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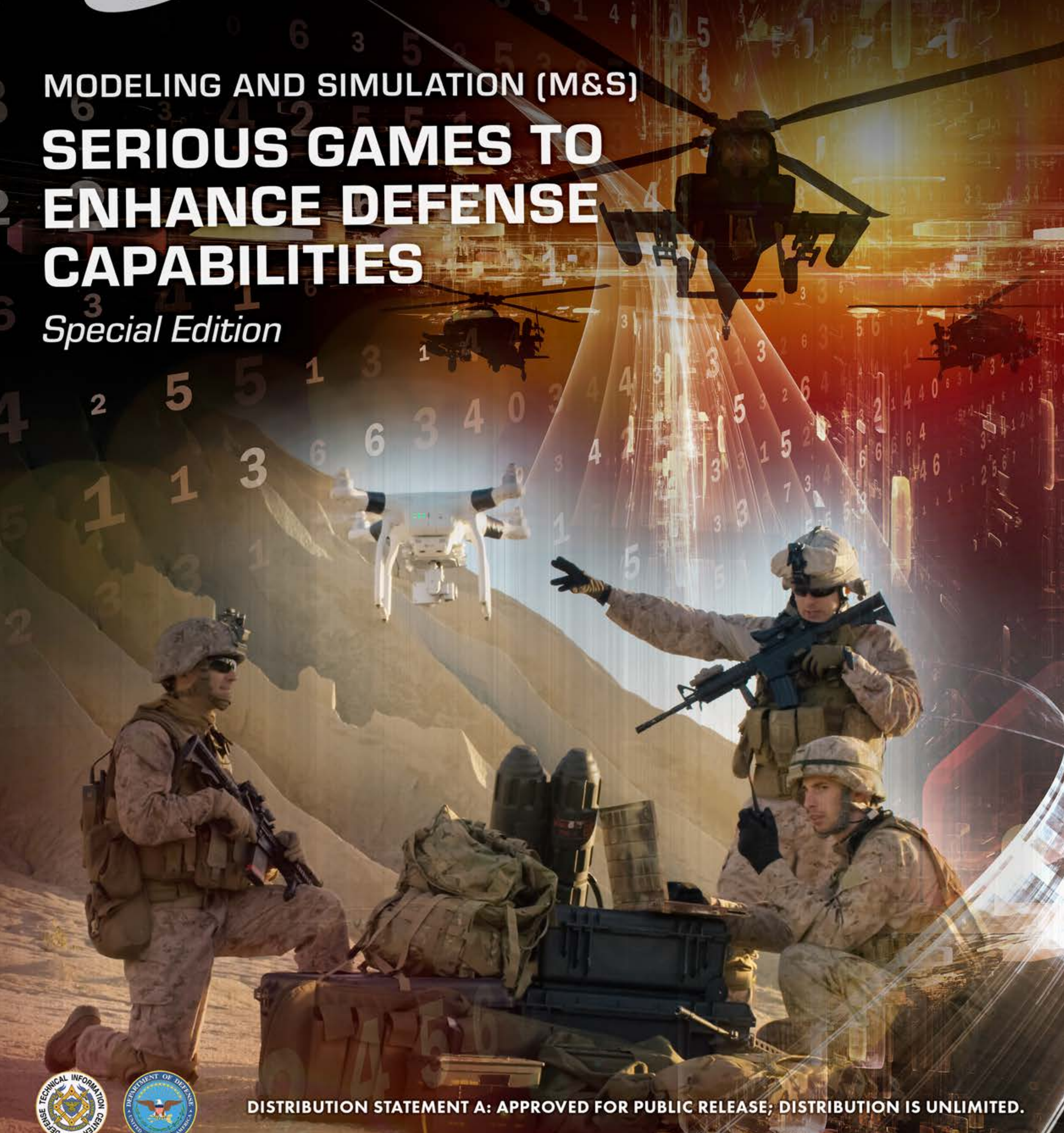
CSIAC JOURNAL

A Quarterly Publication of the Cyber Security & Information Systems Information Analysis Center

MODELING AND SIMULATION (M&S)

SERIOUS GAMES TO ENHANCE DEFENSE CAPABILITIES

Special Edition



Cyber Security & Information Systems Information Analysis Center

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- Software Engineering
- Modeling and Simulation
- Knowledge Management/Information Sharing

The primary activities focus on the collection, analysis, synthesis, processing, production and dissemination of Scientific and Technical Information (STI).

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ABOUT THE JOURNAL OF CYBER SECURITY AND INFORMATION SYSTEMS

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Journal of Cyber Security and Information Systems

Modeling and Simulation - Serious Games to Enhance Defense Capabilities

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2017 SPECIAL MODELING AND SIMULATION (M&S) EDITION OF THE JOURNAL OF CYBER SECURITY & INFORMATION SYSTEMS

By: Dr. Gary Allen & Mr. Fred Hartman

It is our honor to introduce the Modeling and Simulation (M&S) "Serious Games to Enhance Defense Capabilities" Special Edition of the Journal which focuses on wargames and the many uses of M&S that support decision making needed at the various levels of combat.

The origins of board games can be traced back several millennia when the game of Go was invented in China as Wei-chi and is believed to be the oldest board game in continuous play to the present day. The modern game of Go was played by students of the military art during the last century for its parallel to the ink-spot strategy common to guerrilla warfare.

Over time various gaming tools have been used to support military commanders and staffs. The predecessor to today's M&S environment was designed in the early 19th century. The wargame **Kriegspiel** was created in 1812 by Baron von Reisswitz and used for training the Prussian Army. Later, his son, LT Georg H.R.J. von Reisswitz developed a written set of rules for the game in 1824 which made for more consistent play and outcomes.

This year the editors have adopted the wider view of "gaming" by including what is commonly referred to as the oxymoron "Serious Games". The term is used to identify games and game environments that are developed for purposes other than entertainment. While War Games are used to stimulate decision making in the conduct of military operations and planning, the primary focus of serious games is to support education and training.

The current Serious Games industry accounts for over 1.5 billion dollars in annual sales and is generally considered, using current technology, to have started with the issue of **America's Army** in 2002. This is not to imply that 2002 is the beginning of serious games. In the well-researched article **Origins of Serious Games (2011)** the authors show origins of the term dating back to the Renaissance and specifically with the 1912 Swedish Novel, **The Serious Game**. The term, with a definition that closely matches the current use, is also the title of a 1970 book written by Dr. Clark Abt, **Serious Games**. During his tenure as Chairman of Abt Associates (1965-1985), Dr. Abt developed numerous serious games for the military, government, industry, and education. Even though serious games has a long and interesting history, their use continues to grow and as technology evolves so do the capabilities and functionality of this learning environment and thus this issue of the CSIAC's **Journal of Cyber Security and Information Systems**.

In this issue you will find a selection of topics ranging from the uses of serious games for education and training to use of early synthetic prototyping to construct a physics-based game environment for assessing how new technologies might be employed on the battlefield through the use of user/soldiers participating in games.

The first article describes a process to address the need for innovative, effective, and responsive cyber education and training programs. Learning Cyber Operations Through Gaming: An overview of current and up and coming gamified learning environments describes how a part of that strategy includes well designed games. The authors present how games and "gamified" learning environments can be used and provides overviews for four current and emerging programs.

The next two articles were presented at the 2016 NATO symposium (MSG-143) and are presented here to provide interesting insights into the design and use of games and gaming in military training. Authors from The Netherlands provide the article, Serious Gaming Design for Adaptability Training of Military Personnel, with the assumption that a serious game with complex tasks can be devised to enhance players' flexible thinking and thus should improve their adaptability. They proceed to develop a complex decision-making game with the aim to enhance the cognitive flexibility of higher-level military officers. Also from the Netherlands, the next article, **Crowd Driven Tactical Decision Game: Training Tactical Creativity**, describes the results of a two year research project. The study was conducted to establish how the use of serious gaming can enhance the education and training of the individual staff officer at battalion and brigade levels.

The next article, **Early Synthetic Prototyping – Digital Warfighting for Systems Engineering**, is an effort to construct a physics-based game environment to rapidly assess how technologies might be employed on the battlefield. The ESP is envisioned to be a persistent game network that allows soldiers to play scenarios and provide experiential feedback to concept and capability developers. The first effort in the ESP is a small unit first person shooter game, Operation Overmatch.

From the early beginnings of gaming addressed above to today we can trace the logical extension from manual board wargames for military training and education to the application of serious games and gaming technologies to meet current requirements. Some feel games, in addition to training aspects, can provide valuable user/soldier insights to enable analysis and systems engineering decisions. ■

ABOVE: Early Kriegspiel set. Source: Marz, Roman, Photo credits, Berlin, Germany, 2000.

RIGHT: Massive Multiplayer Online Wargame Leveraging the Internet (MMOWGLI) program. Retrieved from: https://www.imagesoffreedom.com/

ABOUT THE AUTHORS

Dr. Gary Allen served 28 years on active duty in the US Army and 14 years as a Department of the Army Civilian and has made numerous contributions to the DoD Modeling & Simulation (M&S) community. Dr. Allen led a successful effort as Project Manager for the DoD High Level Task, "Live, Virtual, and Constructive Architecture Roadmap Implementation" project (2009-2014) and initiated the ongoing Cyber Operations and Training Simulation (COATS) Project. As the Deputy Director of the Instrumentation Training Analysis Computer Simulations and Support (2014-2015) Dr. Allen guided a team that supplied a world class L-V-C training environment in Europe. Dr. Allen is currently a member of the M&S Editorial Board to the CSIAC Journal and an Executive Board member for Phi Kappa Phi national award-winning Forum magazine. His academic background includes MS in Telecommunications Systems Management, School of Engineering, University of Colorado (Boulder), and PhD in Instructional Technology, University of Kansas (Lawrence). Dr. Allen is a Vietnam Veteran, member of the Phi Kappa Phi National Honor Society, a 1999 graduate of the Army War College, and is a DOD Acquisition Corps Level III Certified PM. Dr. Allen currently lives in Germany and devotes some of his time to teaching and consulting on international M&S projects.

Mr. Fred Hartman has an extensive background in models, simulations and training applications with Defense related management and analysis positions in both industry and government. He has specialized in problem solving with use of modeling and simulations, assessing training systems and technical applications for over 40 years. Fred graduated from the U. S. Military Academy with a BS in Engineering and served as a Field Artillery Officer in Korea and as an Army Aviator in Viet Nam. After receiving an MS in Operations Research from the Naval Postgraduate School, Fred completed several Army analytic assignments prior to leaving active duty for an industry career. In 1992 Fred became Chief Operating Officer, was co-founder and on the Board of Directors for Applied Solutions International, Inc, a technology start-up company with consulting services for Defense industries and international trade. Consulting and analysis at ASI included work for the United Nations Development Programme, Army Research Labs, and the Small Business Innovation Research Program (SBIR). Fred joined IDA in 1996 as a modeling and simulation advisor to the DUSD (Readiness). In 2003 Fred joined the Office of the USD (Personnel and Readiness) as Director, Training Transformation Joint Assessment and Enabling Capability and as Deputy Director, Readiness and Training Policy and Programs returning to IDA in 2007. Mr. Hartman continues to support the Department of Defense with strategic planning and training acquisition projects. In addition to leadership positions in modeling and simulation volunteer organizations Fred has served as a member of the Army Science Board, led a study panel for the National Academy of Sciences, Board on Army Science and Technology, and is a past President and Fellow of the Military Operations Research Society.

LEARNING CYBER OPERATIONS THROUGH GAMING:

An overview of current and up and coming gamified learning environments

By: Patrick Shane Gallagher, PhD, Researcher at the Institute for Defense Analyses
and Frank DiGiovanni, Assistant Dep Chief of Naval Operations (MPTE)

Cyber warfare, cyberterrorism, and cybercrime are serious existential threats to the national security of the United States. This is driving a demand signal for expert cyber operators that is far outpacing the supply. As a result, there is a pressing need to rapidly establish innovative, effective, efficient and responsive cybersecurity education and training programs. One program, the Cyber Operators Academy Course (COAC) began to solve the problem but is just one component of a comprehensive cybersecurity education and training strategy. As a part of that strategy, other methods including well-designed games should be considered and interestingly enough, there are many parallels between COAC and what occurs in well-designed serious games or gamified learning environments. This article discusses games and gamified learning environments' place in the cybersecurity training and culminates with brief overviews of four programs currently or imminently available.

Background

Cyber warfare, cyberterrorism, and cybercrime are serious existential threats to the national security of the United States. This is driving a demand signal for expert cyber operators that is far outpacing the supply. One of the root causes of this imbalance is that existing training programs either do not produce enough qualified personnel to meet the demand signal or those that are produced by the cyber education and training pipelines lack the skills to effectively counter the countless numbers and scale of cyber-attacks from criminals and our adversaries. Compounding this issue, the cybersecurity ecosystem continues to evolve at pace of change that is measured in days, as hackers continuously probe our defenses to identify vulnerabilities in this hyper-dynamic operating environment. As a result, there is a pressing need to rapidly establish innovative, effective, efficient and responsive cybersecurity education and training programs.

A current program within the Office of the Secretary of Defense's Force Training Directorate called the Cyber Operators Academy Course (COAC) has shown that using a constructivist theoretical framework and a journeyman-apprentice learning model incorporating situated learning, problem-based learning, experiential learning, and cognitive apprenticeship is not only innovative but highly effective way to train cyber operators. Treating cyber operations as a cognitive "trade" led the course designer to use the cognitive apprenticeship learning model (Collins, A., Brown, J. S., & Newman, S. E. ,1987) and a learner-centered curriculum learning environment to effectively teach and amplify skills such as innovation, problem solving, and critical thinking; and enhance inductive thinking processes. The outcome was a learner who developed a thirst for learning along with a strong intrinsic motivation to "teach oneself" (autodidacticism). These approaches took complete novices and brought them to a high level of competence as cyber operators in six months of intensive learning (Gallagher, 2016).

Within COAC, students were divided into learning teams or "fireteams" and are based on the U.S. Marine Corps' primary infantry fighting unit and the U. S. Army's Warrior Leaders Course (Department of the Army, 2016). Fireteams worked together collaboratively and cooperatively to bond as a team, solve assigned problems, and compete with each other and in external events. Fireteam leads were assigned to each fireteam and provided mentoring, scaffolding, direction and motivation. These leaders generally acted together as coaches and facilitators in lieu of traditional instructors and were highly qualified subject matter experts in offensive and defensive cybersecurity operations.

world is changing at an incomprehensible pace and the military must not only adapt to these changes it must be able to leverage a changing and evolving workforce

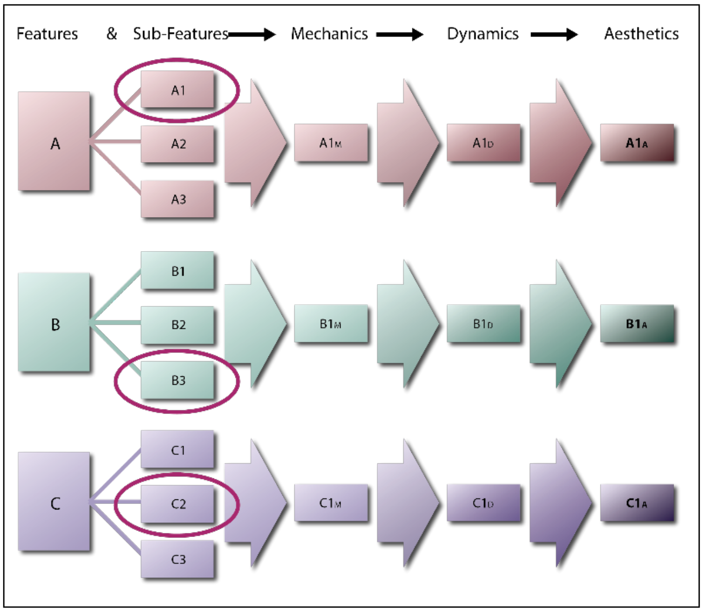
This program, though effective requires six months of immersive team-based experiential learning, problem solving and competitive game play between the fire teams (i.e., capture the flag). Due to a requisite high level of subject matter expertise and the need for virtually 24/7 availability for coaching and tutoring, this approach places high demands on the fireteam leads. Due to these conditions, COAC is but one component of a larger comprehensive cybersecurity training strategy. As a part of that strategy, other methods including well-designed games should be considered and interestingly enough, there are many parallels between COAC and what occurs in well-designed serious games or gamified learning environments.

Why Games?

Games and serious games support both generational differences (as they are ingrained within the culture of Generation X, Y and earlier) and a varied, ubiquitous set of technological opportunities that can now be tracked and be leveraged for learning (Gallagher, 2013). In 2016, the video game market in the United States was valued at an estimated 17.69 billion U.S. dollars, approximately three billion more than in 2011. It is projected that the market will be worth 20.3 billion by the end of 2020 (https://www.statista.com/statistics/201073/revenue-of-the-us-video-game-industry-by-segment/). This statistic shows the magnitude of the investment currently made in readily available games. As noted by Chatham (2011), the world is changing at an incomprehensible pace and the military must not only adapt to these changes it must be able to leverage a changing and evolving workforce. Training had to keep up on both fronts and the popularity and ubiquity of computer games suggested that game informed training might be an answer. This led to the development and deployment of such games as America's Army and DARWARS Ambush. The plausibility of using game based training for cybersecurity builds on a strategy that has been in place within the military for several years.

Well-designed games typically leverage constructivist learning models putting the player into specific situations or problems forcing decision-making and the need to induce rules for incremental success. The game meets the player at his or her emotional, cognitive and/or psycho-motor skill level providing strong emotional connections, context, or goal matching to the environment, puzzles, or problems faced. Games focus on engagement leading to flow (Csikszentmihalyi, 1975) providing a sense of total immersion and intrinsic motivation. Game designs typically rely on the achievement and their broadcasting (typically using leaderboards) of increasingly more difficult goals and, depending on the type of game, collaboration within a team to do so. These are examples of game mechanics that define how one can interact with or within a game through basic actions, processes, and control mechanisms. Other examples of game mechanics are points, levels, and challenges (Bunchball, 2016). Games essentially can allow understanding to develop from interactions with the gaming environment, provide puzzlements facilitating the players' desire to solve and therefore learn, and potentially allow for the social negotiation of meaning through collaboration either virtual or face to face (Kirkley, Duffy, Kirkley, & Kremer, 2011). These design properties place games within the realm of a constructivist theoretical framework.

To specifically create the conditions that foster the cyber operations cognitive skills, games should also have the features that can stimulate the cognitive processes necessary for these skills. Features (and sub-features) are an addition to the familiar MDA (mechanics, dynamics, aesthetics) model of game design (Salen & Zimmerman, 2004) that come before mechanics and represent general design tenets or desirable characteristics that are translated into the mechanics of a specific game. This creates the hybrid model FMDA. Features in this hybrid model, in turn integrate into the game's runtime dynamics evoking a particular aesthetic during gameplay (Gallagher & Prestwich, 2012). The emotions corresponding to the aesthetics in the model have themselves been modeled by Lazzaro (2004) producing what she discusses as the four keys to unlock emotion: hard fun, easy fun, altered states, and the people factor. Using both models, features can be explicitly aligned to the desired emotion targeted.



Relationship between features, mechanics, dynamics, and aesthetics with the addition of sub-features (circled representations) in the FMDA model.

For games designed to foster the cognitive skills necessary for cyber operations, the features are unstated/non-explicit rules; unstated/non-explicit changing of rules; dynamic shifting of environments; open ended choices, and implicit reinforcement for actions or choices leading to goal achievement. Taken together, these features lead to the development of cognitive skills including cognitive flexibility, transference, and metacognitive awareness (mindfulness/goal setting). All these attributes contribute to increases in problem solving ability which is related to executive functions. Over the years there have been several studies considering the relationship between playing video games with these features and executive competencies spanning visual attention to fluid intelligence with positive results (Gallagher 2013). Generally, the aesthetic or emotional category aligning to these features within a game is that of "Easy Fun" - the games awakens a sense of curiosity with many options combined with ambiguity and incompleteness as well as detail (Lazzaro, 2004).

One crucial core mechanic that becomes critical is that of time. Time introduces a quantifiable tool for judging performance to game play and can motivate players to not only reach the goal but reach it rapidly and force metacognitive activities to occur in the micromomentary. This is essential for developing expertise. Timed play can include anything where time is measured to the consequence of the player: either rewards for quick action, negative reinforcement for slow action, or actual time limits on the player's gameplay.

Other than pure game play, many environments may have some combination of gaming mechanics with other uses especially for training. This leads to the concept of gamification. Gamification applies game mechanics to typically non-game activities including training to drive desired behaviors. There are 10 typical mechanics gamification uses for motivation and engagement (Bunchball, 2016):

- Fast Feedback
- Transparency
- Goals
- Badges
- Leveling Up
- Onboarding
- Competition
- Community
- Points

By incorporating the above and other features, mechanics, and aesthetics, games with the right design or well-designed gamified learning environments can develop not only domain specific knowledge but crucial cognitive capabilities as well. Games have historically been used in hacker and cyber competitions. Currently, commercial games, targeted serious games, and gamified learning environments are becoming available to specifically target the types of content knowledge, problem solving and autodidactic behavior necessary to learn cyber operations.

Games place within cybersecurity and cyber operations training

Ever since the hit movie Wargames debuted in 1983 with the iconic phrase, "Shall we play a game?", the idea of hacking and games, especially wargames and blow up the world games such as Thermonuclear War become indelibly linked (Brown, 2008). As a homage of sorts to Wargames and founded in 1993 by Jeff Moss, DEF CON (also written as DEFCON, Defcon, or DC) is one of the world's largest hacker conventions, held annually in Las Vegas, Nevada. Attendees to DEF CON include computer security professionals, journalists, lawyers, federal government employees, security researchers, students, and hackers with a general interest in anything that can be "hacked." The event consists of speaking tracks on computer- and hacking-related subjects, as well as social events and contest or games (DEF CON, 2017).

Besides such contest as lock-picking, robotics, and scavenger hunts is a game called Capture the Flag (CTF). CTF is most likely the best known and is a hacking competition where teams of hackers attempt to attack and defend computers and networks using certain software and network structures. Over the years CTF has been emulated at other hacking conferences as well as in academic and military contexts for such broad uses as entry exams to universities and measurement of skills in cyber protection teams.

CTFs

Used widely for cyber security competitions, Capture the Flag (CTF) games or contests are usually designed to serve to give participants experience in securing a network and/or a machine's operating system, as well as conducting and reacting to the sort of attacks found in the real world. Typically, skills required to successfully play a CTF are reverse-engineering, network sniffing, protocol analysis, system administration, programming, and cryptanalysis. CTFs typically fall into two types: attack/defense and jeopardy.

Attack/defense CTFs require that each team defend a given machine or small network. Scoring is accomplished on successful defense as well as success at offense or attacking others' machines or networks. This is represented by a "flag" usually a long hex encoded string that is either prevented from being captured or is planted on an opposing team's system. Besides DEF CON another annual large scale CTF is held at New York University Cyber Security Awareness Week (NYU-CSAW) - the largest student-centered contest.

it is intended to keep avid learners relaxed and engaged through many elements of gamification

Jeopardy-style CTFs involve multiple categories of problems, each of which contains a variety of questions of different point values and difficulties. Teams attempt to earn the most points in the competition's time frame (for example 24 hours), but do not directly attack each other. Rather than a race, this style of game play encourages taking time to approach challenges and prioritizes quantity of correct submissions over the timing (Wikipedia, 2017; Harmon, 2016).

Games or gamified learning environments for training cyber warriors

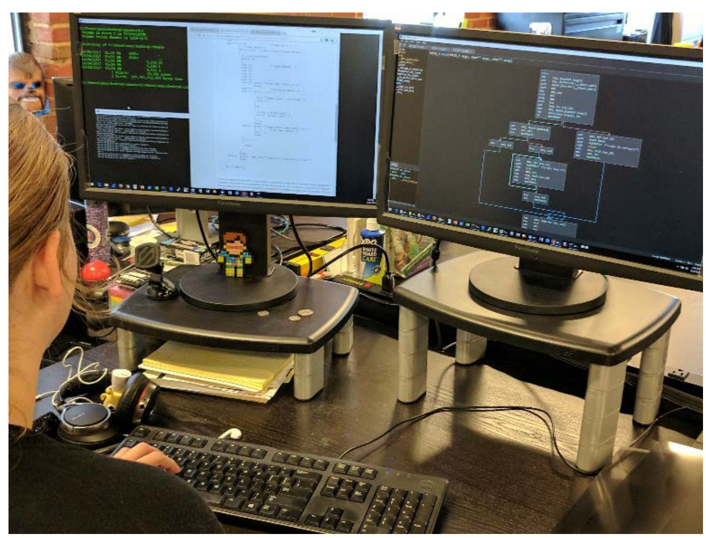
Even though games are a logical component to the overall cybersecurity training strategy and have a long legacy within the hacker and cyber communities, there aren't many serious games or learning environments that have been available until recently. Over the last two to three years, several efforts have been working to produce games or digital gamified learning environments that are serious contenders for teaching deep cybersecurity concepts and skills while reinforcing the cognitive capabilities that make effective cyber operators. The rest of this article is devoted to describing four of these.

ESCALATE

Under development for the past couple of years by the company that has successfully led the development and execution of the Cyber Operators Academy Course (COAC) is a gamified learning environment called ESCALATE. Commercially launched in December 2016, ESCALATE is designed to support the acquisition of skills in the cyber domain which is typically a slow and intimidating process for many novices and professionals alike. Based on challenges not unlike a jeopardy CTF, it is intended to keep avid learners relaxed and engaged through many elements of gamification. For example, it includes the ability to form and compete in teams, provides team and global leaderboards, and awards points for challenge completions. Profile badges are also attained for accomplishing specific achievements.

Using a problem-based approach, challenges are complex with solutions that may not be intuitive or straight forward helping to develop the cognitive skills and problem-solving ability necessary for cyber operators. ESCALATE also incorporates "replayability" by uniquely generating a solution each time a challenge is attempted. Supporting scaffolding and implicit feedback, is just-in-time help based on system connected "helper" material and/or live coaches with struggling learners. However, coaches are there to elicit learner thinking strategies not just to give the answer. Using these elements, ESCALATE works to inspire learner confidences, instill a sense of community, and maximize "on keyboard" for learners that can collaborate and interact with the system and others 24/7.

ESCALATE was developed by Point3 and currently used in the third pilot of COAC as the primary online learning system. It tracks learner behaviors using xAPI (Experience API from ADL or Advanced Distributed Learning - adlnet.gov) and can produce analytics on useful learner behaviors and achievements. It is currently commercially available and for more information contact Point3 at https://point3.net.



Learners interacting with Escalate, Copyright 2017, Point3

Project Ares

Project Ares is a gamified, artificial intelligence (AI) powered cyber training environment by Circadence. It uses real-world tools and tactics in immersive, virtual environments. Project Ares gives the learner access to an evolving library of mission scenarios

Opening screen of Project Ares, Copyright 2017, Circadence

and educational resources such as a how-to video library and various learning games. Learners can work alone or in teams to stop hackers, protect systems, and hone skills inside realistic or mirrors of the business and organizational environments they could eventually defend.

In addition to an overall gamified learning environment, specific learner features also include an AI component powered by IBM Watson™ and SparkCognition™ that acts as a coach, umpire, or even opponent. It provides real-time cyber-attack data that continually evolves and perpetually learns how threats appear, develop, and expose network systems. It provides AI-based monitoring and scoring (umpire), and in-context knowledge to learners and trainers (advisor). AI is also used for offensive and defensive opponents to increase challenge factors.

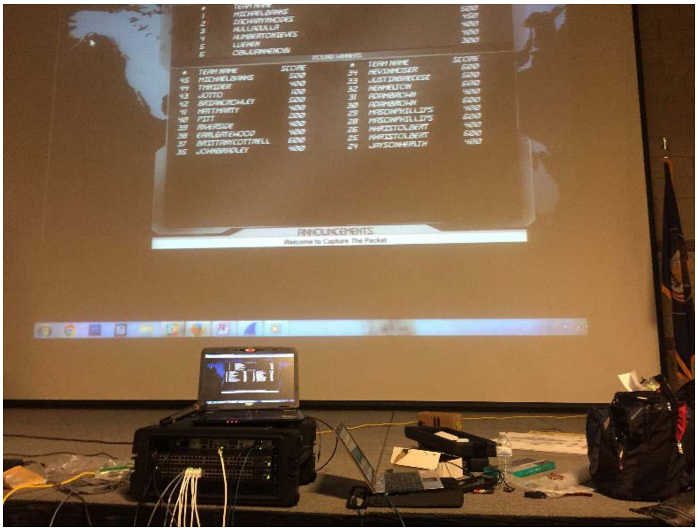
Learners can also prepare in the Project Ares Battle School, which enables asynchronous practice and review of cyber skills and knowledge. Key features include: cyber games for technical topics (i.e. Cylitaire, PortFlow), battle room for non-mission specific tactical practice, and a media center for videos, documents, and other key resources/websites in cybersecurity.

Skill badges and certifications can be earned on single cyber tasks and in large-scale, cooperative settings. As a MMOG (massively multi player online game), learners or players can work with others to cooperatively solve missions, follow others, communicate and develop a sense of community as they progress.

Using an instructor portal with dashboards for monitoring progress, performance assessment, trainers and instructors can facilitate after-action reviews through mission review and playback as well as providing real-time interventions. For the first year of development of the ADL Total Learning Architecture (TLA), Project Ares functioned as a learning activity provider for the first TLA test and demonstration of a reference implementation at Ft. Bragg. Consequently, it is fully xAPI enabled. Project Ares is currently in use or in collaborative mission development with various DoD components and Services. For more information contact Circandence at www.circandence.com.

Capture the Packet Training (CTP) Tool

Capture The Packet (CTP) by Aries Security was originally created by Brian Markus and two colleagues in 2002 as part of DEFCON and is a training tool that leverages 25 years of development and experience running this game at DEF CON. Designed to train to network defense and offensive capabilities, this system offers a user-friendly interface, capable of expanding challenges suitable for key users, or entire teams. Enhanced through a contract for the Office of the Secretary of Defense's Force Training Directorate, the enhanced purpose of CTP is to provide a lightweight Cyber Training Capability with "Capture the Packet" functionality that provides a persistent, realistic, end-to-end cyber mission training resource. The status of DoD's Cyber Mission Force team training capability suggested a lightweight, low-cost, cyber training capability usable from home stations that will support classified and/or unclassified tools was needed. These capabilities were limited by the lack of an integrated portable tool that can provide simple administration, ease of deployment, and semi-automated cyber training challenges. A new cyber training tool was needed to overcome limitations and improve the operational readiness and cutting-edge training of the anticipated 133 Cyber Mission Force teams. Enter Capture the Packet.



Leaderboard and racked equipment for Capture the Packet, Copyright 2017, Aries Security

Originally based on network packet analysis techniques and leveraging the current the Capture The Packet training simulator framework, currently CTP takes advantage of automated tools, techniques, strategies, scoring, and administration capabilities that already existed. It has the ability to train for a spectrum of major threats to obscure tactics. CTP has ready out of the box capabilities, and a portable, enclosed network. According to Aries Security, it allows you to test your team against live threats, evaluate offensive and defensive abilities, and have an actionable growth strategy from day one of rolling out the suite.

Using an existing portable, standalone, ruggedized, 6U system design, CTP provides real-time records of student performance, and skill evaluation of users when operating under time constraints in high-fidelity competitive real-world conditions. This system architecture is designed to easily support classified and/or unclassified training exercises.

a blended learning course that is self-paced, immersive, story-centered curriculum

Technically, CTP provides a player on player environment in which 10 teams of 5 students each can concurrently compete. The students control the operation of a single virtual machine that houses five binaries. Each binary is a custom service that contains two or more memory corruption level vulnerabilities and has at least one anti-debug or anti-reversing technology applied. Through this, students are capable of identifying, patching and reverse engineering vulnerabilities in executable code and operating systems. Students are responsible for finding vulnerabilities in agent services, constructing the necessary exploit payloads capable of retrieving token values from memory and submitting those token values or "steals" to a scoreboard in order to obtain points. Student teams would also be responsible for defending their services by patching their live environments against discovered vulnerabilities. Points are awarded for steals as well as deducted for any down time of any service. If a team's service has been compromised, they can force a key reset at the cost of points.

As a standalone solution, CTP doesn't need an Internet connection making it ideal for secure environments and easily deployed to CONUS and OCONUS locations. For more information contact Aries Security at www.ariessecurity.com.

Cyber Attack Academy (CAA)

Another project completed by the Office of the Secretary for Defense Force Training Directorate is the Cyber Attack Academy (CAA). Developed by Socratic Arts and although not a game per se, CAA provides a problem based approach within a role-playing scenario. It could be called a blended learning course that is self-paced, immersive, story-centered curriculum but that description may not be doing it justice. It also has live and AI-based tutoring providing scaffolds to take you from a complete novice to one who can do such things as reverse engineering within the first task. In a story-centered curriculum, students play an authentic role (e.g., that of a cyber operator) in a realistic story of professional work designed with a pedagogical intent, meaning that the story is designed to require the successful application of targeted knowledge and skills to achieve the goals set for them. Students will do the same work as professionals and will produce the same work products. As in professional practice, some work will be individual and other work will be team based. As they work, students can make use of structured performance support materials including a "plan of attack" for accomplishing the work and learning resources key to aspects of their tasks.

Students will also have access to knowledgeable human mentors who can provide help and advice and, more importantly, feedback on drafts of student work." In most cases 80-90% of the questions that students ask can be anticipated (i.e., the questions recur regularly), so the learning environment is augmented with an *artificial intelligence-based automated mentor*. Integrated into the learning environment, it uses natural language processing to extract key semantic features from student questions *in specific task contexts* and then use those features to retrieve high-quality expert answers to those questions in both video and textual formats. The 10-20% of questions for which the AI Mentor cannot retrieve suitable answers will be referred by the AI mentor to expert human mentors. Their answers can then be incorporated into the AI mentor extending its capability. Automated mentoring of this sort is intended to offload routine question answering from the human mentors, enabling a substantial increase in the student-to-mentor ratio. This provides a scalable training solution enabling the government to address the significant shortage of skilled cyber operators more quickly and effectively.

Opening screen for the Cyber Attack Academy demo

In essence, CAA provides the following capabilities, functionality and/or attributes:

- A remote platform to learn the cyber operator trade through autodidactic learning with mentor support which can either be live or through an artificial intelligence-based mentor with a natural language processing interface.
- Interweaving an on-line, digital, problem based learning environment with live (either in person or via digital means) mentor/coaching.
- Cyber operators with a wide array of technical capabilities, inclusive of basic cyber operations skills in offense, defense, forensics, scouting, and hunting, cyber red team, penetration testing, acquisition and analysis of publicly available information, the Dark and Deep Web and other cyber operations topics achievable within the four to six- month duration of the course.
- Reinforcement of the roles of anthropology, sociology and ethnography to better understand potential adversaries and themselves
- Both remote individual and team learning and a culminating "All Against All" team-based Capture the Flag (offense/defense) exercise to conclude the course.
- The opportunity for a cohort to pass a performance-based industry standard assessment, such as the Offensive Security Certified Professional (OSCP) credential, or a similar industry defensive oriented cyber operations credential, and at a minimum achieve equivalency with Department of Defense's (DoD) Joint Cyber Analysis Course.
- Instrumented to allow the mentor (live or AI-based) to analyze learner performance and more quickly provide advice to the learner.
- Mentors (live or AI-based) with both formative and summative evaluations of the overall performance of the course and cohort performance.
- Be accessible to the government via commercial internet service providers from a cloud-based and/or local digital repository, with a secure password protected log in or other means of ensuring only authorized learners have access to the course.
- Provide unlimited use of the course to the Government.

CAA has recently finished development and will soon be available for access through the Web. To look at the environment and a demonstration of the course go to https://www.schankacademy.com/cyber-attack-academy. For more information go to https://www.schankacademy.com/contact.

Conclusion

In conclusion, games, serious games and gamified learning environments are powerful tools for engaged and motivated learning experiences. With the right design, they are capable of teaching the cognitive skills required for cyber operations and can be an essential component of the strategic and comprehensive cybersecurity training strategy which is a national imperative. Games and digital gamified learning environments can and should be available to provide innovative, effective, efficient and responsive cybersecurity education and training solutions. The four games discussed provide an overview of where these environments are headed and what is or will shortly be available to help produce enough qualified personnel to meet the demand signal or those that are produced by the cyber education and training pipelines. ■

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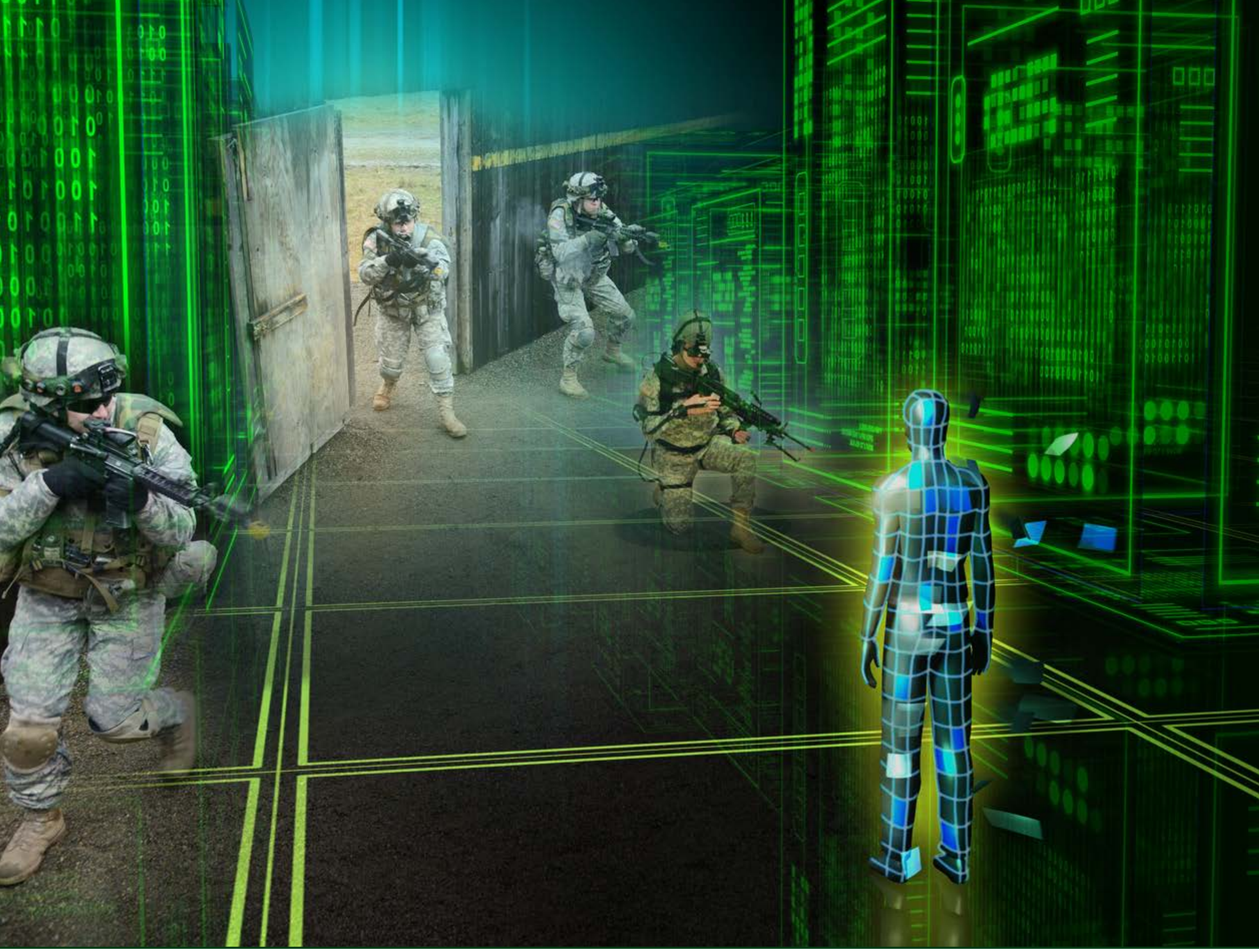

SERIOUS GAMING DESIGN FOR ADAPTABILITY TRAINING OF MILITARY PERSONNEL

By: Yelim Mun, Anja van der Hulst, Esther Oprins, Andrea Jetten, Karel van den Bosch, and Jan Maarten Schraagen

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As the world in the 21st century has become more dynamic and unpredictable, the need for adaptive behavior in the military is of increasing importance. A serious game (SG) seems to be a suitable intervention for improving adaptability to prepare the military to deal with unpredictability. The purpose of this study is to explore the game design for enhancing adaptability of the military in an ill-structured complex decision making context. We introduce rule changes in the game to stimulate learners' sensitivity to detect the applied changes and to develop an appropriate strategy.

The procedure of our SG intervention design and development is described within the framework of the Cognitive Flexibility Theory and that of Reversal Learning. The Job Oriented Training approach as well as rule change is embedded in the game structure. This paper summarizes the results of a pilot (n=12) with the game. The participants' score, time spent to complete the game, and adaptive performance score are described. Survey data shows players' detection of rule change, their experience on difficulty, engagement, motivation, and concentration level of this game play. Finally, we discuss issues and future direction of this study.

Introduction

Training military personnel to be flexible and to prepare them for unexpected, changing circumstances has great importance for defense and security. Countries such as the U.S., Canada, the U.K., and many EU countries have been seeking for ways to build adaptable forces to effectively handle dynamic and unpredictable operational environments [1]. In the Netherlands, TNO is conducting a research program called 'Human and Organizational Adaptability' (HOA) for the Armed Forces. As part of this program, the current paper focuses on a Serious Game (SG) design that aims to improve the adaptability of military personnel to deal effectively with changing work environments.

What is adaptability?

Adaptability is defined as the ability to effectively adjust to novel, unforeseeable and changing situations [2]. Pulakos et al. [3] list eight dimensions of adaptability. These are (1) creative problem solving, (2) dealing effectively with unpredictable and changing situations, (3) learning new skills, knowledge, and procedures, (4) interpersonal adaptability, (5) cultural adaptability, (6) dealing with emergencies, (7) coping with stress, and (8) physical adaptability. All eight dimensions of adaptability are relevant to military operations [4]. For instance, military personnel have to be creative in making strategic plans during unpredictable missions, they have to adapt to other cultures in foreign countries during missions, and they have to physically adapt to extreme situations such as heat.

Serious Gaming for learning adaptability

Our assumption is that adaptability of military personnel could be improved by training in order to prepare them optimally for unforeseen situations. One of the interventions could be a serious game. SGs have been used to provide an authentic context and natural learning environment. Using SGs in military training is deemed beneficial in terms of time and cost compared to field training [5]. Moreover, SGs, in particular wargames, have been used in military training for at least 200 years. Therefore, military personnel are familiar with learning through games, be they board games or digital games.

Some SGs that aim at improvement of adaptability applied change of environments during game play besides other types of interventions. For example, a SG called 'Team Wargame Interaction Simulation Training (TWIST)' [6], forces players to be flexible and adapt to new and different settings by conducting tank operation tasks in various locations such as open pasture, jungle or archipelago to successfully complete tasks. Another SG called 'Apache attack helicopter' [7] creates a learning environment encouraging adaptive performance of players by providing a variety of terrains to operate an attack helicopter. In the above-mentioned games, learners are given tasks or missions. While performing such missions, learners face situations where the environment suddenly changes. In those cases, as learners are not explicitly trained how to perform in the new environment, they will have to find that out by themselves. Adaptability is applied when learners adjust to the new environment and continue the task in different ways. However, it is not clear whether performing learned tasks in different environments are sufficient for adaptability training. Therefore, there is a strong need for designing and developing a serious game that can train adaptability involving more ill-structured tasks and more fundamental changes (i.e., rules that influence complex decision making). To this end, we used concepts developed in Cognitive Flexibility theory and Reversal Learning, to be discussed in the next paragraph.

Rationale

Cognitive flexibility

Cognitive flexibility (CF) is strongly related to adaptability, especially the more cognitive elements of adaptability dimensions [3]. It could be regarded as a predictor, highly influencing adaptive behavior [8]. CF is defined as "the ability to spontaneously restructure one's knowledge, in many ways, in adaptive response to radically changing situational demands [9]." CF theory has been used in various fields to explain and improve learning in ill-structured and complex domains. When situations change, cognitively flexible individuals recognize that a situation has changed. After assessing the new situation, they are capable of adjusting strategies to deal with the new situation. They can provide non-routine (adaptive) responses to successfully perform in new situations. To effectively train CF, it is important to focus on learning how to detect situational change and on how to (re-) define strategies according to the change [10].

Our assumption is that a SG (with ill-structured, complex tasks) which can enhance players' flexible thinking should improve their adaptability. We developed a complex decision making game with the aim to enhance the CF of higher-level military officers.

Adaptability is applied when learners adjust to the new environment and continue the task in different ways

Reversal learning

In line with CF, Reversal Learning refers to behavioral change [11], [12]. Several studies examined how individuals adapt their behavior in changing environments. Reversal learning focuses on how quickly people learn rules, and subsequently how quickly they adjust to changing rules. It could be considered as a specific form of cognitive flexibility, focusing on learning existing and changing rules. This is a slightly different approach than learning how to adapt to changing environments, although both contribute to becoming more cognitively flexible and adaptive.

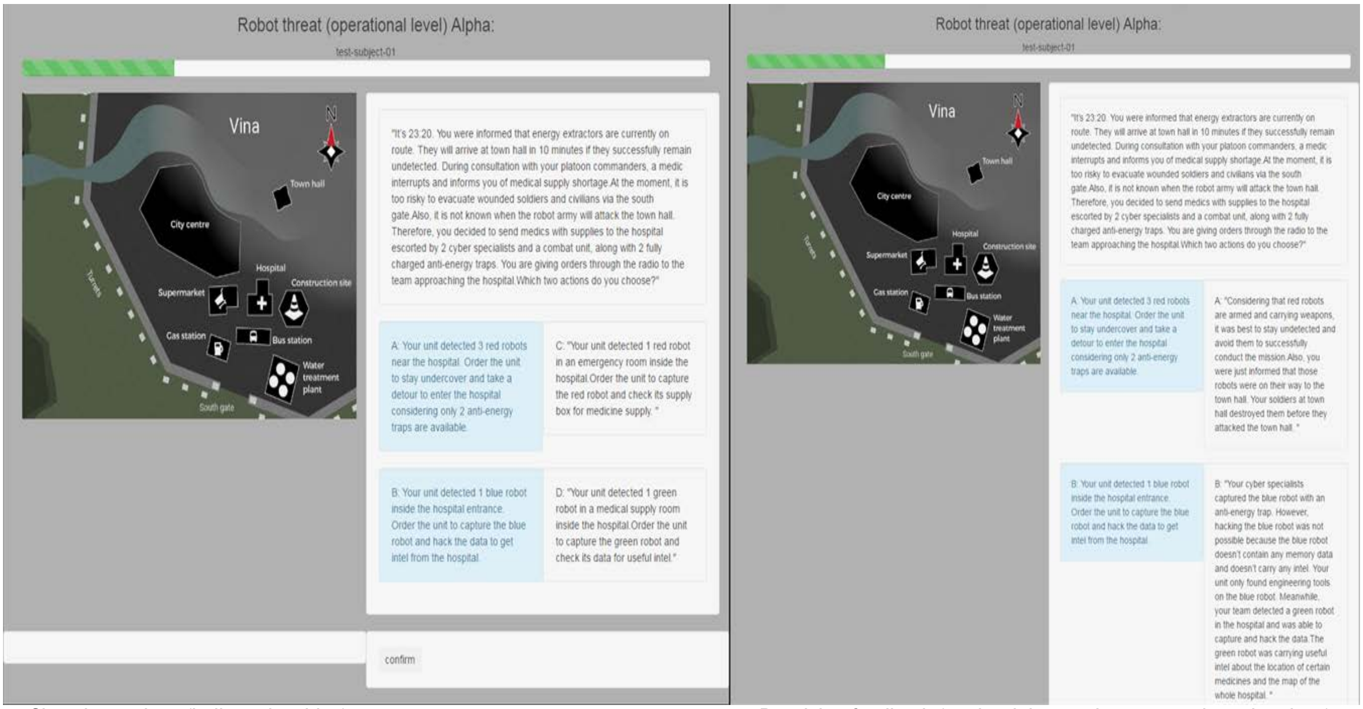
Testing cognitive flexibility

Various tests have been developed to measure how cognitively flexible people are, such as the Wisconsin Card Sorting Test (WCST), Iowa Gambling Task (IGT) and reversal learning task [12]. These tests have some characteristics in common. Usually, individuals learn to perform a simple task (i.e., card sorting in the WCST or IGT). Direct feedback such as right or wrong (WCST), or a financial reward (IGT) is given after each action. At a certain point, the rules suddenly change (i.e., a different rule is introduced for sorting cards in WCST) and the learner is not informed that the rules are changed. The learner must detect the rule change when they receive negative, direct feedback for the same performance that was positively rewarded before the rule change. CF is assessed by measuring how long it takes a learner to detect the rule change and adjust his behavior after the rule change, and how many good answers the learner gives. CF tasks such as the Wisconsin Card Sorting Test, Iowa Gambling task and the reversal-learning task all measure the individual's cognitive flexibility. However, these tasks are simple and procedural with testing as their main purpose instead of learning. As the tasks are presented without a real life context, learning CF using these tasks has its limits. Therefore, the assumption for our game design is that a SG with a rule reversal learning mechanism (similar to that of existing CF tests), yet requiring learners to do complex tasks (complex decision making) in a rich military context can improve CF. Hence, the hypothesis is that adaptability of military officers can be increased via SG-based rule reversal learning in a realistic context, relying on the main principle of rule change adopted from CF testing.

Game design

Didactical approach: Job Oriented Training

Job Oriented Training (JOT) has been recognized as a successful military training method and claimed to accelerate adaptability of learners [13]. By using SGs in a JOT setting, military students are encouraged to learn and perform in a safe yet realistic environment



1.Choosing actions (indicated as blue)

2. Receiving feedback (on the right panels next to selected options)

Figure 2: Examples of the game play

[14]. Hence, our game design embedded some of the JOT characteristics. These are:

- Planning-execution-reflection: The game starts with a briefing and ends with a reflection phase.
- Active learning: Learners are active decision makers during the game play. They learn by trial-and-error. Explicit instruction is not present.
- Relevant reality: Learners play a company commander role, making decisions in the game to complete a military operation.
- Challenge: Learners need to plan and make decisions under time pressure while the situation is complex and information is missing.
- Cooperative and reflective learning: Individual reflection is conducted before the second briefing and at the end of the game play. Players have to answer questions regarding the rules and decision making for a self-reflection moment. After the individual reflection, learners discuss and share their strategies, thoughts and decisions on the game play during the group reflection phase.
- Although group reflection is a listed feature of JOT, we did not embed it within this particular game. As the game can be played individually or in a training session, separate questions were developed to facilitate the group reflection upon the completion of the game. A facilitator (or trainer) is required to facilitate the session and to give appropriate guidance to players.

Game structure

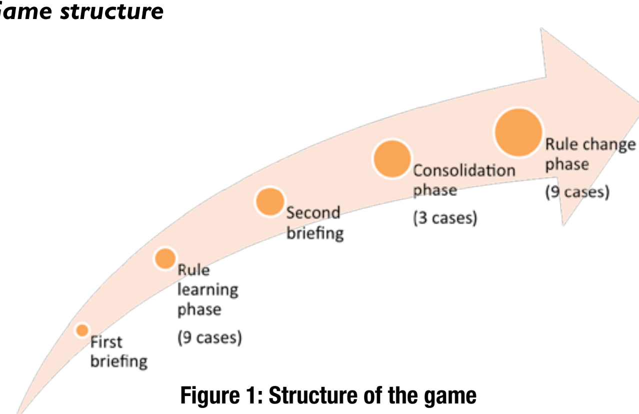


Figure 1: Structure of the game

A PC-based decision making game was developed to enhance adaptability of individual players. The game consists of five phases (see Figure 1). During the briefing, players are informed about background information, the current situation at the onset of the game scenario, and the objectives of the operation. Maps were added to the game to help players visualize the area. To complete the game, players have to make a total of 21 decisions (cases) by choosing answers based on a case description. Case means an assignment to players. Feedback is provided after every case to inform the player about the results of chosen actions. During the rule-learning phase, players learn three rules while solving nine cases. Four different courses of action are presented to fulfil each case and players can select two choices per case. The game provides players with feedback only on the chosen options as a result of actions. Case 1 to 3, 4 to 6, and 7 to 9 are designed to learn three main rules. Cases 3, 6, and 9 are used to test whether players learned the rules. During

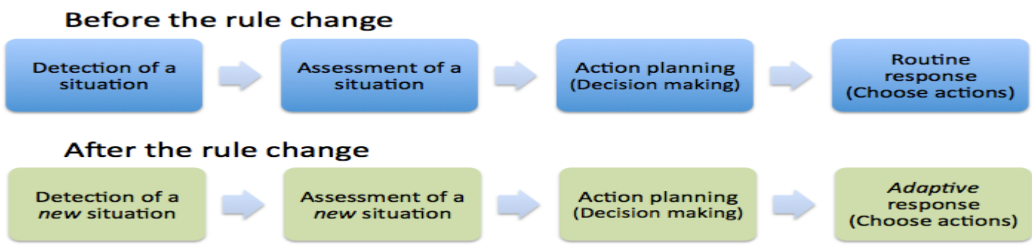


Figure 3: Hypothesized attentional process model of the game players

the consolidation phase, players practice the assignment with the original rules. At each case administered during the consolidation phase, players are tested on the learned rules. If players were not able to learn the rules by playing case 1 to 9 (rule learning phase), the consolidation phase provides an extra opportunity to learn the rules. During the rule change phase, players need to figure out the altered rules by assessing the feedback to the selected responses. The rules learned in previous phases no longer apply. The responses selected by players on the cases 14, 15, 18 and 21 are used to measure whether the players have mastered and adapted to the new rules.

Building narrative

The game contains a rich narrative for ill-structured complex decision making. We created a fictitious scenario involving military operations against a robot army. The rationale for creating a fictitious scenario instead of using existing military scenarios is that in the latter, some players may have more background knowledge on the scenario than others, possibly confounding the results. It is important that players detect the rule change not by using their military experience, but by using the feedback (results of the action) in the game that contains situational cues.

In the game, a player is a commander of a Dutch military unit deployed in a fictitious country in 2030. The enemy has an advanced robot army and the mission is to defeat the enemy and evacuate civilians. During the game play, players have to discover three rules: 1) the behavior of turrets (weaponized mounts) guarding the walls of the target location, 2) functions of each robot type (red, blue and green-colored robots), and 3) the specific vulnerabilities of each of these robot types. After the consolidation phase, the event of a solar storm is introduced in the story. Players are not told that this event changes the rules governing the behavior of the turrets and robots, and the vulnerabilities of the robots. Rather, players have to discover changed rules by using the feedback on the selected responses. Below is an example of the game play. The green bar represents the remaining time to complete the game. The color of the bar changes to orange and then red as the player approaches the time limit.

Rule change

As discussed in the rationale of this paper, rule change (based on reversal learning) is the crucial element of this game for training CF. Players should not be informed of the rule change, yet they will have to detect that rules governing the robot and turret behavior have changed and they will have to change their decision making accordingly.

Our focus within the game design is players' detection of the changes occurring in the turret and robot behavior (rule change) and whether players adapt their responses (choosing actions appropriate for the changed situation). Therefore, a minimum amount of situational cues were given. These were provided gradually so that learners can actively figure out the rule change. Below is the hypothesized attentional process model of the game players before and after the rule change. The model is taken from the CF theoretical framework [10].

Game mechanics

In this section, we describe the game mechanics.

- Role-play: Players take the role of commanders and need to make decisions to successfully conduct a mission. The role-playing element aims to achieve realism as well as immersion in the game play.
- Selecting two actions: For every case, players have to choose two options (taking actions) out of the given four. This gives players a feeling of active control of the game. It is the player who actively creates the story. It also provides a learning environment that allows players to try out different strategies. Moreover, this mechanism adds that players' actions are limited and the limited selection forces players to make the best decisions.
- Feedback: The types of feedback available in the game are negative, positive, and neutral. Negative feedback indicates that chosen actions caused negative results. For example, assault vehicles were destroyed due to the action made by the commander (player). Positive feedback shows positive results from the chosen actions. For instance, ordering to stay covert when facing combat robots results in no casualties and it allows the unit to continue the mission with limited loss of time. Neutral feedback provides information that can be helpful to learn the rule or situation.
- Noise options: Every time players choose an action, they receive relevant feedback. However, some feedback contains information that is not directly relevant to the rules (hence, called a 'noise option'). For example, when a player orders a unit to search nearby empty houses for civilians, he receives feedback that only a cat was found in the houses. The noise options are added for realism that in reality, not all actions have direct actionable results.
- Low physical fidelity: This game intends to train players' cognitive skill (decision making). Hence, high physical fidelity is unnecessary for this game and might even confuse players.
- Fog of war: As frequently used in many war games, this element adds realism and increases the difficulty of the game. We purposely limited players' access to

information (i.e., clouds around some locations so players find out about the whole area gradually by playing the game). Also, it provides an opportunity for players to deal with unknowns and make decisions in circumstances where information is missing.

› Time pressure: In reality, military officers make decisions under time pressure. Time pressure is added in the game as narrative (i.e., 'It is urgent for the remaining units to get safely into the target location and evacuate the citizens as soon as possible.') for realism and setting the difficulty of the game.
› Visual aids: The game puts a high cognitive load on players because they have to constantly make decisions in complex and unknown situations. It is not our intention to measure either memory or cognitive load. Thus, we provide visual aids (i.e., maps) to help players with their decision making.
› Scoring system: Scores are calculated automatically within the game system based on the actions chosen by the players. The action quality as well as the inclination to build up situational awareness are measured. For example, plus points are given for situational awareness actions (i.e., actions to get more intel). Minus points are given for wrong actions (i.e., order to send a transport helicopter when the turrets will destroy the helicopter) and plus points are given for correct actions (i.e., order to capture green robots knowing that green robots carry intel). During the rule change phase, adaptive actions (actions chosen to apply new rules) are given plus points and actions based on obsolete rules are given minus points. The final score is calculated automatically by the system, ranging from 0 to 100.

Game testing

The purpose of the game testing to be described below was to validate the game design rather than to find statistically significant effects of the game play on adaptability. Therefore, we used a convenience sample of students rather than military personnel.

Participants

Twelve 'Game Study' Master's students (one female and eleven male) play-tested the game during the Game Master's introductory workshop at a University in the Netherlands. The students have no military background. All of them have extensive gaming experience and knowledge.

Procedure

First, the students were informed about the purpose of the game testing and received a brief introduction to the game. The topic of rule change was intentionally not mentioned during the introduction of the game. Subsequently, an overview of how to play the game as well as the procedure of the game testing session was given using PowerPoint slides. All students used laptops or tablets to play the game. We provided a paper-based glossary with descriptions and pictures to help students with the concepts and entities used in the game. Also, pens and blank papers were distributed for students to take notes of relevant information during the game play. The rationale for taking notes is that memory should not be a factor to play a role in the game play. A survey was conducted after the game testing session. Due to time limitations and for practical reasons, formal group reflection was not conducted during the game testing session. However, one of the game designers gave informal group reflections (few students at a time) upon the completion of the survey. The testing session took approximately 90 minutes. Due to a technical problem, one student could not download his game play data file. Therefore, we present 11 game play data results and 12 survey results.

Results

The students' total game scores (n=11, *M=72, sd= 9.08*) varied from a minimum of 54 to a maximum of 86 out of the total score 100. The amount of time students took to complete the game varied widely from a minimum of 23 minutes to a maximum of 67 minutes. The Pearson's correlation coefficient (r=.30, p=.38) between time spent to complete the game and the total game score was positive but not significant with the low number of participants. The high standard deviation of the students' game scores and the low correlation between the total time and total score might be explained by the individual differences of players such as differences in information processing, decision making, detection of rule change, and cognitive load.

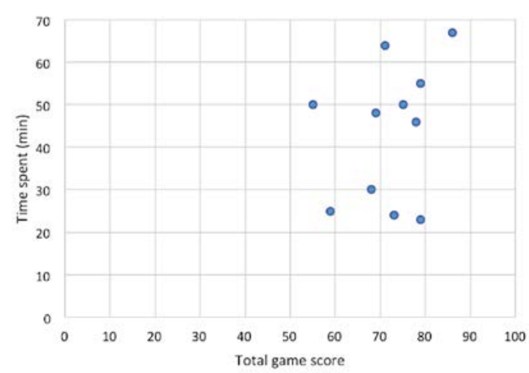


Figure 4: Correlation between players' total game scores and time spent

The game data file gives insight into which options players chose throughout their game play. Case 14,15, 18 and 21 contain adaptive options (options that are contradictory to previous rules but appropriate to changed rules). Therefore, adaptive performance can be measured by examining those answers. 27% of the students chose adaptive answers in case 14 and 63 % of students chose adaptive answers in case 15. Considering cases 14 and 15 are pertinent to the changed rule 1 (behavior of turrets), the results show gradual detection of the rule change (27 % -> 63 %, the number of students choosing adaptive options increased) with some individual differences (not all students chose adaptive options). Thirty two percent of the students selected adaptive options in case 18 with revised rule 2 (functions of the robots) and 68 % chose adaptive options in case 21 with the changed rule 3 (vulnerability of robots). As rule 3 is closely related to rule 2 (functions and vulnerability of robots changed depending on the colors of robots), it is evident that players also gradually detected and applied new rules similar to cases 14 and 15, although the point of application differs individually.

The survey was conducted to examine the game play experiences of the students. Students were asked whether they detected any changes in the scenario (i.e., behavior of turrets) and when they detected the change for the first time. Out of 12, 11 students reported that they detected the changes in the scenario. The detection moment varied per player. Most of the students said detecting the changes was obvious and easy. However, the student who reported 'did not detect the change' described that the amount of information in the game overwhelmed the player to detect any changes. This participant scored total of 59 out of 100 and left the comment that 'I had a long day today.'

The visibility and usability of the game was assessed by means of open questions. Some students reported that maps were unclear and the game contains too much text and information. Others reported that the maps are useful and the game is very easy to use. Afterwards, students were asked to answer an open question on what they thought the game was about. Most of students mentioned complex decision making and one participant specifically wrote that the game is about dealing with situational change.

Figure 5 shows the students' opinion ratings on difficulty, engagement, motivation, and concentration in the game play. Overall, the engagement and motivation were scored positively. The difficulty of the game differs per individual. It is possible that the game is difficult for some students due to their unfamiliarity with decision making in a military context. Another possible reason could be the amount of complex information and missing information (fog of war) while decisions have to be made under time pressure. As for concentration, some students reported they were distracted. Fatigue could be a plausible explanation for low concentration as the testing session started at 15:30. It was the last session of the game introductory workshop, which started at 09:00.

Conclusion

In this paper, we reported the objective, theoretical framework, the game design and game testing results in order to develop a SG to train adaptability of military officers. The testing results cannot automatically be regarded as representative for the military population, as the participants were Master's students in Game studies. Their knowledge of, and experience with, games could yield different results from those of military personnel.

This game will be improved based on the game testing results and comments. Afterwards, the game will be used during the training at the Major's school in the Netherlands in order to increase the adaptability of the officers [15]. Future studies should examine whether this game can improve adaptability and investigate the learning effects of the game intervention, as this research was an exploratory study on the game design only. ■

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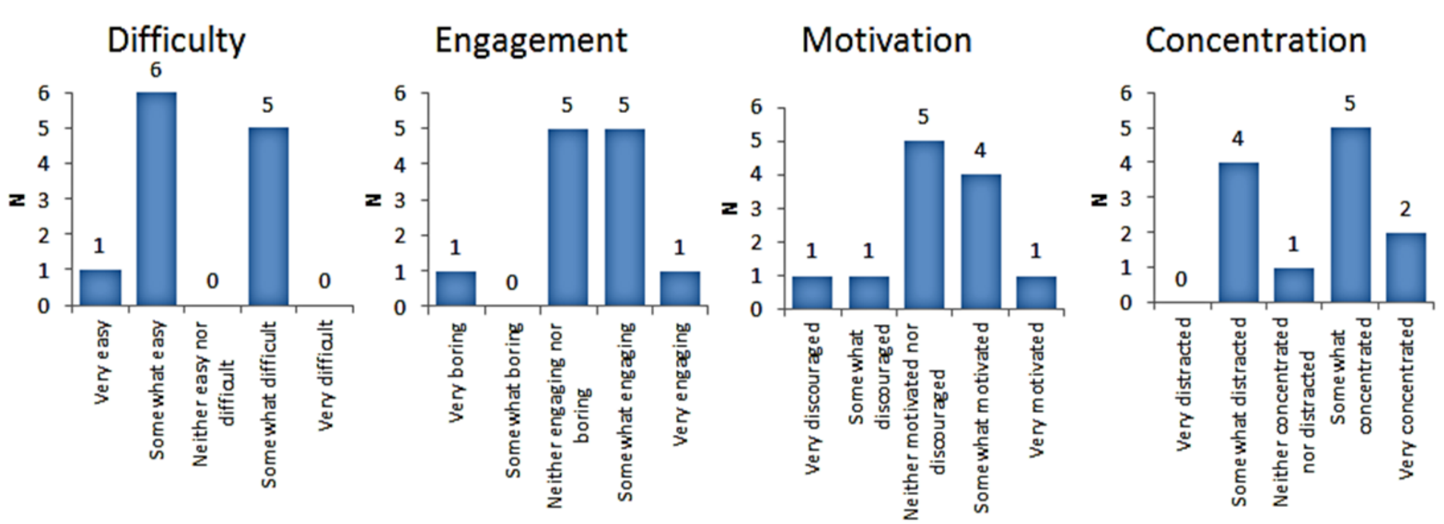

Figure 5: Results of students' assessment on the game

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CROWD-DRIVEN TACTICAL DECISION GAME: TRAINING TACTICAL CREATIVITY

By: Rudy Boonekamp, MSc, Floor Thönissen, MSc, and Maj. Erik Douze

In this article we describe how we used the concepts of serious gaming and crowd-sourcing to design, develop and play-test a game to train tactical creativity for staff officers (level 5-6, battalion and brigade) in the RNLA. In the game, trainees solve complex tactical challenges, analyse and discuss them with peers in a structured manner and make adaptations based on the creative insights they gain. Evaluation of the proof-of-concept shows that the crowd-driven game is a promising way of social learning for tactical creativity.

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Introduction

The (Dutch) Ministry of Defense has to operate in a fast-changing, dynamic and complex world. The armed forces need to always be able to conduct several sorts of missions and the Chief of Defense must at all times have units ready to contribute to (international) missions. But, like many other Ministries of Defense, the Dutch Ministry has been facing financial budget-cuts for many years. Ever since the economic crisis a severe decrease in defense spending has been ongoing. The budget-cuts have led to several consequences, one of which was the fact that less money is available for training and education of military units at all levels.

In order to retain a certain level of readiness other means to educate and train military personnel have been sought. One option is the use of simulation. Like the Dutch Ministry of Defense's Strategic Knowledge & Innovation Agenda (SKIA) puts it: "simulation can be used for education and training purposes, but also for other purposes like mission preparation, doctrine development etc." (SKIA 2011-2015). According to the SKIA, simulation, and serious gaming in particular, can play an important role in (partially) preventing, or at least minimizing, a decline in readiness in certain training areas. In order to do so the potential of serious gaming must be used to the utmost.

simulation can be used for education and training purposes, but also for other purposes like mission preparation, doctrine development etc.

The goal of our research project was to establish how the use of serious gaming can enhance the education and training of the individual staff officer at level 5 (battalion) or 6 (brigade). The present article is the result of that 2-year research project. In order to gain insight into the education and training related challenges that staff officers at level 5 and 6 face, we conducted a series of 16 interviews with army officers and other subject matter experts, we visited exercises and we studied literature. This paper describes how we think that serious gaming can help the individual staff officer gain knowledge and experience in one particular topic, tactical creativity, by playing the "crowd-driven tactical decision game". The central research question is "is it possible to (better) train tactical creativity by using a serious game?"

Tactical Creativity

In the exploration phase of the project the main goal was to determine what the biggest challenges are in the education & training branch of the Royal Netherlands Army (RNLA). In order to do so we conducted interviews, observations and did a literature study. All our interviewees (16) were somehow involved in the education & training branch of the RNLA and / or have affinity with serious gaming. Moreover we have observed during staff exercises and used literature to get an idea of the challenges in the education and training branch.

During the interviews, several topics came up. Topics ranging from "thinking out of the box" to "efficiency of large-scale exercises" were mentioned by various interviewees. There was however one topic that was mentioned as an important challenge by all 16 interviewees and that is the problem of tactical creativity. According to the interviewees, officers are not / no longer proficient in 'The Art of War'[1], because there is too little time available to train them in this topic. The Art of war "requires the intuitive ability to grasp the essence of a unique military situation and the creative ability to devise a practical solution". (US Marine Corps, 1997: 18). An important topic, however in the current set-up of the education & training cycle, staff officers gain only some experience with it.

Tactical creativity is an important aspect of the Art of War and is defined as thinking and reasoning fast and without knowing everything being able to come to a plan or a decision. This plan does not have to be perfect, since "there is no such thing as a perfect strategy or even plan; indeed, to seek such perfection is to forget or deny that the enemy is not inert and has a free creative part in the conflict which is directly opposed to one's own. As such, one should be seeking to devise a strategy that is better than his in the circumstances" (Smith, 2005: 13). Even though the plan does not have to be perfect, it needs to be composed faster than your adversary's plan. For this, tactical creativity is indispensable.

We found that within the education and training branch of the RNLA, attention is mostly focused at things that are somehow measurable. This is not surprising of course, because it is only human to want to determine what the result of an effort is. The effect however is that during exercises only an operations process is carried out with too little focus on the quality (i.e. suitability) of the plan.

But by 'just' following the steps to come to a plan, there is very little need for the staff officers to be creative during the process.

A critical article written by a captain of the RNLA identifies and summarizes the problem of tactical creativity as well. He puts that the desire to measure effects (in exercises) hinders the way tactical creativity ought to be trained. The exercises are not dynamic enough because education within the military focuses mainly at analytical skills and not on the actual execution of the plan. As Captain Soldaat[2] puts it: "tactics needs to be exiting, fun and dynamic again, because that is the sole essence of tactics. The best way to enable this is to use a game" (Soldaat).

1 The Art of War refers to classic treatises, written by, amongst others, Sun Tzu and Clausewitz.

2 This article dates from some years back. The writer is currently lieutenant-colonel and still active within the RNLA.

Tactical creativity; a definition

In order to address the challenge of training tactical creativity, a clear definition of the concept is needed.

Creativity
Creativity is a broad concept that knows many different definitions. For our project we have used Sternberg and Lubart's definition of creativity. They define it as follows: "it [creativity] is a production of ideas, insights or products that are both original and suitable" (Sternberg & Lubart, 1999). Ideas that are original but not a suitable solution to the problem are considered irrelevant.

Tactics
The Dutch dictionary describes tactics as a "well thought-out plan to reach your goal". In order to develop such a (military) plan, battalions and brigades in the RNLA use a tactical decision making model.

Tactical creativity
What then is tactical creativity? Using both earlier descriptions we can describe tactical creativity as follows: "it is a way of thinking where original, yet useable insights, help to reach a military goal".

Types of creativity
In her research on creativity, Margaret Boden (2004) identifies three types of creativity. Where conceptual creativity explores the possible actions to be taken within a set conceptual space, transformational creativity bends the rules of this conceptual space in order to extend the possibilities. The third type of creativity, novel combination creativity, is about making unfamiliar combinations of familiar ideas. This concept is of particular interest in this research as interviews with didactical experts and the Ministry of Defense's competence dictionary indicate that exchanging ideas between peers can lead to new, more creative solutions to a problem.

Concluding, we will explore how the concept of novel combination creativity can be used to gain original, yet usable insights that help reach a military goal.

Gaming for tactical creativity
A game can help present the tactical situation in an engaging manner and let actions and solutions be programmed. These solutions can then be shared among trainees for creative reflection. To explore this potential, we first examine the state of the art of serious gaming for tactical training.

Serious Games for Tactical Creativity

Serious games and simulations are already being used for tactical training at several levels of command in NATO military forces. Especially at platoon and company level the use of serious games for tactical training is common. Simulations like Virtual BattleSpace and Steel Beasts are used to practice combat procedures. However, when concerned with battalion and brigade level, decision making becomes more complex, procedures become less strict and simulation less straight-forward.

In this chapter we explore what games are being used for tactical education and training at this level of command, and if these games support the training of tactical creativity. By determining the game elements successful for training tactical creativity, this serves as a starting point for developing a dedicated tactical creativity game concept.

A number of games have been reviewed varying from proven designs to experimental concepts and from commercial products to hobby projects. The results are based on expert sessions with the Simulation Centre of the RNLA, literature research and a visit to the 2014 CONNECTIONS wargaming conference in Quantico, USA.

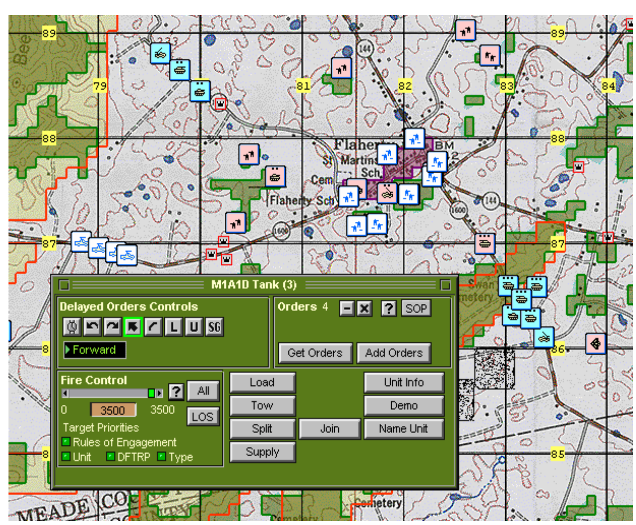
The games are distinguished on four main characteristics:

- *Interface*: The way players interact with the game. By digital or paper interface?
- *Adjudication*: The means of judging actions and effects. By a human judge, rulebook or digital model?
- *Perspective:* The way the state of the game world is represented. Conceptual indicators, a tactical map or a virtual environment?
- *Single/multiplayer*: Whether the game involves one or more players.

Three typical game examples are discussed below.

TacOps4 – A single player, digitally adjudicated game

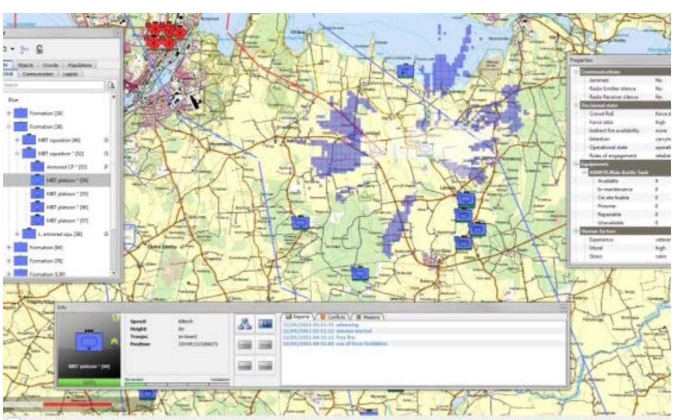
Interface	Digital
Adjudication	Digital model
Single/Multiplayer	Single player
Perspective	Tactical map



TacOps 4 is a game about modern tactical warfare, and is an officially issued standard training tool in the US military. Tactical maneuvers are simulated on battalion and brigade level. The collection of vehicles, units and weapons from BLUFOR and OPFOR forces is elaborate and these can be issued a range of maneuver related orders. However, the type of actions that the trainee can include in his course of action are predetermined and especially when one considers a more comprehensive approach, for example influencing local population, the limitations of the game are clear. This is no bad thing as the learning goal is tactical procedures, but for encouraging tactical creativity this game design is limiting. The design with predetermined actions and predetermined effects without a human adjudicator in the loop, makes a digital model responsible for responding to complex battalion or brigade level decision making. Additionally, more complex collaborative or adversary interaction is limited because the game is single player only. Human ingenuity still trumps digital models when it comes to out-of-the-box tactical solutions.

MASA Sword: A multiplayer, digitally adjudicated game

Interface	Digital
Adjudication	Digital model
Single/Multiplayer	Multi player
Perspective	Tactical map



MASA Sword is a wargame that simulates forces with a high level of artificial intelligence, used for tactical training and analysis. Compared to the previous category of game, it is more complex in that it supports a large number of human players as allies or opposing forces. Furthermore, it includes tools to model AI decision trees, making it possible to expand the digital adjudication model. Still, the decision trees pass judgement on player actions given a predetermined set of parameters, which not necessarily encompass the complexity of a players reasoning. Thus, while multiple players explore their conceptual space and apply novel combination creativity, they cannot apply transformational creativity.

While this simulation platform is great for training and analysis of tactical procedures, it will not likely result in unprecedented tactical solutions, such as the case of the historic battle for castle Itter, where German forces allied with US forces to defend against SS troops.

Diplomacy: A multiplayer, human adjudicated game

Interface	Board game or digital
Adjudication	Human / rulebook
Single/Multiplayer	Multi player
Perspective	Tactical map

Diplomacy is a game in which players represent one of seven world powers in Europe at the start of the 20th century. The goal is to take ownership of as many supply lines as possible. Originally, it was released as a board game but in 2005 a digital version was published. The game is a great example of a limited set of simple rules combined with the complexity of human strategizing and the freedom of partly human adjudication. The game master can take into account not just the player's actions, but also the reasoning behind them, and respond accordingly. These characteristics support all three types of creativity, including transformational creativity, and therefore innovative, unpredictable solutions can be played out.

The three game examples above illustrate how multiplayer, human adjudicated games are best suited for training both conceptual, transformational as well as novel combination creativity. Therefore, teaching tactical creativity is most feasible in these kind of games. The human-in-the-loop design is essential for this learning goal. Current classes in the MMO course already include such training in the form of paper Combat Tactical Challenges (CTC), but the nature of the paper-based approach makes it harder to share creative solutions among trainees, anytime, anywhere. The idea was formed of creating a digital platform that leverages the concept of crowd sourcing to make tactical challenges more accessible and to gather and exchange volumes of creative insight.

Crowdsourcing

Examples of crowdsourcing are ubiquitous in the current day: Kickstarter projects ask crowds for micro-investments in innovative technology, the protein folding game Foldit uses the combined wits of thousands of volunteer players for scientific efforts and increasingly social media is used by commercial and governmental bodies to source opinions and judgements. Given that it sees such varied usage, a clear definition of the concept is desirable. According to an extensive literature study, crowdsourcing is "a participative online activity in which a non-commissioned, undefined public is called upon for the voluntary undertaking of a task" (Estellés-Arolas & González-Ladrón-de-Guevara, 2012).

In history this voluntary concept has been applied before, such as gathering meteor observations of the public for astronomy research, but the emergence of online platforms has enabled crowdsourcing to become much more practical. Online or digital platforms make it possible to reach out to a worldwide audience, with minimal delay. This way, creative input can be sourced or digital tasks can be distributed. Often, volunteers are intrinsically motivated to contribute, think for example of Wikipedia contributors or moderators. In other crowdsourcing applications, game elements motivate participants to engage in seemingly boring tasks. For example, the Foldit game uses 3D visuals and a points reward system to create incentive. The AstroDrone project challenges players to fly a drone through an augmented reality obstacle course; while it collects data on facial expressions.

The premise of crowdsourcing combined with gaming elements, namely intrinsic motivation to engage in meaningful tasks, could be applied to the process of learning. Where gaming elements can help the student engage with the learning material, the crowdsourcing element can support social learning by exchanging insights and lessons learned with peers. To see if this idea could potentially help educate tactical creativity, the concept of the Crowd-Driven Tactical Decision Game was developed.

The Crowd-Driven Game Concept

To determine whether crowdsourcing indeed has potential for training tactical creativity, a game concept was designed and implemented as proof-of-concept at a technology readiness level (TLR) of 3. The goal of this proof-of-concept is to give an impression of the gameplay and to determine whether it can be of value for education and training for the Defense organization. In an evaluation session, the game concept was used to evaluate learning outcomes in a mid-career course on tactical level land operations (MMO) in a classroom setting.

Game design process

To work towards an innovative concept, an iterative process of design was used. First, a paper prototype of the game was developed and evaluated with Defense and TNO experts in the field of simulation and gaming. Based on the feedback, the first digital version was implemented and play tested with instructors of the MMO class. This led to the second and final version of the game for evaluation in a pilot with MMO trainees.

Game concept

The game concept is a Combat Tactical Challenge (CTC) where trainees are challenged to solve tactical problems on a digital tactical map. However, the trainees are also asked to analyze and dissect each other's solutions. This is facilitated by a digital interface that visualizes the differences between individual solutions in terms of military principles. A database stores all tactical solutions – a growing database of tactical approaches that can serve as inspiration for subsequent classes.

The game concept combines the proven use of CTC in the MMO class with the innovative aspects of crowdsourcing and peer analysis.

- Crowdsourcing: Trainees generate tactical solutions for a series of tactical scenarios. These solutions are stored in an ever-growing database. By collecting solutions through the years, a substantial database of tactical knowledge with different creative approaches arises. This database can then be used to inspire tactical decision makers within the military. Furthermore, the fact that one is contributing to a body of tactical knowledge can enhance intrinsic motivation for learning, as it is no longer one-way traffic.
- Peer analysis: By asking trainees to analyze each other's solutions in a structured manner, they gain insight in the diversity of tactical approaches. The structured approach involves the use of 13 tactical characteristics for deliberation, which stimulate the trainee to think outside the box yet within suitable and realistic bounds. An important aspect is that trainees are not asked to judge solutions as right or wrong, but to characterize them by attributing a fixed number of points over the 13 characteristics. In this way, diversity is stimulated by not focusing on a singular optimal strategy. The alternating role between problem solver and analyst creates an opportunity to gather creative inspiration and directly apply this in an adaptation of your earlier solution. The face-to-face interaction between trainees in this process of alternating roles harnesses social learning.

Design of the digital environment

The proof-of-concept has to meet a number of practical demands:

- It has to be playable on standard-issue laptops in use in the classroom
- The tactical solutions have to be stored centrally on the network
- The freedom for tactical solutions should not be limited by digital interface interaction

Platform

A web-based platform based on ASP.Net, JQuery and SQL was chosen to quickly develop a prototype that can be accessed easily

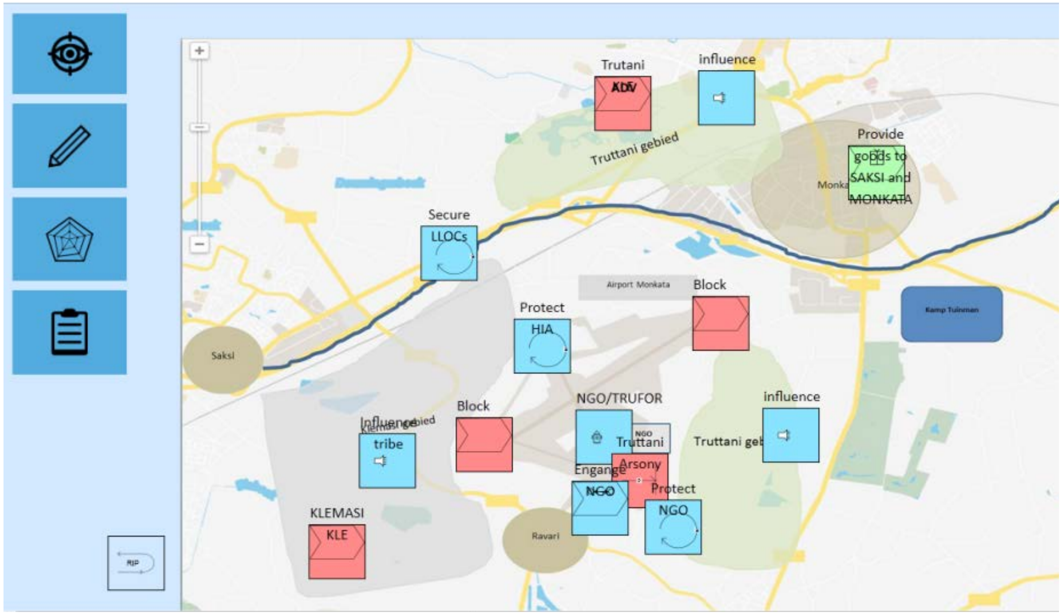


Figure 1: A solution drawn on the tactical map

in a distributed manner. The use of JQuery allows for relatively easy adaptations in interaction-design. ASP.Net provides standard functionality for a Model-View-Controller framework and SQL takes care of the central database. These development frameworks have allowed us to make quick progress in an iterative manner.

Menu interface

The interface of the game is opened in a web-browser. The trainee logs in with his or her personal account, and chooses to either view solutions or to solve challenges. The trainee then chooses a scenario. In case of viewing solutions, the trainee can choose from all solutions that are available in the database for the given scenario. The main tactical map view of the game is first displayed.

Tactical map view

The tactical map is schematic with limited detail information on the terrain. There is also no possibility to zoom in to a more detailed level. This is chosen so trainees are not tempted to micro-manage their tactical approach: comparisons should be made at the same level of abstraction.

Database

To store tactical solutions, a data model was created that connects the identity of trainees, solutions, tactical scenarios and instantiations of standardized tactical symbols from the military APP-6C and comprehensive approach V1227 tactical symbol sets 3. Furthermore, the analysis of tactical solutions are stored. This makes it possible to characterize solutions by averaging over a number of analyses.

Tactical symbols

An important design decision was to limit the usual APP-6C symbol set, because it is nigh impossible to work swiftly with more than a thousand symbol possibilities. Therefore, based on an analysis of tactical solutions from earlier classes, the symbols where limited to the task-verb and operation activity categories of APP-6C and furthermore the whole of the V1227 comprehensive approach symbol set. The total number of possible tactical symbols amounts to 45.

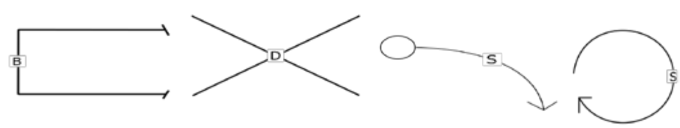


Figure 2: Task verbs breach, destroy, seize, secure

When placing symbols on the tactical map, the trainee is asked to add a descriptive text of the effect and furthermore the actor/unit the symbol relates to. More extensive functionality, such as adding comprehensive approach themes or drawing areas of effect for a symbol, has not been implemented.

As we do not want to limit the creative freedom of the trainee, he should not be limited to the symbol set only. Therefore, the trainee also has the option to use a free-drawing tool. This can be used to supplement symbols with areas of effect, movement directions, and so on. These illustrations are stored together with the symbols in the database.

Analysis interface

As the trainees switch role from problem solver to tactical analyst, they enter a different interface view. In this interface, the trainee

3 The V1227 comprehensive approach symbols have been developed in a different TNO project. The symbols have been used and tested in various other, earlier, planning exercises by the RNLA. The symbols are not used in a NATO context yet.

controls a spider diagram with 13 dimensions, each representing an aspect of tactical characteristics:

- Versatility
- Surprise
- Sustainability
- Safety
- Legitimacy
- Economical use of resources
- Simplicity
- Offensive action
- Independence
- Development activities
- Hearts & Minds
- Diplomacy
- Collaboration

Each dimension can be attributed a maximum of 5 points, out of 40 points in total that have to be attributed. By dragging the axis of each dimension, the trainee divides the points according to what he thinks is the focus of the solution. In this way, a tactical blueprint is created that is descriptive of the solution, at least according to this analyst. These blueprints are aggregated and stored in the database.

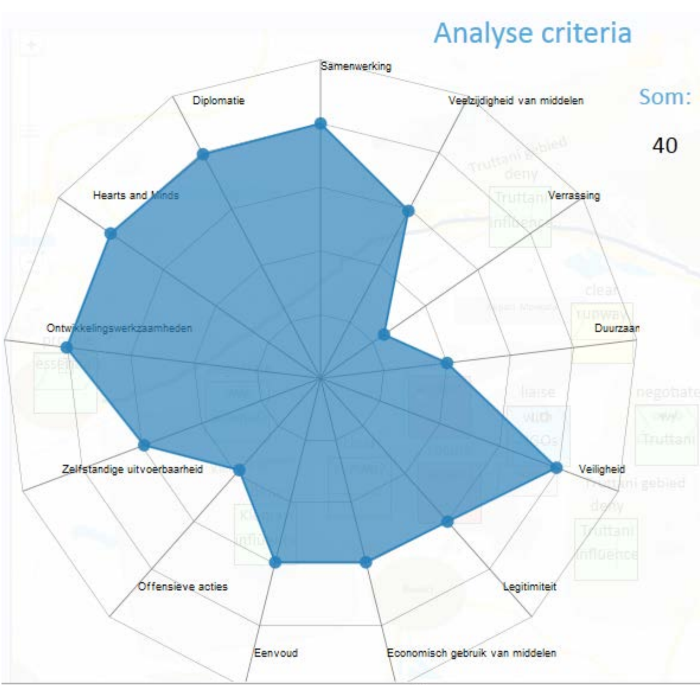


Figure 3: The analysis diagram

Step-by-step game process

The game play cycle consists of three main steps. Some steps are done individually, others are done in couples.

Step 1: Tactical solution (individual)

The trainees are introduced to the problem scenario and get 60 minutes to enter their initial solution in the digital interface.

Figure 4: Trainees working on their initial plan during the pilot

Step 2: Analysis (in couples and individual)

In the second step, the trainees come together in couples and asked to explain their tactical solution to each other. They then separate and judge each other's solution using the analysis criteria in the digital spider diagram.

Step 3: Adjustment (individual)

Based on insights in other solutions, and feedback from the judgement of other trainees, the trainee now gets the opportunity to adjust his tactical solution, or even create a completely new one.

The game session ends with a plenary classroom reflection and discussion on the initial solution, insights and adaptations based on the peer-analysis process.

Limitations of the proof-of-concept

The proof of concept was built at a TRL of 3 and therefore there are some limitations to its implementation, when compared to the design outlined above.

To share solutions, network file sharing was used instead of a fully functional database. This choice was made as our database implementation was not complete enough to guarantee an unrestricted creative process. This means the premise of an ever-growing database of tactical solutions still remains to be tested.

Discussion about the tactical solutions was done in person in the classroom, while the finalized concept would offer the possibility to view, add and discuss solutions in the web-based application.

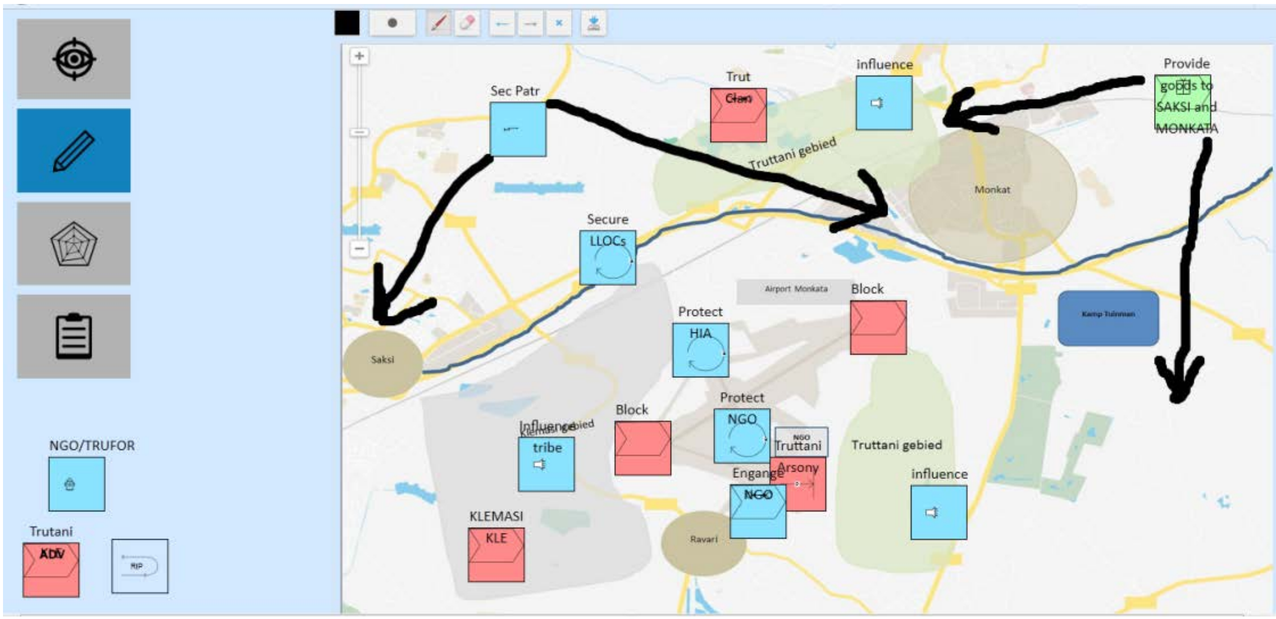


Figure 5: The adjusted plan of one of the trainees

Pilot

To evaluate the premise of the crowd-driven tactical decision game we conducted a pilot with our primary target audience, battalion and brigade staff officers. The pilot was carried out during a mid-career course on tactical level land operations in the RNLA (MMO). The 14 participants, all MMO trainees, are ranked Captain or Major and their background is diverse; from infantry officers to medical doctors. The main goal of this particular course is to prepare the officers to function as staff officer at level 5 or 6 and therefore much attention is paid to the Tactical Decision Making process. The level and experience of the participants vary; some of them have already acted at level 5 or 6 where others have not. In our pilot group the division between experienced and non-experienced at this level was about 50/50.

A scenario was developed based on the general Trutta scenario that is often used for comprehensive approach training in the RNLA. The participants were challenged to act as the commander of the Dutch troops in Monkat, Trutta, contributing to an international operation carried out by a coalition of the willing.

The scenario provided the participants with several capacities (construction, logistical, a battlegroup and a staff). The participants were free to use other capacities (available via the next-higher level) if needed. The mission's goal was to establish peace and stability in the region and to monitor the conflict between two rivaling clans. A central challenge in the scenario was the restoring of the control of the airport in the area, a central hub for food supply etc., which had been taken by insurgents from both (rivalling) clans. It is the commander's task to make sure that the airport is freed from the sieging parties and made operational as fast as possible. It is to be suspected that the insurgents will not accept this without a fight. The participants were challenged to define their Course of Action within the hour.

Results and reactions

During the pilot we have observed the reactions of the participants, and asked them to fill out an evaluation form to get their feedback on the CDTDG concept. We asked their feedback on the design (user-friendliness), content of the game and on their motivation to play the game if it would be made available to them (future use). The first reactions to the concept and the user-friendliness of the game were positive. The participants were able to use the system without much explanation from our side and the debates on the plans were lively and triggered discussions amongst the participants.

Available time

In our set-up we gave the participants 60 minutes to develop their initial plan. However while they were busy working on their plan we noticed that 60 minutes was not enough and therefore extended this to 75 minutes.

Use of symbols

There was a great difference between participants who immediately used the symbols provided by us to draw their plan in the digital environment and the participants who first designed their plan on paper, without using the symbols. The instructors identified the participants using the symbols as the experienced staff officers at battalion or brigade level. The participants who found the use of the symbols difficult had –in general- no experience at this level. Eventually all participants were able to draw their plan in the digital environment.

The scenario

We did not use a 'standard' scenario that is normally used in exercises. We did this on purpose hoping that we could persuade the participants to think differently. The scenario we used was fully written out and little to none military abbreviations were used. Overall the participants could work with the scenario, but some told us they missed the Organization of Battle (ORBAT) and the commander's intent.

Reflection and analysis

The digital environment was regarded as the essential part of the game. Discussing and analyzing each other's plan was not directly seen as part of the game. During the pilot the atmosphere amongst the students during the reflection, feedback, discussion and analysis was rather casual. The plans were heavily discussed, but in the end not many of the participants adapted their original plan. The participants did tell us that this last step is useful. Why then not many of them adapted their plan (or only very limited) has not become clear to us. Perhaps the participants were (still) satisfied with their original plan.

Criteria for analysis

The criteria for analysis we provided to the participants were useful to analyze their peer's plan, however all of the participants missed some criteria. In general the participants listed the fundamental principles for military performance as most important. If the game is further developed in the future, these principles will be used as analysis criteria. Other criteria that were suggested are, for instance: is the plan the right estimate of timings and space? Are the desired effects accomplished?

The digital environment

As mentioned before, all participants could easily work with, and in, the digital environment. Except for some small design mistakes the digital environment functioned as designed. All participants did however give us the feedback that they would rather see this game environment integrated into one of the systems that are already in use by the RNLA, for instance Steel Beasts. This is a conclusion that we had already drawn and for a possible further development of the game this is indispensable.

Feasibility for training tactical creativity

The participants indicated that playing the game and discussing their tactical solutions helped them reflect on their tactical options. When asked whether the game could improve their tactical creativity, most participants answered positively.

Future of the game

We asked the participants whether they would voluntarily play this game if this was available at the workplace. Interestingly enough their feedback was that they would like to play the game more often, but that they felt like they would not have the time. This is in line with our previous experience with informal learning; when people are busy in their daily life, these are the types of activities that people tend to skip first. We therefore have concluded that for the game to have to desired effect, it must either be easily accessible anytime, anywhere, or integrated in the education and training curriculum.

Conclusions and Recommendations

The main research question in this paper was "is it possible to (better) train tactical creativity by using a serious game?" This research presents an indication that the use of peer analysis and crowd-driven game mechanics can indeed help train tactical creativity. While the Crowd-Driven Tactical Decision Game was implemented as a proof of concept only and tested on a small scale, military officers offered positive feedback regarding the future usage for training tactical creativity. The results of the pilot lead us to believe that with more refinement and higher production values, this concept can be turned into an effective training instrument.

Future use

The participants were very positive about the idea of using crowd-sourcing within the Ministry of Defense. But on the question whether they would play this game when it is not part of an assignment or their daily job, we received less enthusiastic responses. Participants indicate that they are too busy with their daily tasks.

One solution may be to make the game more attractive and easily accessible anytime, anywhere. This is why a follow-up project was initiated that explores the use of tactical challenges in a mobile application.[4]

Another solution is to make the game part of the education & training curriculum and guarantee structural use through inclusion in classroom sessions.

The premise of crowd-sourcing

Once the game is structurally used in classes throughout the years, a growing body of creative tactical solutions can be recorded in the database along with their characteristics. This enables future trainees to make more novel combinations of tactical solutions. In this way, the learning material becomes fluid, able to include new solutions for a changing solution space: warfare in the battlefield of the future. The potential of crowd-sourcing for both social learning and adaptation to the changing circumstances of warfare, is enticing.

4 The 'Mobile Gaming' project led by Tijmen Muller explores the use of mobile games for military training

Modeling of effects

While participants indicated that they were learning from each other's tactical solutions, they were hesitant to adapt their plans. A possible explanation is that because the game does not present any effects, the participant has no clear indication of which solution is better suited. In future, partial digital adjudication could give more incentive to adapt. However, it remains of utmost importance to refrain from judgement as right or wrong, in order to stimulate creativity. ■

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EARLY SYNTHETIC PROTOTYPING
DIGITAL WARFIGHTING FOR SYSTEMS ENGINEERING

By: Robert E. Smith, PhD and LTC Brian D. Vogt

It is widely accepted that many state and non-state adversaries are approaching technical parity with United States military. This is especially the case where commercial research and development produces militarily useful technologies such as cyber, robotics, and drones. (The Operational Environment and the Changing Character of Future Warfare, 2017) The global diffusion of technology has reduced the cost of entry barrier to technological warfare. In fact, in many areas, commercial research budgets far exceed DoD expenditures. Often when the DoD does develop technological "things", the duration of advantage often quickly erodes as technology is the easiest thing to copy.

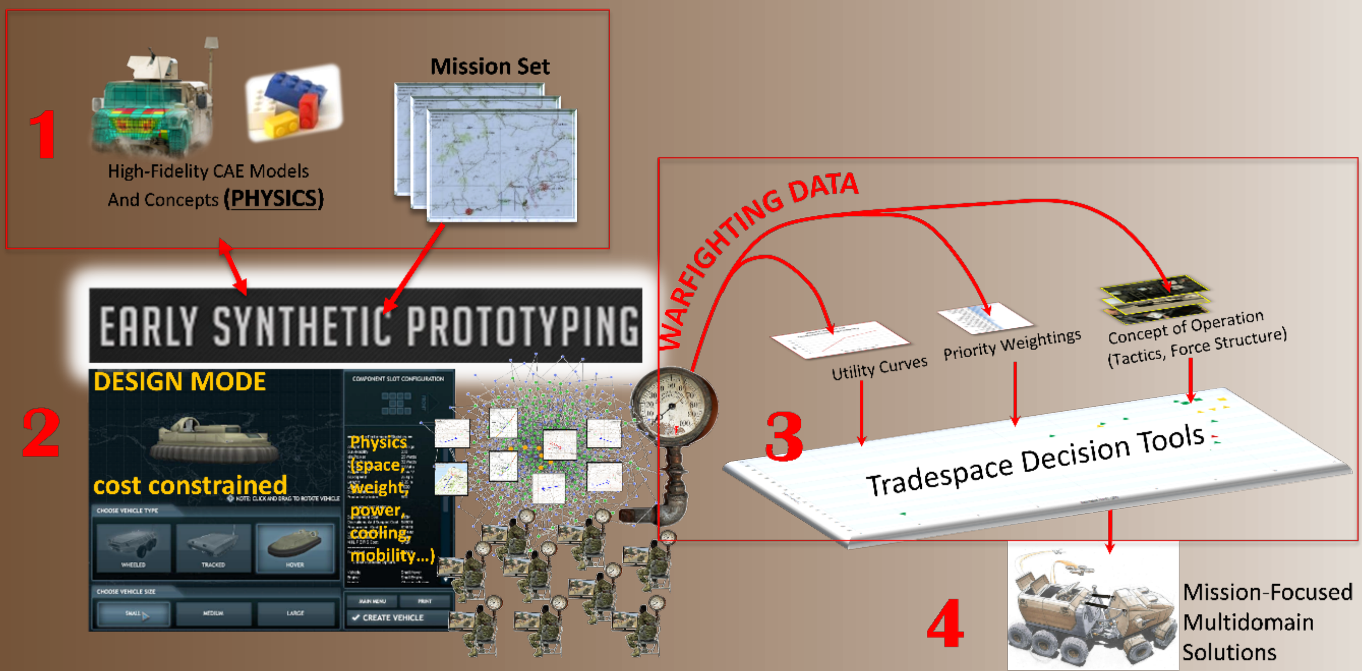


Figure 1: Physics-Based Digital Warfighting Connection to Tradespace Decision Tools.

Technological overmatch is still achievable in the time domain by creating a faster process to ingest and operationalize new technologies from anywhere. The hardest thing for U.S. adversaries to duplicate is the integration of advanced technologies with skilled soldiers and well-trained teams. Investing in an advanced process to operationalize technology will produce an enduring source of overmatch versus purely creating technological "things." Succinctly stated: "Process over Platforms." (Martin & FitzGerald, 2013)

Early Synthetic Prototyping

Early Synthetic Prototyping (ESP) is an effort to construct a physics-based game environment to rapidly assess how technologies might be employed on the battlefield. ESP is presently led and funded by the Army Capabilities and Integration Center (ARCIC) and supported by U.S. Army Research, Development and Engineering Command (RDECOM) labs. The first effort is a small unit first person shooter entitled Operation Overmatch. The bulk of this paper will focus on Operation Overmatch. Operation Overmatch is currently at an alpha stage at the time of this writing and expected to be production-ready by October of 2019. There is a lot of challenging research that needs to be performed to integrate ESP in systems engineering processes, especially in the area of data analytics.

ESP is envisioned to be a persistent game network that allows Soldiers to play scenarios and provide experiential feedback to concept and capability developers. Soldier assessment from the game environment will be used to inform materiel tradespace exploration while simultaneously assessing force employment and force design development. ESP will greatly enhance the communications between engineers and Soldiers. Engineers often lack a deep understanding of how new materiel may be used and what performance is needed. At the same time, Soldiers gain an early understanding of potential new technologies for the U.S. Army and how a future enemy might exploit the same. Here's how the process might work:

First, concept and capability developers, as well as scientists and engineers from across the Army will postulate various force employment, force design, and materiel capability theses. These ideas are then modeled in the game environment with an appropriate amount of physics rigor. Scenarios are created that specifically address what the Army wants to learn about the postulated solutions. For example, the Army may want to explore how future platoons should be equipped and employed in an airfield seizure against a near-peer threat.

Next, the game is distributed to Soldiers across the Army (presently over Steam, a digital gaming distribution platform developed by

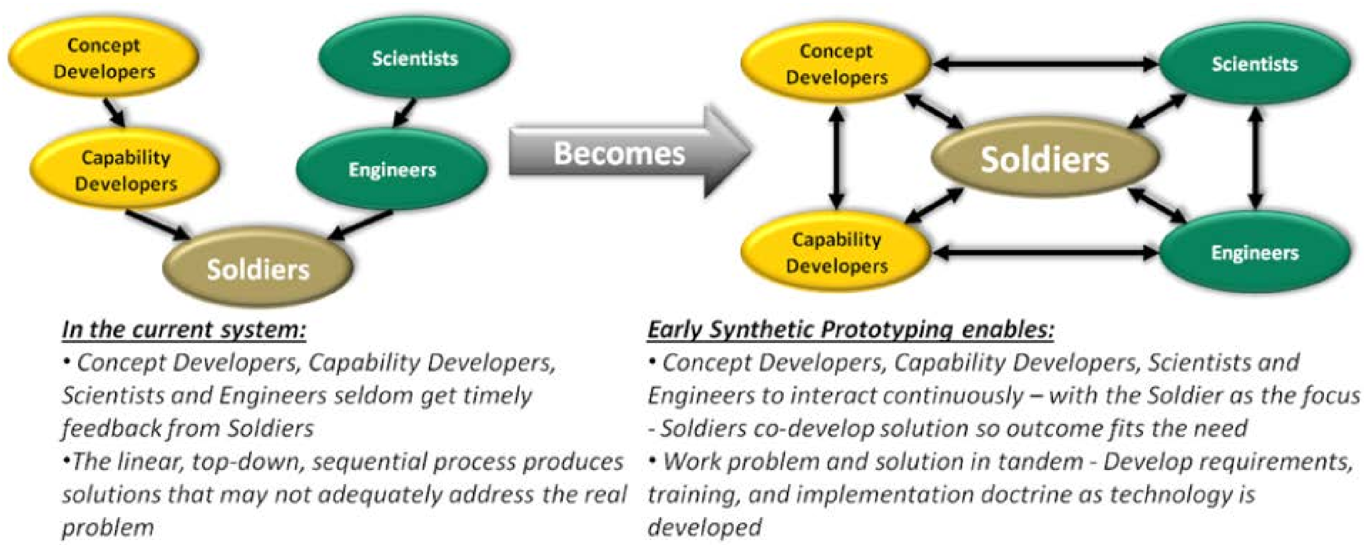


Figure 2: Early Synthetic Prototyping Enables Soldiers and Engineers to Co-Develop Solutions.

Valve Corporation) and they are able to learn how to use and modify the equipment in single-player missions before engaging in multi-player scenarios against other Soldiers. Some Soldiers will play as an opposing force using emerging threat platforms and some will play as the U.S. player. Following each scenario, the players are able to provide feedback about what they liked/disliked and provide recommendations. Additionally, the game server will collect game data for analysis. This process is intended to repeat continuously with changing equipment, scenarios, organization, goals, rules, and objectives.

Where ESP Fits with Systems Engineering

The idea of ESP fits tightly with the latest Office of the Secretary of Defense (OSD) systems engineering initiatives: Digital Engineering (Gold, 2017). ESP also supports the OSD Mission Engineering concept (Gold, 2016) that treats the end-to-end mission as the system in the operational context to drive performance requirements for individual systems. Inherent in Mission Engineering is to use an assessment framework to measure progress towards mission accomplishment through test and evaluation in the mission context. ESP creates a digital operational assessment loop and provides measurable data to systems engineers as shown in Figure 1.

Starting in the upper left, technological solutions are analyzed using traditional higher-fidelity computer aided engineering (CAE) simulations. These simulations are turned into real-time lookup tables inside the game to assure accurate game physics. Scenarios are simultaneously developed over some mission set. Next, players can use design mode to construct a vehicle (in this case) that they feel will best achieve the mission at a good score. Players are provided a limited virtual budget which would allow them to, for example, up-armor the vehicle. Up-armoring will add weight and cause more rollovers and slower acceleration during the game. Budget constraints assure Soldiers do not simple pick the highest tech solution and forces them to make cost-constrained trades based on their evolving virtual experience.

The current process of developing a capability from concept to product is a largely linear process that seldom gets continuous feedback from Soldiers. According to Boehm (2010), "The weakest link in SE is often the link between what the warfighters need and what the development team thinks they need, together with a shared understanding of the operational environment and associated constraints and dependencies." GEN Perkins stated when presenting Win in A Complex World (Perkins, 2015), "A CONEX full of electronic gear is not a capability…that is a property accountability nightmare…a capability is technology in the hands of Soldiers, who are trained to use it, and can apply it on the battlefield." When Soldier feedback is captured, it is typically from small focus groups of Soldiers. The ESP process enables continuous feedback among all stakeholders as illustrated in Figure 2.

There are several advantages of incorporating ESP into the concept and capability development process. First, ESP allows Soldier feedback early in the development process where design changes are significantly less expensive in terms of resources, time, and money. Second, ESP allows orders of magnitude more design options to be explored in a crowd-source game environment because Soldiers could make changes in model performance in a game environment in a short period of time whereas physical prototyping could take weeks, months, or years to change a physical prototype's characteristics. Third, the ESP process enables the

Army to develop a greater understanding of the problem while developing a greater understanding of potential solutions that span materiel (capabilities), doctrine (force employment), and organization (force design) considerations.

Early Synthetic Prototyping might inform tradespace tools such as Army WSTAT (Edwards, 2012) and Marine Corps FACT (Browne, Ender, Yates, & O'Neal, 2012) as shown in area 3 of Figure 1. For example, ESP warfighting data could allow data-centric rank ordering of performance requirements instead of relying on subject matter expert (SME) options. Additionally, tactical utility functions may be computed on requirements to assess the mission success value of exceeding threshold towards objective requirements of various engineering solutions over multiple vignettes. Tactical utility may be loosely defined as: Probability Mission Success / Total Burden.

Allowing soldiers to test-drive virtual systems in various operations will enable program managers to compare system resilience and tactical utility against cost, schedule, and risk. An example of how this might look for an analysis of alternatives is shown in Figure 3.

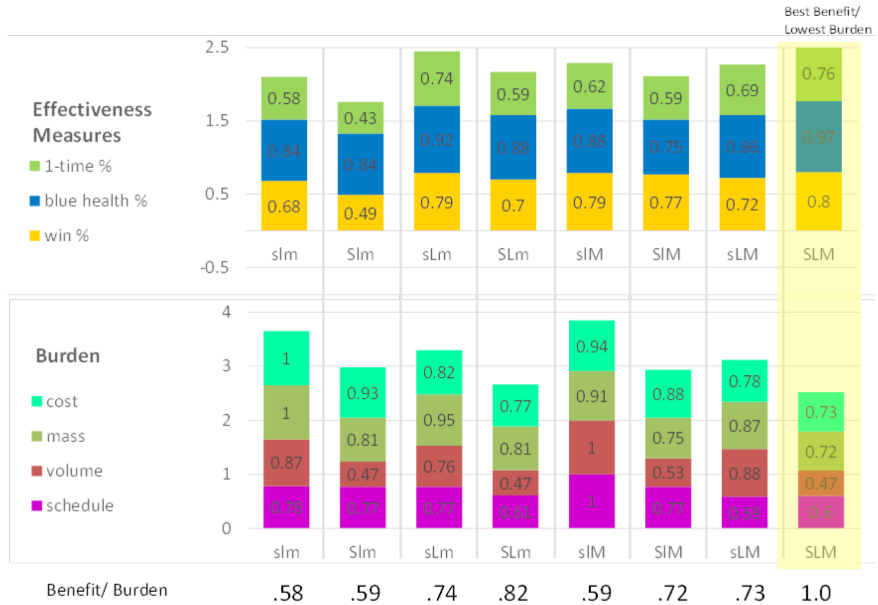


Figure 3: Assessing Maximum Warfighting Benefit at Minimum Burden. Source: Keena(2011)

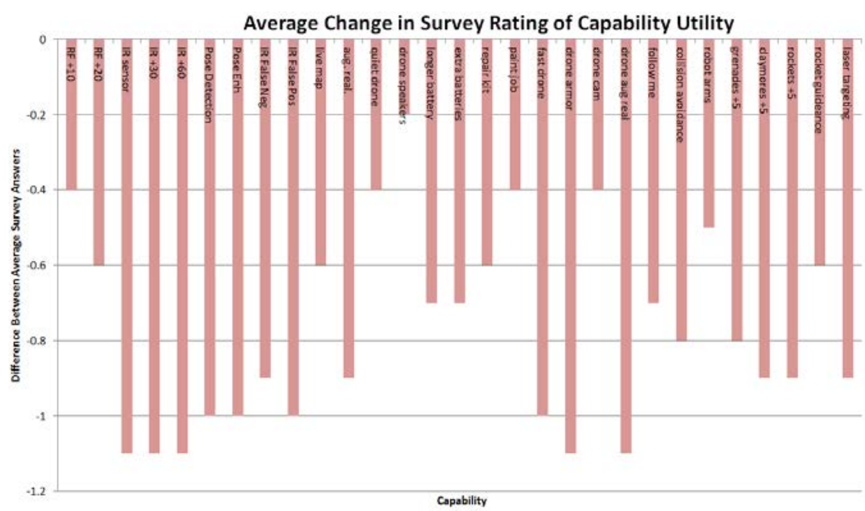
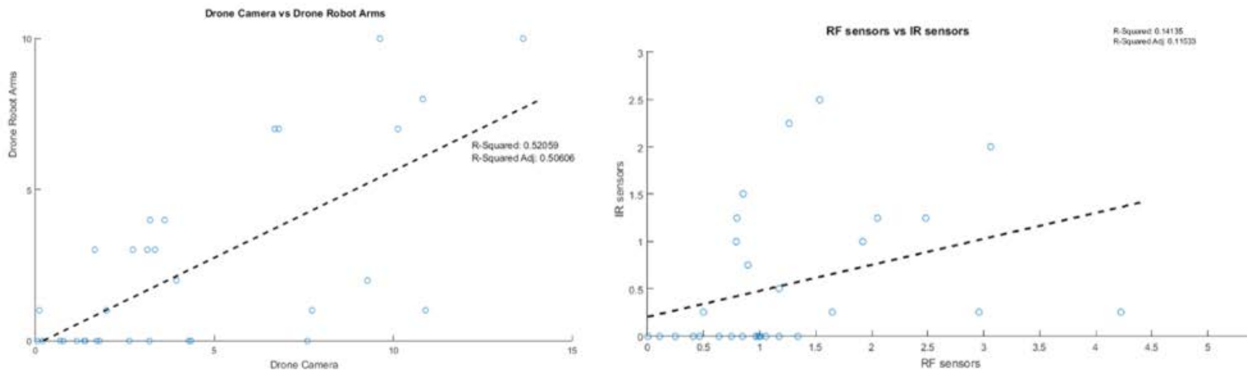


Figure 4: Average Change in Survey Rating of Capability Utility. Source: Seater (2016)

Figure 3 was created from Keena (2011) game data consisting of 1400 runs in MindRover on robotic ground vehicles. MindRover is a Defense Acquisition University (DAU) teaching game from the capstone PM course. MindRover has limited physics, but the data is illustrative of what could be done with more rigorous efforts under ESP. The labels at the bottom of Figure 3 show s=acceptable survivability, S=enhanced survivability; l=acceptable lethality, L=enhanced lethality; m=acceptable mobility, M=enhanced mobility. All the data was normalized and based on random trials with participants testing forced vehicle configurations. It is relatively easy to find the best tactical utility on this simplified unweighted tradespace.

Seater (Seater, 2016) demonstrated for the Air Force (contract FA8721-05-C-0002) that within a game environment, players do discover novel and effective strategies. Seater created an unmanned aerial system (UAS) game and conducted game-based experiments using 36 participants over 5 trials. Participants were given a budget and chose technologies to test on their UAS. One result was corroborating that gameplay significantly changes player opinions as shown in Figure 4. In this figure, each bar is one capability. Bar height is the difference between the average survey-based utility rating (1=low, 5=high) that capability received before and after players used cost-constrained gaming. This shows that the act of playing the game with in-game tradeoffs between capabilities and different strategies changed players' opinions of the utility of the proposed capabilities. In particular, gameplay nearly universally made players more critical about which capabilities would be useful to have in the field. This suggests that ESP won't just quantify a systems engineering analysis that is traditionally ad-hoc, but also improve the quality of qualitative feedback from participants by providing confidence that the preferences exhibited by players are not just wishful speculation.

Further, Seater showed that it is possible to discern mission success correlations in combinations of technologies as shown in Figure 5.



significant correlation shown in data *no significant correlation present in data*

Figure 5: Assessing Utility of Combinations of Technologies from Game Data. Source: Seater (2016)

The figure shows there is a synergistic effect between choosing the drone camera and drone camera arm, where there is no advantage to choosing RF and IR sensors. His work also found limits in the statistical significance of data with only 36 participants which ESP's crowdsourcing approach should eliminate. Since the goal of Mission Engineering is to treat the mission as the system, individual platform combinations and redundancies might also be isolated.

Operation Overmatch

Operation Overmatch is a first-person shooter type game within the Early Synthetic Prototyping effort. Through a collaborative effort between TRADOC, U.S. Army Research and Development Command and Army Game Studio, Operation Overmatch is being government-developed using the Unreal 4 commercial game engine. Initially, within Operation Overmatch, Soldiers will be able to play eight versus eight – against other Soldiers, where they will fight advanced enemies with emerging capabilities in realistic scenarios. Players will also be able to experiment with weapons, vehicles, tactics and team organization. Game analytics and Soldier feedback will be collected and used to evaluate new ideas and to inform areas for further study. A screen shot of the current alpha release is shown in Figure 6.

Figure 6: Operation Overmatch Alpha Version Screenshot

The game currently models a few future vehicles to include variants of manned armored vehicles, robotic vehicles, and UAVs. The scenarios are centered on manned/unmanned teaming at the squad and platoon level in an urban environment. Through game play, Soldiers will provide insights about platform capabilities and employment.

Operation Overmatch will have several defining features: 1) It will be physics-based. The fidelity of accuracy will vary depending on the stage of acquisition, but this distinguishes it from commercial games such as Call of Duty. 2) It will be crowd-enabled. Survey data from an ESP pilot study at Ft. Bliss (Vogt, Megiveron, & Smith, 2015) indicates a potential of up to a million hours of game play a month. The Ft. Bliss test found more than 87% of Soldiers played video games and 50% of Soldiers played more than 10 hours of video games per week. 3) Operation Overmatch will produce measurable data regarding warfighting theses on equipment. 4) Lastly, it will provide some sort of leaderboard and discussion area so innovative ideas may be piggybacked off each other.

Data Mining Challenge

Since observers will not be able to interact with players after experiments in ESP, which are conducted at the leisure of participants, it is important to mine game telemetry to gain understanding. The volume of telemetry data collected in Operation Overmatch creates a challenging big data/ spatio-temporal data mining problem. Tactics and mission performance specifications are interrelated. For example, a heavy/slow tracked vehicle would be used completely differently than a light/wheeled vehicle. It is important to discern the best tactics, along with the design of the system corresponding to the tactics. This is complicated by the fact that people have tastes and preferences. Additionally, players may just be "playing around", or simply learning.

Currently researchers at the Tank Automotive Research Development and Engineering Center (TARDEC) are doing internal research work and have sponsored two Phase II SBIRs

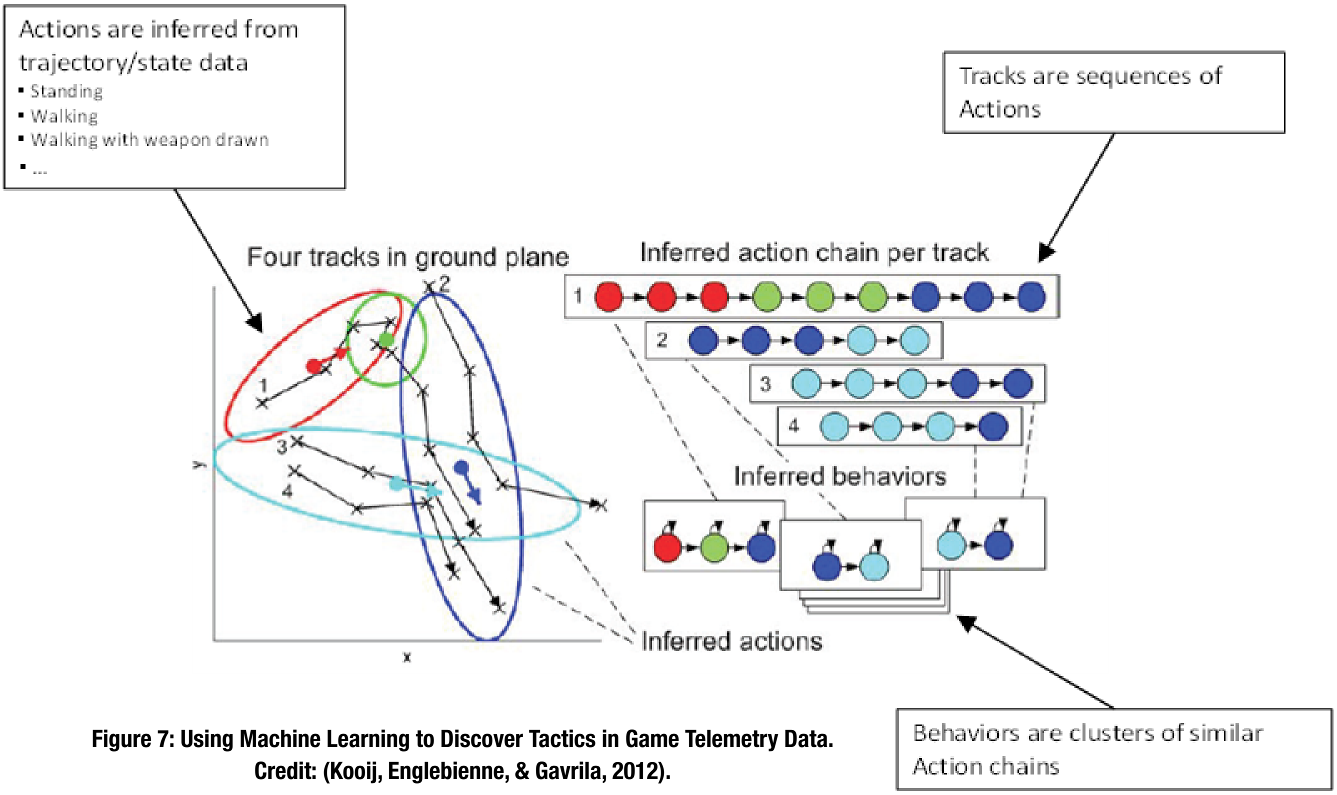


Figure 7: Using Machine Learning to Discover Tactics in Game Telemetry Data. Credit: (Kooij, Englebienne, & Gavrila, 2012).

on Tactical Behavior Mining. In lieu of Operation Overmatch data, the performers are using large public game data sets from the commercial game Defense of the Ancient 2 (DOTA2). DOTA2 is an excellent surrogate for Operation Overmatch since it's somewhat strategic and there are different characters with different powers (similar to different platform configurations).

Figure 7 shows how low-level actions can be learned and inferred from telemetry, which then may be assessed for their ultimate contribution to mission success or failure. This unsupervised learning method clusters the telemetry data into unlabeled actions (which an expert manually labels later), such as standing, walking. Next, sequences of actions are grouped into behaviors, forming a hierarchical model of agent behavior. These groupings are context dependent, based on the state space.

Once the data is organized into actions and behaviors, it is possible to further use machine learning to discover the behaviors that drive mission success and to understand the optimal actions that should be taken in a given scenario to accomplish a mission. The wealth of extracted data will provide sufficient coverage of possibilities and contexts to determine the combinations of technologies and tactics that are most appropriate to achieving an objective. The challenge of learning optimal behavior strategies requires first learning the relative importance of various reward factors. Using an Inverse Reinforcement Learning technique (Tastan & Sukthankar, 2011), it is possible to essentially generate the reward functions from observations of successful missions. This feedback allows analysts to develop an understanding of optimal tactics for specific battlefield mission and conditions, in the context of soldier skill sets and equipment load-outs.

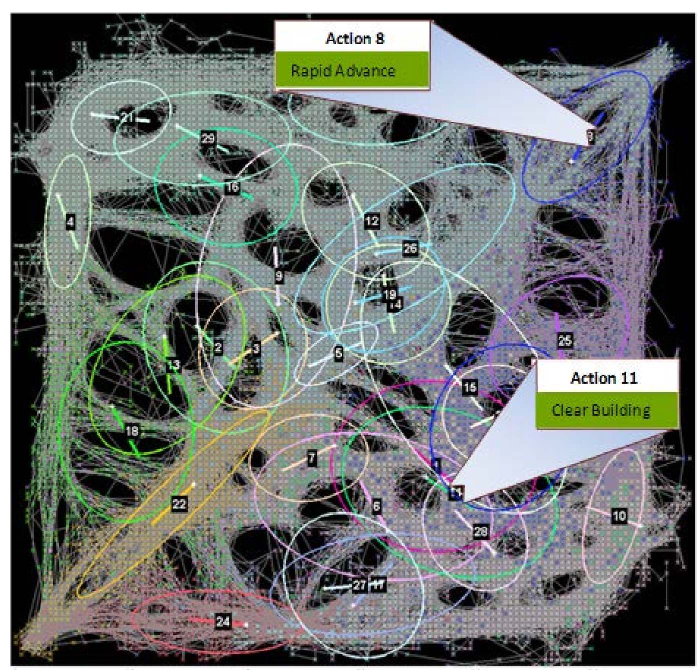


Figure 8: DOTA 2 Action Discovery Over Game Playfield. Credit: Decisive Analytics Corporation.

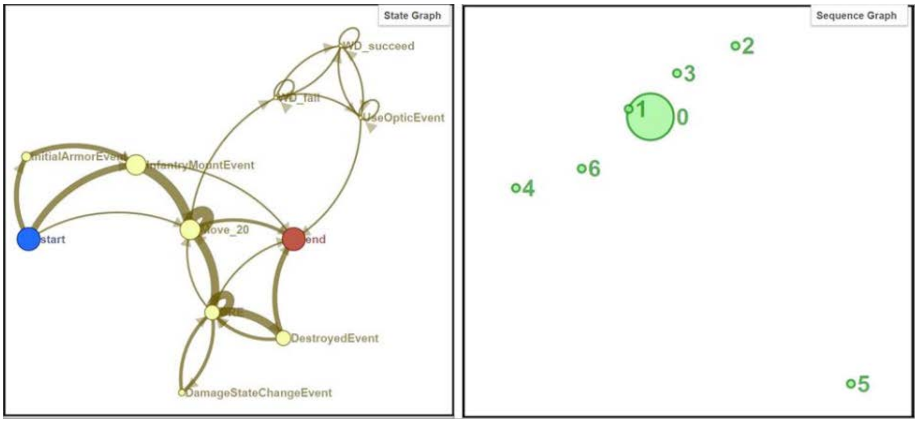


Figure 9: Glyph Visualization. Credit: Soar Technology, Inc. and Northeastern University.

Figure 8 shows some of the initial data mining work from Decisive Analytics Corporation (contract W56HZV-15-C-190) on a DOTA 2 dataset. The clustered Actions are automatically identified, but require experts to label them. The Action labels are in white numbers, the ellipse shows the radius of influence for each Action, while the line with white * shows the mean direction of motion. Two example Actions are highlighted. Each shows a hypothetical Army analogy for what the label of the Action might be.

Figure 9 shows some early results of data mining and visualization from SoarTech and Northeastern University (contract W56HZV-15-C-188). Glyph is an interactive visualization system, designed for understanding behavior traces of user groups (Nguyen, Seif El-Nasr, & Canossa, 2015). This visualization is showing a state transition diagram (left) and a cluster of behaviors (right) for 8 entities in a play session of ESP. The figure on the left shows behaviors of different units from start (blue) to end state (red). All discrete actions were visualized, such as InfantryMounEvent (infantry mounting a vehicle), InitialArmorEvent (initializing the armor configuration on vehicle), DRE (Damage Received Event), UseOpticEvent (when a unit looks into a view), WD (Weapon Discharge Event), DamageStateChangeEvent, and DestroyedEvent. Movement events were collapsed to Move_20, which is movement for 20 seconds. The figure on the right shows the patterns of behaviors (represented as nodes) and their popularity (encoded as node size) as well as their difference (encoded as distances between nodes). For example, pattern 5 was done by few people but was very different from all other patterns. The big circle in the middle (labeled 0) is a popular pattern exhibited by many players.

Scoring Mechanism Research

One important aspect of ESP is that Soldiers act in a tactically sound manner to ensure that data collected is accurate. Scoring drives is one method to drive realistic behavior in a game environment and it also may increase player enjoyment. The scenario needs to be realistic and an appropriate scoring mechanism should be developed. For example, it may be desirable for the friendly force scoring to be different than the opposing force. For the friendly force, scoring might be weighting to discourage collateral damage and death of non-combatants. The opposing force may gain points for collateral damage.

Ross (2016) investigated scoring mechanisms that ensure relevant data to answer engineering design questions used to inform acquisition decisions. Ross suggests that metrics should maintain traceability to the research questions that the ESP study is seeking to address. This ensures that the scoring mechanisms are encouraging the intended behaviors. Ross also suggested that once a scenario has been determined, a study team would determine what outcomes would constitute mission success. The players would then be provided outcomes as game objectives. Scoring algorithms would provide scores to successfully meeting rewarding mission objectives or reduce scores by a flat rate for violating punitive mission objectives. The value of completing an objective will be proportional to its overall significance in contributing to mission success. The challenge of this method is in not over constraining tactics and reducing creativity. Additionally, for players attempting multiple scenarios/ games over time, how to normalize scores remains an open research challenge.

Seater (2016) investigated combining game theory with auction theory to drive players to think critically about customizing their platform with technology (the design area shown in section 2 of Figure 1). Seater set up a technology market with non-fixed prices. So, for example, choosing to up armor a platform would have an initial cost. If that technique proved useful and more players started up armoring, the price to up-armor would increase. The market based costing for the customization shop can be shown to increase creativity by forcing players to explore other options. Additionally, it will force a quicker convergence to the true value of the technology versus other choices.

Conclusion

Early Synthetic Prototyping is poised to help the DoD achieve an enduring time-domain overmatch even if U.S. adversaries achieve technical parity. ESP provides a rapid digital assessment framework to measure progress towards mission accomplishment through test and evaluation in the mission context. Combined with advanced manufacturing (Smith, 2016) (Martin & FitzGerald, 2013), ESP could enable the DoD to ingest technologies from anywhere, figure out how to use them on the battlefield, and rapidly place the output into the hands of Soldiers who are readily able to employ them on an evolving battlefield. The hardest thing for U.S. adversaries to duplicate is the integration of advanced technologies with skilled soldiers and well-trained teams.

ESP is not a turn-key software implementation. There are many challenging research questions, many of which have still not been addressed. Foremost is continuing research on data mining and data farming. Security considerations also present unique challenges. The DoD labs might help to address some of these and additional research questions, including:

Are the results of analysis from Soldier feedback significantly different from the results of analysis from traditional experimentation? How do you begin to allow the Soldiers an active role in the design of platforms? How can we perform autonomous interviewing to understand why Soldiers made tactical choices? How do you assure that the correct level of physics has been captured or quantify the error? Can an AI be used for the opposing force or must human on human play always be used?

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November

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December

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