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Abstract - Over the past several years, several senior leaders of the United States military have pushed for a transformation in the way military operations are planned and executed. Some of these have been codified in the National Security Strategy and the National Defense Strategy. Their vision and other stimulus have led to the formation of doctrine and alteration of the way some in the military services characterize and envision current and future warfare. The transformation, called Multi-Domain Operations (MDO), seeks to create synergy by integrating operations from all warfighting domains (land, sea, air, space, and cyber) and therefore creating multiple and various dilemmas to which an enemy cannot sufficiently defend against. Dr. James D. Campbell describes MDO as “visualizing and executing operations with simultaneity and depth through the air and on the land to dislocate the adversary and outpace his ability to respond.” Challenges to implementing MDO in throughout the military is definition and visualization. To address this challenge, we propose a complex serious game to both engage current and future DoD personnel and identify successful strategies to help shape our understanding of multi-domain operations. This paper explains the methodology and results of two human subject experiments of DoD personnel playing the game in a classroom environment. Analysis reveals the game is effective in developing ideas about MDO and Multi-Domain Command and Control (MDC2) while providing an engaging experience for players creating a desire for future play.

Keywords

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1. INTRODUCTION

In recent years, the United States and its military has increasingly focused on near-peer adversaries as a primary threat. The 2018 National Defense Strategy explains, “Inter-state strategic competition, not terrorism, is now the primary concern in U.S. national security [14].” One way the military is addressing this reality is by transforming the way military operations are planned and executed moving away from the traditional, domain-centric model to Multi-Domain Operations (MDO). MDO, in the words of James D. Campbell, is “visualizing and executing operations with simultaneity and depth to dislocate the adversary and outpace his ability to respond [3].” Current definitions focus on the integration of military capabilities across the warfighting domains of land, sea, air, space, cyber, and cognitive. While high-level definitions exist, exact specifications are not yet known for how MDO should be implemented in a broad spectrum of areas. Much attention is currently placed on offensive operations, but other transformation is needed in supporting functions and even installation defense. Flack and Reith discussed six challenges facing the integration of MDO education in the U.S. military. These include (1) scalability and breadth, (2) currency, (3) complexity, (4) definition, (5) community integration, and (6) hands-on learning. This paper focuses on a Serious Game to serve as a hands-on learning tool, helping to address these challenges and provide enhanced definition of the problem, shared visualization of potential solutions, and credible innovation.

1. BACKGROUND

A shift to MDO will require education and training of the total force. The AF is approaching this challenge by integrating MDO into many of their existing education and training courses. The U.S. Army also recognizes the challenge of MDO and have placed considerable focus on MDO training, especially from the Army Training and Doctrine Command, shown in the publications of recent strategy documents such as “The U.S. Army in Multi-Domain Operations, 2028” published in November 2018. In just the past year there has been a stronger alignment, led by the Army, for Multi-Domain Operations between the Army, Air Force, and Marines. In July 2018, General Stephen Townsend, commander of Army Training and Doctrine command, aligned the high-level terms between the Army and Air Force shifting from Multi-Domain Battle to MDO. Until that time MDO and MDC2 were terms used primarily by the Air Force. The term Multi-Domain Battle was used as a synonym of MDO, but the alignment of terms shows the truly multi-service nature of operations across domains [2]. At the same time, the term Multi-Domain Command and Control (MDC2) has found credence outside of the AF as the central problem or challenge to overcome to establish MDO [1].

Many have written recently seeking to understand the issues of understanding and implementing MDO as well as the solutions that it offers. David S. Alberts provides a historical look at MDO to identify what must change and what is a continuation of past efforts or methods. He focuses on the integration of the virtual (cyber) and social (cognitive) domains which will have far reaching impacts. Specifically, Alberts writes that portions of multi-domain operations will be unfamiliar to almost all operators leading to a greater synchronization of operations and effects [4]. Other voices for the advancement of MDO include the current AF Chief of Staff, General David Goldfein. He projects that MDC2 is the key to winning in current and future conflicts, “Having the ability to credibly attack enemies independently by land, sea, air, space or cyberspace – or all at once – creates untenable dilemmas.”[17] He refers to this as “vicious harmony.” [19] He argues that “developing the systems, training, and methods by which to practice this new brand of warfare will require extraordinary focus from our military.”[17]

There is a growing demand signal for engaging training tools that provide integration of currently disparate communities. Yannakogeorgos and Geis recommend that games and competition be used to identify and attract top talent in the cyber domain.

--need more here--

The study of Serious Games, a continually growing and maturing field, provides a framework for developing education tools that engage learners in various ways. Serious games are a growing area of physical and digital game development. An overview of the literature shows varied perspectives of the definition of serious games. Many agree on the basic meaning that serious games are games used for the purposes other than entertainment. According to the Mirriam-Webster dictionary, serious refers to something “requiring much thought or work.” This fits into the description above; however, the term “game” is harder to define. While games have existed for five millennia [3], a clear definition has not emerged. Ludwig Wittgenstein, as paraphrased by Crookall, said “it is almost impossible to define [a game], but we recognize one when we see it” [15]. Even before there was any study of Serious Games as a learning tool, the military was using playing cards to train servicemen and civilians how to recognize foreign and friendly aircraft[21]. It is fitting then, that Blumberg traces the popularity of the term ‘Serious Game’ to 2002 with the launch of the US Army’s America’s Army video game and the Woodrow Wilson Center for International Scholars founding of the Serious Game Initiative [6].

The field of serious games seek to move beyond the teaching of facts and rote memorization to encompass other aspects of education such as teaching, training, and informing [4].

Blumberg identifies five key characteristics that make games appealing: interactivity, agency and control, identity, feedback, and immersion. Immersion leads to flow which is defined as “game play is perceived as all-absorbing and seemingly automatic despite the cognitive resources needed to master the game (pg. 5).” Specifically, in educational settings, games provide more opportunities for learning. Key takeaway for my research is the nature of games to teach children, especially as games allow them to explore their world.[6]

Building on the proven results of serious games to excel at experiential and hands-on learning, we will offer a framework for using a serious game as an innovation tool. The research will present the theory, a research framework, and a serious of human subject research studies identifying the efficacy of using a serious game as an innovation tool. This research will contribute a method for creating and evaluating a serious game as a tool for innovation and framing a broad, undefined subject area.

Squire [12] approaches the topic of serious games in 2007 from three perspectives: (1) popular gaming culture, (2) design of learning environments, and (3) examining educational practice in the technology boom. He seeks to shape the serious game movement to make it more academically and educationally relevant. However, in 2012, Bedwell et al. hold, “The use of serious games is progressing without explicit knowledge as to why games are effective teaching tools” [16] However, since 2012, the growth in the number of empirical studies examining serious games as well as the rigor of many of those studies has brought more legitimacy to the field. This will be discussed in more depth in section 2.1 below.

Bedwell et al. presented a taxonomy for identifying the attributes of serious games that lead to desired training outcomes. They determined nine distinct attributes of games that map to learning outcomes: (1) Action Language, (2) Assessment, (3) Conflict/Challenge, (4) Control, (5) Environment, (6) Game Fiction, (7) Human Interaction, (8) Immersion, and (9) Rules/Goals. These attributes are matrixed to at least eleven learning outcomes identified in the extant literature.

* 1. Evaluating Serious Games in the Classroom

Serious Game researcher have focused effort on proving the positive impacts of serious games, specifically in a classroom setting. Connolly et al. analyzed 129 papers describing the empirical evidence concerning the impacts and outcomes of computer and serious games. Through their research they developed a multidimensional approach for categorizing games. Most often, positive impacts of serious games was linked to knowledge acquisition and content understanding and affective and motivational outcomes [9].

As the title suggest, these authors followed Connolly’s work to update the literature and empirical evidence for the positive impacts and outcomes of digital and serious games. This study concludes, after examining 143 papers, that the games provided a range of affective, behavior change, perceptual and cognitive and physiological outcomes. The key takeaway is the summation of current research and their methods for a systematic approach to research on serious games [10].

Roozeboom et al. is an example of a recent study showing the methodology and results of a rigorous empirical study to prove the efficacy of serious games compared to traditional forms of instruction. The study compares three serious games and a professional video designed to train participants about cognitive bias. A key takeaway are the robust methodology section, the description of control conditions, and an example for quality data analysis [11]. This journal article shows the methodology and results of a rigorous empirical study to prove the efficacy of serious games compared to other form of instruction. The study compares three serious games and a professional video designed to train participants about cognitive bias. The study also used a control group that did not address the subject matter. The study was careful executed using a standardized test for all participants with rotating questions created by individuals not connected to the experiment. Additionally, independent validation and verification as well as multiple control conditions were implemented during the experiment design. The experiment examined the difference between procedural knowledge versus declarative knowledge. Procedural knowledge addresses *how* to do something (hands-on knowledge) while declarative knowledge focuses on *what* something is (tested knowledge). Both phases of the study demonstrate that serious games had advantages over video-based discussion when teaching procedural knowledge but performed equally well for declarative knowledge. Additionally, a subset of the games tested increased knowledge retention over time, 8 to 12 weeks in this case.

One clear strength of this study is rigor. The sample size (1,219 participants) is significant for human subject research studies addressing the efficacy of serious games. Also, the independent validation and multiple control conditions provide more confidence in the author’s conclusions. Also, using multiple serious games in parallel ensured that poor game design did not significantly skew the results. Finally, the pre/post/delay test given to participants included attention check questions that allowed researchers to exclude participants who did not pass at least two of the items. There are a few weaknesses in the study. First, there is little discussion about the design elements of the serious games used for the study. An existing framework for serious game design could have been used to bolster discussion and identify the most effective elements. Second, no data is collected showing the participants proclivity to learn through games or the response to participants to either the instructional video or the game. Did participants who enjoyed their method of instruction score better on the standardized test? Finally, discussions of serious games do not necessitate the exclusion of other instructional materials and methods but are usually paired with traditional instruction to enhance the learning process. The study could have easily extended their study to include a group that both viewed the instructional video and played a serious game. Examining the use of serious games to engage military personnel is currently focused on pairing games with traditional instruction (where it exists) or attracting personnel who may have access to traditional instructional material, but do not take the time to engage with the material in order to learn.

* 1. Serious Games in the US Military

Wargaming,

Computer Based Games

Gamification,

Cyber awareness challenge

Cyber Education Hub Rethinking

* 1. Current MDO Training

the Air Force’s Air Command and Staff College have altered their approach to embrace Multi-Domain Operations (MDO) [3]. They have implemented a MDO Strategist focus.

TRADOC

Weapons Officer Training Capstone

These current efforts in operations, education, and training are needed and will continue to expand and be integrated into other areas. At the same time, however, solutions are needed to capture the attention of DoD personnel across all services and functional areas. Given the nature of serious games to attract attention, engage a broad spectrum of people, and teach….

* 1. MDC2 Card Game Overview

Leverage interactive learning tools, like the MDC2 Card Game, to challenge Airmen with MDO concepts building strategic thinking leading to adaptive behavior and innovation across all warfighting domains.

Multi-Domain Operations, while defined at a high level, has not been implemented across the AF. Transformation from current (stove-piped) operations to MDO will require shifts in the force’s mindset and behavior across all functional areas. While solutions are beginning to appear, there is a need for tools that will seize the attention of our information-saturated culture both to leverage the potential of current Airmen and recruit the next generation.

The Multi-Domain Command and Control Card Game is designed to challenge Airmen (and others) to develop warfighting strategies using military capabilities from air, land, sea, space, cyber, and cognitive domains to defeat a near-peer adversary. Furthermore, players must adapt their strategies by making operational and tactical adjustments during conflict to counteract enemy moves. To help shift the mindset from counter-insurgency to near-peer warfare, the game pits two players against one another with the same pool of capabilities and resources. The game also has great potential to help players visualize a multi-domain conflict and see how more abstract domains (like cyber and cognitive) might be integrated. Rich learning takes place during the game as well as in discussions between players concerning winning strategies. Future research may reveal data to help frame and direct our thinking concerning multi-domain operations.

The MDC2 Card Game was developed by the Air Force Institute of Technology’s Center for Cyberspace Research and AF Cyber Technical Center of Excellence. The principle designer is Alan Lin and further development and research is ongoing. Currently, 60 capabilities exist in a physical deck that players must possess to play the game. This hampers scalability and adds significant cost for initial rollout and subsequent releases. The next version of the game, currently in development, is a digital version that can be easily scaled to be globally available to any authenticated users with a computer and smart device. Options are available for iPhone/iPad/Android applications as well as play through a web browser. Dedicated funding and development would enable collaboration to add more capabilities and build scenarios to address unique situations. Specifically, funding is needed to provide a publicly available game server to utilize the game in niche communities like ROTC and J-ROTC and to leverage the game as an innovative recruiting tool.

1. EXpiriment design

We gathered initial data testing the efficacy of the MDC2 Card Game in two classroom environments. Both experiments used a voluntary pre-test to gauge participants interest in games, background in military and cyber operations, and self-reported knowledge and familiarity with MDO concepts. Following a demonstration and playtest of the game, participant were asked to complete a post-survey capturing their response to the game, suggested improvements, and whether they would play the game again. The circumstances of the two experiments differed slightly, therefore the exact procedures could not be duplicated. Details of both experiments are included below.

3.1 AFIT Classroom Study

The first experiment occurring during a Master’s course at the Air Force Institute of Technology (AFIT) titled “Introduction to Cyber Warfare and Security.” The instructor provided class time for students to participate in the study and complete the optional surveys. Most of the fourteen participants were junior officers including two Army officers. Twelve participants completed the pre- and post-surveys. Each person was given a copy of the card deck (59 cards) and game instructions one week prior to the playtest study. They were asked to examine the cards and select an initial strategy to employ during the next class period (one week later). At the start of the next class period, students were requested to complete an optional pre-survey and chose a partner to play against. In the 80 minutes allotted for the demo, each pair finished at least one game, and several were well into a second.

3.2 Cyber Conference Study

The second experiment targeted a broader audience who voluntarily registered for a training seminar as part of a cyber conference in Colorado Springs, Colorado. The 3-hour class focused on MDO and cyber education innovation and was capped at thirty participants. However, the classroom could accommodate 34 individuals, of which 33 participated in playtesting the game and 28 completed both pre- and post-surveys. Participants included active duty military members, DoD Civilians, and contracted personnel from at least three branches of the U.S. military. From observation, participants covered a wider range of ages and backgrounds when comparted to the AFIT classroom study. Most participants and the researchers travelled to the conference the day before the training class, therefore there was no effective way to distribute the cards to the participants one week prior to the playtest. Therefore, the play test was broken into two 45-minute blocks. The first half included 10 minutes for game and rules explanation and 30 minutes for participants to examine the game cards and choosing a strategy. The second half of the study was for play-testing and discussion. Researchers observed that participants in the second study had more trouble getting started with the game and most pairs did not finish playing their initial game.

1. RESULTS AND Analysis

Due to significant differences in experiment procedures and a few key changes to the feedback mechanism (pre- and post-survey) and lack of control group, each study will be analyzed separately using qualitative analysis methods.

One of primary purposes for performing these two tests were to receive feedback from a wide range of participants on the game, particularly what improvements the game needed. The comments provided through the post-survey provided several categories that need attention but also reveal a unique roll this game could “play” in MDO education and training. In response to a question asking what improvements could be made to the game, responses fell into four main categories: (1) game fixes, (2) game enhancements, (3) instruction improvements, and (4) time. While many of the comments identified things that needed to be changed, 35 of the 41 comments received had a positive tone with only one response showing negativity to the game. More on this comment below.

Six participant comments identified explicit fixes that needed to be made to the game itself. Example comments are “Certain cards could be clearer” or “Some of the values could be better balanced” or “Too many rules.” One participant felt that the game was not balanced and wrote “niche game only; nongamers will not engage.” This was the only negative comment received during the experiment.

Other responses focused on the directions for the game. Critiques for instructions written on the cards, game instructions, and video/verbal instructions from the facilitator were grouped together into this category. Participants thought the game instructions needed to be simplified but also explain more complex game elements such as cyber effects and close air support. Others wanted further explanation of scenarios and more guidance from instructors during gameplay. There were two example game scenarios in the game instructions, but this did not seem sufficient. Several individuals with knowledge of the game were present during both experiments, however, time was limited as there were 16 pairs playing at the same time during the Cyber Conference experiment.

Fourteen responses focused on specific game enhancements. These comments pointed to something that could be added to the game or changed to make it more appealing or useful. Three participants wanted a realistic wargame scenario to help them decide on a specific strategy. Three participants explicitly wrote that they wanted maritime capabilities, another three wanted more and varied cyber effects cards, and one participant wanted more Space cards. One participant wrote, “You probably need a slimmed down version for a quick learn option,” which was reflected in other comments as well.

The final category was time. All of these responses were from the Cyber Conference Experiment, which is most likely due to the shortened timeline for game familiarization, strategy development, and gameplay. We interpret these comments as

In response to the statement “I can explain the concept of Multi-Domain Operations” 48% of participants (19/40) moved at least one point on the 5-point Likert scale, while 20% moved at least two points up (8/40). 67% (27/40) reported that they agreed or strongly agreed with the statement “I enjoy learning through games and believe they can be a useful teaching tool.” Of these 27, only 5 said they strongly disagreed, disagreed, or were neutral on the statement, “I enjoyed learning through this particular game and believed it is a useful learning tool.” That means that of those who enjoyed learning through games, 81% (22/27) thought this game was enjoyable and a useful learning tool.

The post-survey for the AFIT Classroom study included a questions asking participants to rate if the game seemed more designed for fun, more educational, or a balance of fun and education. Of the 12 participants, 10 (83%) reported that they thought the game balanced fun and education. One thought . The post-survey for the Cyber Conference test asked questions, on a 5-point Likert Scale, concerning if the game was fun

1. FUture work

As the review of the literature has shown, the field of Serious Games is focused on showing the efficacy of game attributes to produce specific learning outcomes in a way that is predictable, reliable, and reproducible. However, future work for this game will seek to frame and define the nebulous topic of Multi-Domain Operations and MDC2 in order to facilitate a shared vision of potential innovation. Squire [12] writes, “Just what the mix of technologies associated with digital media will result in remains to be seen, but…the shift seems to be toward understanding complex systems, and crucially, identifying leverage points within those systems where one can have potential impact.” The MDC2 Card Game, with further design effort and more testing, has the potential to help understand the complex system of Multi-Domain Operations both now and in future conflicts.

5.1 Methodology

To test this relatively unexplored use of serious games, I suggest that the serious game be leveraged as a tool during a MDO innovation workshop. The study will be conducted by drawing test participants from a wide range of military services, organizations, and functional areas. All subjects will be given access to a physical or digital version of the MDC2 Card Game and engage in at least two games against an opponent. This will allow for further research in the efficacy of the game to help develop understanding of the challenges and complexity of MDO. In the second half of the study, participants will take part in small group

The limitation of this idea is that it is hard to determine that effective innovation has taken place.

1. CONCLUSION

This will in turn transform the mindset of a broad population of the military from traditional operations to MDO transform their thinking

performing MDO and Future work will focus

Military trainees perform better using a computer-based game than those presented with two forms of paper-based training [18].

He wrote that MDO characterizes “the way we fight today and ensure overmatch against our adversaries tomorrow.” [2]

national cyber talent. he authors analyze the current cyber workforce and suggest specific and wide-ranging recommendations for Air Force leaders to enact to improve training, retention, operations, etc. Some of their recommendations point to more engaging current and future service members with games to peak their interests and show their skills. Future games, such as the MDC2 Card Game could provide a recruiting aspect where top players are “interviewed” for their interest and eligibility to join the Air Force either through direct accession or a commissioning source [5].

Standard serious game approach: starting with learning objectives, designing game, test results using participants self-reporting knowledge or standardized tests.

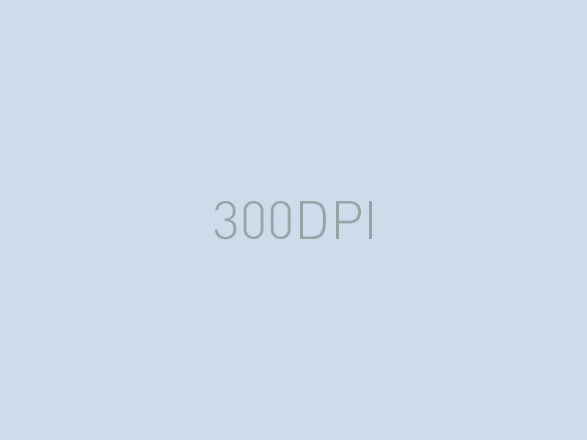


Figure 1: Word cloud of comments on the NPRM.

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| Table 1  Lorem ipsum dolor sit amet | |
| **Field** | **Description** |
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