maintenance are two separate competency goals that require different approaches. For example, the effectiveness of feedback is dependent on the level of skill for the task related to the objectives of the simulation and the experience of the trainee. Feedback for initial learning on complex tasks is best when it focuses attention on lower levels of the task. As skill increases, feedback should orient more towards overall task performance (Balzer, et al., 1992, Sniezek, et al., 2002).

It is recommended to differentiate between the tactical and operational levels of war for decision training. This will assist in the determination of an appropriate feedback approach. As well as insurance of the dynamism of a critiquing system through possession of the ability to evaluate
performance and apply the appropriate type of feedback at various levels since detail and style of explanation depends on the experience levels of trainees (Mao and Benbasat, 2000; Snizek et al., 2002). System developers should consider this issue and offer multiple options for feedback inputs (when and how) for specific types of decisions being trained.

Data Capture
Assessment for NDM training requires objective standardized testing and data capture (Ehrlich, et al., 1997). All of the evaluated simulators captured performance data. SB Pro records trainees’ accuracy and attempts, among other data. FSC records parts of a trainee’s mission for replay; DC-Train and VirtuTrace capture performance data points for analysis.

![Figure 11. Capturing behavioral data during a training scenario in VirtuTrace. Image used with permission from N. Keren.](image)

However, trainers are often faced with the issue of assessing trainees’ performance. For example, in a study looking at CBTs, instructors explained difficulties in tracking training performance assessment due to lack of objective performance standards required for effective NDM training. Such performance assessments consist of informal observations by an instructor as trainees participated in simulated tasks (Beal, 2005). Issues occurred due to the difference between instructors, who may offer different levels of coaching and feedback. Additionally, the instructors’ proficiency with the simulated trainer and overall experience with the task being trained can cause challenges in assessing trainees’ performance (Beal, 2005; Sniezek, et al., 2002). Satish and Streufert (2002) advocated that proving SBT efficiency can only progress at the same rate of proving training competency.

Salas and Burke (2002) argued that all simulators should not only offer assessment of performance opportunities, but should capture "moment-to-moment" actions and behaviors.
Handling this issue by applying automatic performance tracking capabilities in decision-making tools mitigates the concern by capturing actions throughout the simulation.

Trainers such as SB Pro and RDT capture a trainee’s performance during critical tasks for later review. Other SBTs, such as DC-Train, capture performance and instead rely on instant feedback and data for tracking trainee progress. The gap between the type and amount of SBT data capture coincides with the aim of training scenarios and the importance of immediate feedback for training. DC-Train requires specialized crisis scenarios, in which simulation performance requires feedback and critiquing as part of the training process; this has been linked to increased quality of decisions (Sniezek, Wilkins & Wadlington, 2001). Since DC-Train and VirtuTrace require instructor facilitation throughout the training experience, they create the undefined environments (Orasanu & Connelley, 1993) required for effective NDM. Therefore, due to the high level of facilitator involvement, data capture for later analysis is ineffective.

VirtuTrace captures physiological data. Capturing physiological data may be of importance for VirtuTrace trainers because it ensures that a high fidelity trainer maintains efficacy eliciting stress responses when training scenarios are altered with scenario customization. Situational awareness training is common for firefighting (Randel et al., 1996). To ensure accurate training for a high fidelity, modifiable, DM simulator, ensuring stress for NDM training is of great importance.

**Decision Making Task Fidelity**

Fidelity is the accurate representation of physical and functional properties of simulations. The selection process of fidelity in decision-making trainers relies upon the corresponding gradation of functional and physical properties of a simulator. A simulation for training is considered to have high fidelity if it evokes the same psychological processes as the scenario it trains for (Sneizek et al., 2002).

The two requirements for NDM training in a simulator are a task factor and a setting factor. As outlined by Orasanu and Connolly (1993), the task factor is that there must be time stress for the decision. The environmental factor is that the situation must have consequences.
Time pressure has been proven to be an effective way to train for DM. The pressure of time is an important factor in the utilization of the Recognition-Primed Decision model (Keren et al., 2013a; Klein, 1998). Therefore, a trainee experiences a high fidelity decision making simulation if the simulation provides repercussions for their choices (Perla and McGrady, 2011).

Tactical fidelity concerns the consequences of planning and conduct of battle and requires environmental consideration to train for perceptual cognitive skills (Schmorrow, 1998). For instance, levels of destruction and civilian casualties have been cited as affecting the combat decisions and actions of military decision-makers (Bohrer and Osiel, 2013). Therefore, correct representation of the physical consequences of operational and tactical decision making accurately reproduces psychological representation of the process’s training objectives. The superiority of functional properties over physical in decision-making simulations has shown to be important for training. An evaluation for leaders that trained on both Full-Spectrum Command and Rapid Decision Trainer reported that training value was based on the accurate representation and practice of tasks rather than realistic graphical depictions (Beal, 2005).
Additionally, fidelity of reactivity requires consideration in operational decision-making training. The continuous debate on the appropriate amount of fidelity generates an array of research and opinions. Some researchers support the notion that higher fidelity in a simulation equals better training (Cantrell, Meakim, & Cash, 2008; Medley & Horne, 2005; Wang, Fitzpatrick, & Petrini, 2012). Alternatively, studies also support the use of low to moderate environmental fidelity simulations such as DC-Train and SimFX showing increased knowledge transfer and skill enhancement (Hoadley, 2009; Johnson, et al., 2009; Kardong-Edgren, Anderson, & Michaels 2007). The importance of this recommendation lies in the assessment of the task relevancy associated with the desired level of training.

**Limitations**

Although warfare involves strategic, operational, and tactical aspects (see Background section, above) this literature review and analysis focused on two of the three: operational and tactical DM trainers. It must be acknowledged that the design needs for strategic behaviors may be markedly different because of the difference in cognitive demands of that area.

**Conclusions**

SBT for decision making aims to depict the situation (environment) as well as provide interactive choices for the appropriate actions of a trainee in order to obtain and demonstrate knowledge. Accurate representation of a training scenario within a SBT does not automatically correspond to a high fidelity training environment. The implications for training NDM and SA for the operational and tactical levels of war have revealed insight in terms of feature modification, performance tracking, choice presentation, metrics of performance, and feedback.

Selecting a simulation for training decision-making involves the evaluating of the choices presented to trainees. Options for choice should reflect the amount, variability, and relevancy of choice. The experience of the trainee influences the speed, and accuracy at which they apply strategies, as well as the type of strategy (Payne, Bettman, & Johnson 1993). Therefore the choice presentation should have consideration for the skills and the experience of the trainee through solution differentiation and correlation of cue usage with cue validities (Doherty & Kurz, 1996; Herbig & Glöckner 2009).

The ability to adjust an SBT based on the experience or progress of a trainee reflects a simulator’s modifiability. Some simulators are highly modifiable, such a VirtuTrace. Other SBTs offer low modifiability (scenario editing), such as EST 2000, offering environmental settings adjustment for collective training, and scenario escalation and multiple outcomes for individual training.

The benefits of modifiable simulations past prototype can be beneficial and important to potential buyers; modifiable features of the simulation reflect dynamism in the role and experience levels of the trainees. The benefit of modifiability lies in a trainer’s ability to modify a trainee’s role, the number of assets, and complexity of the battlefield (Beal and Christ, 2004). The advantages are also in the ability to create a large number of novel scenarios. This is
especially important for operational soldiering skills such as crisis management. As a trainee’s exposure to total number of scenarios and different types of scenarios increases, the trainee’s ability to cope with uncertainty and transfer training to a real crisis improves. Experience managing many kinds of crisis scenarios reduces the chance that an actual crisis will be so novel as to render all training experience irrelevant (Sniezek et al., 2014).

Modifiability in difficulty and adaptability of training requirements and roles ensures value throughout the system’s lifetime. Beal and Christ (2004), in their evaluation of the capabilities of Full Spectrum Command, found discrepancies in training value between their percentage of duty time in assignments above company echelon and below company echelon. Beal and Christ (2004), indicated training value may be dependent upon experience of the trainees and that the difficulty of training scenarios should be adjustable to accommodate the varying skill levels of trainees. Modifiability ensures SBT relevancy as environments, tools, and techniques continuously change (Beal, 2005).

Often, trainers are faced with the issue of assessing trainees’ performance. For example, in a study looking at computer based decision makers, assessments consist of informal observations of instructor as trainees participate in simulated tasks (Beal, 2005). Issues occurred due to the difference between instructors, who may offer different levels of coaching and feedback. Additionally, the instructors’ proficiency with the simulated trainer and overall experience on the task being trained can cause challenges in assessing trainees’ performance (Beal, 2005; Sniezek, Wilkins, Wadlington, & Baumann, 2002). Satish and Streufert (2002) suggest simulation based training is reliant upon the evaluation of trainee competence. Salas and Burke (2002) contend that all simulators should not only offer assessment of performance opportunities, but should capture "moment-to-moment" actions and behaviors. The application of automatic performance tracking capabilities in DM trainers handles captures actions throughout the simulation.

Therefore, metrics of performance must be appropriate for the desired training objectives and evaluative methods. Demonstration of mastery of the skills associated with the training of a specific simulator should revolve around measures of performance rather than process.

Embedded features of an SBT to capture trainee information, such as ammunition consumption, unit losses, and ground coverage, should be relevant to training goals. Considerations of the feedback tools that come standard with an SBT should account for differences in the context and types of decisions along with experience of trainees. The Selection of the suitable feedback methods for decision making necessitates evaluation of training objectives and trainee experience.

Evaluation of training for decision-making in crisis situations confirmed that outcome is a poor indicator of performance because in crisis situations, and optimal training may occur when feedback is used to prevent poor decision making rather than mitigate the consequences of decisions (Sniezek et al., 2002). Additionally, the function of feedback is task and experience dependent. For example, Brewster (2002), found that a main advantage of tactical decision exercises is the ability for trainees to receive feedback of their proposed strategies from their peers. Much like feedback methods for crisis simulations, the advantage of feedback in tactical
decision-making exercises lies in the reception of feedback before the decision-making occurs (Brewster, 2002).

The advantage of functional properties over physical in decision-making simulations has been shown to be important for eliciting stress in training. An evaluation for leaders that trained on both Full-Spectrum Command and Rapid Decision Trainer reported that the most valuable aspect of learning was in the practice of tasks in various conditions (Beal, 2005). A trainee experiences high fidelity decision making in a combat simulation if emotional and psychological stress can be derived from a training scenario which offers consequences for a trainee’s actions (Perla and McGrady, 2011).

The assessment of the characteristics of SBTs for warfighting training outlined in this review can be categorized in the three steps for SA as outlined by Loukkala and Varrantaus (2014). Perception of the environment can be influenced through level of detail. Comprehension of the situation and projection of the future status of the situation can both be guided through feedback. In this review, scenario customization, feedback, and the capture of behavioral and physiological data have been evaluated as tools to enhance the cognitive processes underlying and tied to SA for skill maintenance as well as the facilitation of novice trainees towards expertise. Opportunities for future work lie in the further validation of these characteristics in more specific training applications.
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Biography
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