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"Collective C2 in Multinational Civil-Military Operations"

Understanding the potential of virtual environments for improving C2 performance

Topic:

Primary: Topic 5, Collaboration, Shared Awareness, and Decision Making

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ABSTRACT

Effective Command and Control (C2) is enabled by information technology, but the potential of C2 through virtual environments offers opportunities for radical increases in awareness and performance. To realize such radical increases, we are engaged in a campaign of experimentation to assess C2 in virtual environments through the ELICIT (Experimental Laboratory for Investigating Collaboration, Information-sharing, and Trust) multiplayer online counterterrorism intelligence game. Currently ELICIT has only a primitive textual interface. This research seeks to investigate the impact of translating game-play into more immersive virtual environments, where participants interact as avatars and in modes that are reminiscent of physical experiences. Indeed, drawing from research in modeling and virtual environments, we hypothesize that a more immersive virtual environment offers potential to improve performance. Building on previous work in establishing design parameters for virtual environments, this research moves toward a more complete integration of ELICIT into the virtual space. This is accomplished by augmenting basic game-play functionality with more complex interactions in the virtual space and by investigating a fully automated agent-based experimentation utilizing ELICIT in virtual environments. The research described in this paper explores the impact of virtual environments on game-play and seeks to understand which aspects of C2 can be performed better through virtual environments than their physical counterparts.

Keywords: avatar, collaboration, ELICIT, experimentation, virtual environment

INTRODUCTION

Modern military organizations have adapted and evolved over many centuries and millennia, respectively. Hierarchical C2 organizations in particular have been refined longitudinally (e.g., through iterative combat, training and doctrinal development) to become very reliable and effective at the missions they were designed to accomplish. However, recent research suggests that the Hierarchy may not represent the best organizational approach to C2 in all circumstances (Nissen, 2005), particularly where the environment is unfamiliar or dynamic. Indeed, alternate, more flexible C2 organizational approaches such as the Edge have been proposed (Alberts & Hayes, 2003) to overcome Hierarchy limitations, but the same recent research suggests that the Edge may not represent the best organizational approach to C2 in all circumstances either, particularly where the environment is familiar and stable.

Of course, the Hierarchy and Edge both represent organizational archetypes (Orr & Nissen, 2006), each of which offers considerable latitude in terms of detailed organizational design and customization. For instance, recent research demonstrates further how the performance of both Hierarchy and Edge organizations is sensitive to factors such as network infrastructure, professional competency and other factors that can be affected through leadership, management and investment (Gateau, Leweling, Looney, & Nissen, 2007). With incessant advances in information technology (IT) that appear to be continuing, one may be able to overcome the limitations inherent in Hierarchy, Edge or other organizations or even enable such organizations to adapt—through IT—to shifting conditions.

This notion is fundamental to Network Centric Operations (NCO), where people and organizations operate principally in network-enabled virtual environments as opposed to their physical counterparts. Unfortunately, empirical evidence to support the asserted superiority of NCO remains sparse, and the capability enhancing properties of virtual environments remain more in the domain of lore than empirical assessment. To remedy such empirical sparseness, we continue a campaign of laboratory experimentation using the ELICIT (Experimental Laboratory for Investigating Collaboration, Information-sharing, and Trust) multiplayer online counterterrorism intelligence game to understand the comparative advantages and disadvantages of alternate C2 approaches, organizational forms, technologies and like aspects across a range of current and anticipated operational environments.

In this particular stream of research we focus specifically on the information technology (IT) that enables C2 through virtual environments, looking intensively for radical increases in awareness and performance through immersion in such environments. Indeed, drawing from substantial research in modeling and virtual environments, we argue that a more immersive virtual environment offers potential to improve performance. Currently ELICIT has only a primitive textual interface. This research seeks to investigate the impact of translating game-play into more immersive virtual environments, where participants interact as avatars and in modes that are reminiscent of physical experiences.

Building on previous work in establishing design parameters for virtual environments, this research moves toward a more complete integration of ELICIT into the virtual space. This is accomplished by augmenting basic game-play functionality with more complex interactions in the virtual space and by investigating a fully automated agent-based experimentation utilizing

ELICIT in virtual environments. The research described in this paper analyzes the impact of virtual environments on game-play and seeks to understand what aspects of C2 can be performed better through virtual environments than their physical counterparts.

BACKGROUND

The aim of this research is to study the impact of ELICIT game-play with participants who are immersed in a 3D virtual environment. By definition, these environments, where players interact as avatars, are open-ended, with the spectrum of visual and auditory stimuli available. The first step in approaching this project is to determine both which virtual world product would be leveraged for experimentation, and what type of environment would be created to house those experiences.

To that end, the available, suitable virtual worlds were evaluated based on the following criteria:

1) Accessibility: Virtual environment platform must be universally accessible between operating systems. The environment must be intuitive in terms of its usage, reducing to the bare minimum the training load for all participants.
2) Communication: Virtual world platform must allow for both text and voice communication. This communication apparatus must be straightforward to learn and simple to use.
3) ELICIT specific requirements: ELICIT game-play is a proctored clue-based game that collects information about game-play in a database so that researchers may examine statistical records of each game round. Currently the game functions are handled by JavaScript, so ideally, the virtual environment will support the inclusion of JavaScript without significant re-coding of the environment.
4) Customization: The virtual environment must support complete customization of spatial aspects. This customization can preferably be done in an expedient manner. (Hudson & Nissen, 2010)

While many of the available virtual world products could be tailored to the ELICIT experiments, the public world of Second Life was chosen as the most readily adaptable to this purpose, based on cost, speed of development, and native tools to enable ELICIT game-play, without extensive programming.

Having determined the platform for experimentation, the next step in preparing the environment was to design and develop a suitable neutrally toned space, so that environmental elements did not overtly stimulate participants. This allows researchers to examine the core interactions between participants, while avoiding cognitive overload due to excessive and extraneous elements. This component of the experiential design is critical for adjacent proposed research utilizing Functional Magnetic Resonance Imaging (fMRI) to evaluate neurological activity during ELICIT game-play; the more neutral the base environment is, the more accurate the fMRI results will be in mapping brain activity during game-play in the virtual environment.

To ensure a neutral experience, researchers developed a rubric of suitable textures, layouts, and color combinations that would render the space as neutral as possible. Not only does this provide a baseline experience for the experiments, but also makes available the possibility of

adding elements to stimulate emotional states conducive to game-play at a later time, and then to compare the ELICIT results from the various trials.

The ELICIT game-play itself is nested into the virtual environment by loading the webpage, and playing the game in the same manner that it would be played in other contexts. Desks with computer monitors were created within the virtual space, and participants interacted with the ELICIT game through and within the virtual environment in a way that is analogous with the traditional web-based version of the game. The difference being that the participants are co-located in a virtual environment while they play ELICIT.

CAN VIRTUAL ENVIRONMENTS IMPROVE PERFORMANCE?

The overarching aim of this research is to determine whether or not virtual environments can improve performance in a C2 context. Research suggests that these environments are highly suited to increase performance in training and learning situations. However, can and will this substantiated application of virtual environments translate into success with command and control situations?

One primary example of the application of virtual environments that increased performance in a training context is the Canadian border simulation run out of Loyalist College. In this experience, students in the Customs and Immigration program participated in simulated border crossing interview as a method of rehearsing mandatory questioning skills. The simulated crossing, also developed in Second Life, accurately recreates a border checkpoint, and each student in the class is given a chance to enter the booth and conduct interviews with travelers entering Canada.

The student border officers adhere to strict interview guidelines and must conduct the questioning in a professional and representative manner. Each student avatar is provided with basic training in operating the virtual environment, and each has a border officer uniform for their avatar. The students stand in a border control booth, and have access to primary relevant traveler information (passport, license plate) displayed on the monitor within the booth (Figure 1). The students interview the traveler, ensuring that the information provided verbally synchs with the database of information relative to that traveler. They then decide either to admit the traveler into Canada, or refer him to secondary or immigration screening. Each traveler interview is followed up with an after-action review, where questions and comments related to the interview could be discussed.

Figure 1: Loyalist College Border Simulation

In contrast to previous uses of in-class role-play to teach these interview skills, the Loyalist College students significantly out-performed earlier classes by leveraging the virtual environment. Grades associated with these interview skills increased 28% in the first trial, and an additional 9% with a subsequent group of students. Additionally, students reported an increase in confidence, and reported a depth of knowledge, not associated with previous in-class experiences (deGast-Kennedy & Hudson, 2009).

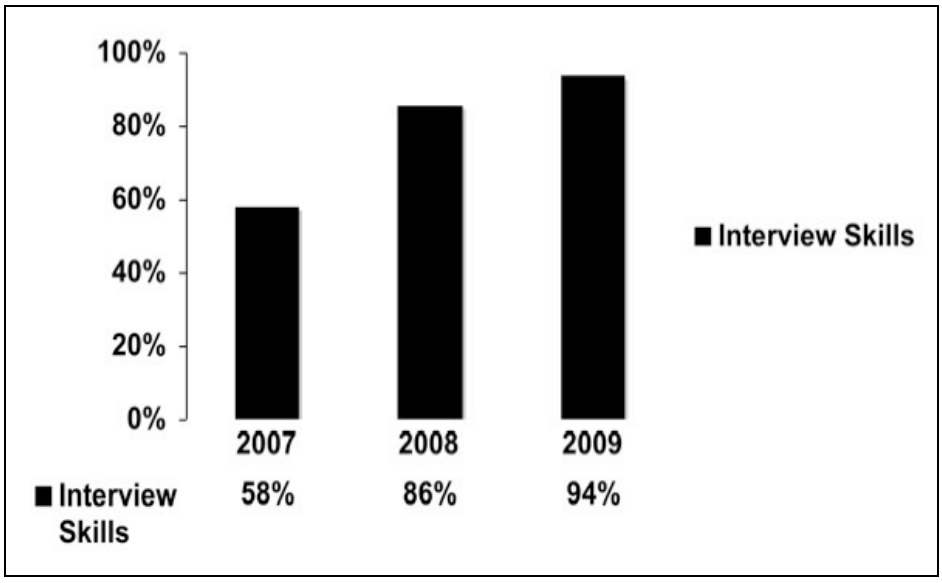

Figure 2:Increased success using virtual environment

The success of the Loyalist College experience led to collaboration with the Canada Border Services Agency (CBSA), who agreed to trial this simulated training environment with new recruits to the agency. Applied to a distributed pre-training course for new recruits, the intent of the simulation in this context is to prepare learners for arrival at basic training by giving them a sense of the complexities the role would require. The CBSA results echo those from Loyalist College, seeing recruits who participated in the virtual environment simulation being 39% more successful at the first testing milestone than those who did not participate in the virtual world experience (Hudson & Nowosielski, 2009).

ATTRIBUTES OF VIRTUAL ENVIRONMENTS LEADING TO BETTER PERFORMANCE

The border simulation at Loyalist College is a hallmark of successful application of virtual environments for applied learning experiences. But what are the attributes of virtual environments that led to this success, and can they be harnessed and applied to non-instructional situations, such as the ELICIT counter-terrorism game? There are several factors in the design of these experiences that lend themselves to the development of an appropriate learning experience in virtual environments.

In *Learning in 3D*, Karl Kapp and Tony O'Driscoll (2010) identify aspects of successfully designed learning experience that leverage the inherent attributes of virtual environments. Those elements include, participant centered experience, contextually situated learning, and experiences that fully utilize the style of interactions and experiences native to virtual environments, including the identification of self with avatar within the environment (presence), and the sense of sharing that environment with others (co-presence).

Analyzing the border simulation in this light, we see that it capitalizes on all of these native attributes as a pathway to success. It is contextually relevant, having participants interact within a virtual border crossing environment; the participants themselves drive the action or activity, making this experience participant centered; the participants assume the role they are enacting by dressing their avatars in the appropriate uniform for the experience; and the experience is dependent upon meaningful interactions that require both border officer and traveler to be mutually present within the simulation.

The promise of increased performance in virtual environments is connected to those attributes native to these environments that make them distinct from other mediated experiences (web, teleconference, and so forth). In order to realize enhanced performance, virtual experiences must align themselves with those features in order to capitalize on these unique attributes.

ELICIT IN VIRTUAL ENVIRONMENTS

The initial phase of experimentation playing ELICIT within the virtual environment failed to meet the expectation that this platform would enhance performance. Two aspects of the ELICIT game-play experiment conducted in the virtual environment were compared to trials run in the physical environment. These two aspects, time and accuracy, are critical to ELICIT, and, of course, crucial for effective command and control functions.

The results demonstrate that while there was no measurable differences in the time it took both groups to play ELICIT, the group that was playing from within the virtual environment was less successful in terms of accuracy than the corresponding group playing in a physical environment (Bergin, Adams, Andraus, Hudgens, Lee & Nissen, 2010), see Table 1. In order to understand these results, we will compare the experimental constructs for each, and then evaluate the virtual experience in light of the inherent strengths and unique qualities of the virtual environment.

Table 1: Table of results from initial ELICIT experiments in virtual environments comparing computer mediated (CM) with face to face (FTF) results.

Variable	Mean	N	Standard Deviation	Standard Error
ID Time CM (in seconds)	2685	14	219	58
ID Time FTF (in seconds)	2554	14	279	74
Who Score CM	.140	14	.363	.097
Who Score FTF	.790	14	.426	.114
What Score CM	.321	14	.249	.066
What Score FTF	.536	14	.365	.098
Where Score CM	.570	14	.514	.137
Where Score FTF	.790	14	.426	.114
When Score CM	.262	14	.297	.079
When Score FTF	.333	14	.320	.086
Identify Composite CM	.324	14	.206	.055
Identify Composite FTF	.610	14	.327	.087

On the surface, the two groups, one virtual and one physical were playing the same ELICIT game. Both were interfacing with the ELICIT game through a web browser, one group in a physical room with computer monitors, and the other within a virtual space designed to mimic the physical room, also with computer monitors stationed at desks. However, in analyzing the mode of interactions with ELICIT, the physical space afforded the comforts of the familiar, allowing participants to interact with ELICIT in what can only be called a “normal” or “regular” manner compared to the way they would interact with any web or computer-based application.

On the other hand, the virtual environment players, in addition to negotiating the unfamiliar virtual space, played the ELICIT game in a manner that eclipsed the potential benefits of the virtual environment. The virtual computer interface requires users to interact in an extreme close-up view, excluding all other visual information from their sight. Therefore, the virtual subjects were not necessarily experiencing themselves within the virtual space (identification/presence), nor were they experiencing the other participants who were co-located in the same space (co-presence), in the way their physical counterparts were, who were clearly part of a team of participants. Instead their complete focus was dominated by the computer screen and the ELICIT interface (see Figure 3). Ironically, it could be observed, that they were less immersed in the virtual environment (the aim of the experiment) and, in fact, more immersed in the text-base ELICIT web interface.

Figure 3:VE ELICIT interface obscures view of environment in initial experiments

Furthermore, building on the known advantages for interaction within virtual environments, the participants in this experiment were in a neutral space, which may or may not have registered as contextually relevant to them. Conversely, the physical participants were in a boardroom setting, one that evokes a seriousness of task, allowing for one basic reading of the semiotics of this kind of environment.

Building out from the best practices for applying virtual environments, one could argue that, in this case, performance was not enhanced because the experiments failed to engage participants with the inherent strengths of virtual environments. Also, the interface for the ELICIT game-play as developed in the virtual environment did not in any way further immerse the participants in the game. And, because there was no interaction between participants during the experiment, the co-presence advantage of virtual environments was rendered moot.

While the results of the initial experimentation did not further the hypothesis of the advantages of virtual environments, the relative failure of this first trial points to the need to further integrate the ELICIT game within the virtual space so as to allow the inherent strengths of these environments to register within the experiment. Once there is sufficient integration of ELICIT, there still exists a belief that performance enhancements will be evident.

ELICIT INTEGRATION

The initial phase of this research project was to enable experimentation with ELICIT to be located within a 3D virtual environment. The next steps involve the further integration of ELICIT within the virtual environment by providing facilitators and researchers with the ability to play the game and conduct experiments in a way that closely evokes the physical experience.

The challenge in extending functionality beyond the web-based ELICIT game is that each virtual environment has pre-determined types of interactions that are hard-wired in their platforms. For example, Second Life, while allowing input onto a webpage (like the ELICIT web game), does not allow for simple Player to Player (P2P) interactions, like handing a physical clue. Those types of P2P interactions are removed from the manner in which the same experience would be handled in a physical setting.

For example, the simple task of passing a physical clue from one participant to another, or posting that clue on a common whiteboard, is severely limited in Second Life. If the game-play is being conducted through the ELICIT website, there is no content that is technically "in" Second Life to be manipulated; the content continues to rest solely on the ELICIT website.

The only way to bypass this restriction is to host the ELICIT content within the virtual environment itself. This is the case with a "paper clue" version of ELICIT that is being developed for Second Life. Clearly there is no paper in the virtual world, but also, there is no ready and simple manner to create a virtual piece of paper, and then distribute or present those clues to participants. Rather, a complex and removed system of interaction needs to be developed to handle even the most elementary information transaction within the virtual space.

Therefore developers must seek technological analogues in the virtual space to physical interactions. One approach to replacing tactile interactions is through the use of a Head's Up Display (HUD). The HUD is a programmed display that loads on the screen in from of the player in the virtual environment (Figure 4). In this case, the HUD would display any clues that were passed to the individual player, and would allow the player to further share or post that clue in a manner that resembles the physical manipulation of clues in a paper version of the game.

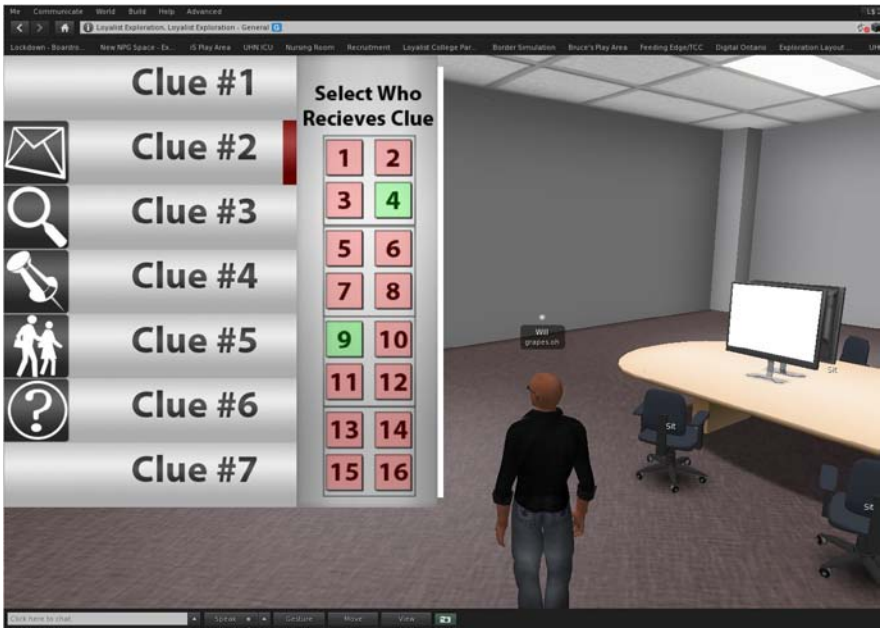

Figure 4: ELICIT "paper clue" HUD prototype

This style of interaction raises many questions regarding the influence of the interface in such a transaction versus the lack of interface in a physical version of the game. Can these two styles of “paper clue” ELICIT even be compared as somewhat equal versions of the game? Clearly, the HUD will enable players to functionally replicate physical game play, even though the medium (digital versus paper) has shifted. It is believed despite the dramatic differences in format, that the essence of the game-play will remain integral in such an approach.

However, there is not the same confidence that a hybrid model of game play could be sustained within the virtual world, where participants could at once interface with the main ELICIT game via the website, and, as well, manipulate the content of the clues in an interactive and interpersonal manner. One of the key limitations of a public or “off the shelf” virtual world, is the lack of programming support to insert content into the environment. The HUD could also be employed, however, again without the content being hosted within the virtual environment, there are numerous hurdles to overcome in communicating with the base game (hosted on the internet) to allow for content interactions within the virtual world.

One approach to compensate for the limitations of interacting with ELICIT in the virtual environment is to transfer game-play from a computer monitor situated in the space to a HUD interface. It is believed that this will correct the limited viewpoint created by the computer monitor, which had the unintended effect of blocking a view of the other participants. This approach will enable participants to both interact with the ELICIT client, and to interact with one another and their environment (Figure 5). This could provide a solution to the static virtual workstations of the initial experiment that, as we have shown, did not support enhanced performance. Whether or not this change, slight as it is, would demonstrate any significant changes in results, is uncertain. However, given that it would align the experience with best-practices guidelines for success in virtual environment, it is worthy of investigation, and leads to new hypotheses for further experimentation of ELICIT within virtual environments.

Hypothesis 1: Player's performance of the ELICIT task game will increase within the virtual environment when the native strengths of those environments are leveraged.

Hypothesis 2: Player's performance of the ELICIT task game will increase within the virtual environment when the interface for game-play are aligned with their physical analogues.

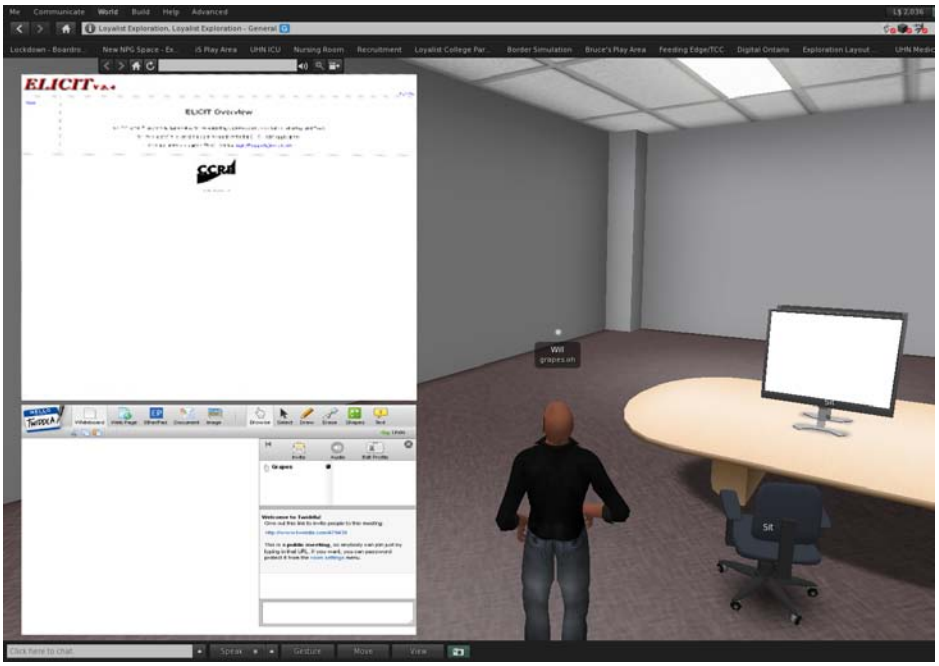

Figure 5: Full ELICIT game-play and whiteboard functionality HUD prototype

AGENT-BASED ELICIT

The virtual worlds industry and available products and platforms have expanded greatly in the past two years. To say that these products change quickly is a profound understatement. From the inception of this research, the evolution of virtual environments has been staggering. Little more than one year ago, some of the functionality that is required for ELICIT game-play was not available within Second Life. The preliminary research to determine which virtual world platform to use indicated that there are a range of environments that would support ELICIT, but only as a native "within the browser" application that is played in the virtual world.

The agent-based version of ELICIT (abELICIT) allows for a single player to participate in the ELICIT game, while the other players are controlled by autonomous or programmed agents. The aim of integrating agent-based game-play within the virtual world is the subject of this second phase of development and experimentation. There are multiple reasons why such a state would be advantageous, primarily the ability to conduct ELICIT trials with a single or limited number of participants.

While the Second Life platform is reliable for developing and launching a rapid prototype of ELICIT in virtual worlds, it is wholly unfriendly as regards large programmed elements added

on to the world. The complex backend of ELICIT, which not only serves the experience for participants, but also tracks the manner and choices made within the game, is by definition incompatible with a virtual world. This is true of straightforward informatics, as shown above, and even more so with driving “unmanned” avatars within a virtual space.

As is the case in the entire virtual environment sector of technology, we see solutions arriving just in time to support the evolution of needs and applications for these spaces. So while there is a relative impossibility in adapting agent-based ELICIT game-play into a public world like Second Life, there are emergent rigorous solutions that provide a range of customization that could support such a development.

One leading solution is the Unity3D authoring toolset. While not a virtual world, per se, Unity offers developers the unprecedented ability to design and program custom virtual world solutions in a streamlined and affordable manner. This product is very much like videogame authoring tools, with the important exception that it supports MMO + VW (massive multi-player online + virtual world) style interactions. As well, the Unity tools create virtual worlds that can be accessed through any web browser, without the need for expensive hardware upgrades.

We know that the ability to construct a game environment has been available for some time. However, a game is not a virtual world, in that virtual worlds allow for a range of choice and interactions usually not supported in traditional videogames. In a videogame, you play the game, but you can’t necessarily communicate or inter-relate with the other participants in a free flowing manner. In most cases, these interactions are scripted in the fabric of the game to keep the interactions relative to the game narrative.

However, in a virtual world, while one may play a game (like ELICIT in Second Life), there exists the ability to interact with other participants, to adapt or change the environment to suit the experience, or to have multiple environmental constructs to support a range of experimentation. So while not as “out of the box” as a Second Life, these virtual world authoring tools allow for integration of complex programmed elements while maintaining the flexibility native to virtual worlds.

These new authoring tools are powerful enough to accomplish complex hybrid designs for experiments. So while an agent-based ELICIT in a virtual world like Second Life would be impossible to achieve, it is highly feasible using the Unity3D toolset. So that not only could a custom environment be created but also that environment could support autonomous agents playing ELICIT as avatars, and interacting with the live participants in a very realistic manner. Additionally, this type of experience would also be able to support all of the data collection methodologies that are inherent in web based ELICIT as part of the program code in the virtual world, without having to bridge the two applications to have a fully functioning virtual ELICIT.

While these developments render it possible to achieve this level of integration within the virtual environment, further research is required to determine the process by which such integration will be achieved.

CONCLUSION

Virtual environments offer the potential for increases in awareness and performance for C2. To realize such gains, we are engaged in a campaign of experimentation to assess C2 in virtual environments through the ELICIT multiplayer online counterterrorism intelligence game. Currently ELICIT has only a primitive textual interface. This research seeks to investigate the impact of translating game-play into more immersive virtual environments. However, a simple transposition of real world experimental environments into virtual spaces did not yield any improvement in task performance. In analyzing the experimental construct, it is observed that the replication of the physical experimental space diminished the participant's experience of the strengths of virtual environments for collaboration and performance. Those strengths, the identification of the self with the avatar (presence), and the sense of sharing the environment with others (co-presence) have been identified as differentiators that render virtual environments unique in relation to other information technologies. To further this research, we intend to recast the environmental design to dovetail with these native attributes. It is hypothesized that in doing so, ELICIT game-play within virtual environments will be augmented, and that participants will demonstrate increases in their game-play performance.

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