How Immersive Technology Augments Operations Centers

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ABSTRACT

Operations centers are designed to bring together and assimilate massive amounts of data for commanders to make decisions in reaction to real time stimuli. They provide command and control, continuity of operations, and resources required to sustain operations. The scope of responsibility often requires a large support staff dedicated to processing a significant amount of time sensitive data. Immersive technology can augment decision cycles in operations centers by intuitively representing complex data in physical space, enabling users to more easily understand and process that data. Additionally, virtual spaces can bring personnel closer to the action who may not physically sit on the operations floor due to space constraints or geographic proximity. Immersive technology offers Commanders the flexibility to maintain an operational and training environment in the same space. Imagine a scenario where trainers interact with trainees in a virtual space that so perfectly overlays on top of the operations floor the trainees believe they are actually in the operational space? What if, in this scenario, trainees interacted with real world data and through their training experience offered solutions Commanders could use to solve current problems? In operations centers with a classified mission, immersive technology could enable multiple levels of access through existing access control mechanisms without having to lower the overall classification of the physical ops floor. This environment could significantly increase collaboration, efficiency, improve partnerships, and open the structure of operations centers to configurations that may have previously challenged operations security. This paper will examine the implementation of immersive technology into an operations center by exploring the benefits of augmented and mixed reality through the concept of presence, experiential learning, virtual displays, training, and parallel virtual collaborative environments.

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INTRODUCTION

All military commanders face the challenge of effective communication and maintaining a working environment conducive to the mission. Immersive technology can augment decision cycles in operations centers by intuitively representing complex data in physical space, enabling users to more easily understand and process that data. Virtual spaces can bring personnel closer to the action who may not physically sit on the operations floor due to space constraints or geographic proximity. Additionally, Immersive technology offers Commanders the flexibility to maintain an operational and training environment in the same space. These benefits aid Commander's communication and productivity by presenting a more natural, active, adult learning environment capable of assimilating and presenting complex data sets with holistic, intuitive displays. This paper will examine the implementation of immersive technology into an operations center by exploring the benefits of augmented and mixed reality through the concept of presence, experiential learning, virtual displays, training, and parallel virtual collaborative environments.

Artificial intelligence (AI) would also greatly augment the display of operations center data using immersive technology by acting as an underlying layer to assimilate and parse through data sets. Moreover, some studies have identified cyber security concerns when integrating immersive technology within operational and classified environments (Berardino & Tucker IV, 2020, p. 250). Both cyber security and artificial intelligence are crucial components of immersive technology adoption within operations centers. However, aside from a brief discussion about AI, both AI and cyber security are not within the scope of this paper.

IMMERSION AND PRESENCE

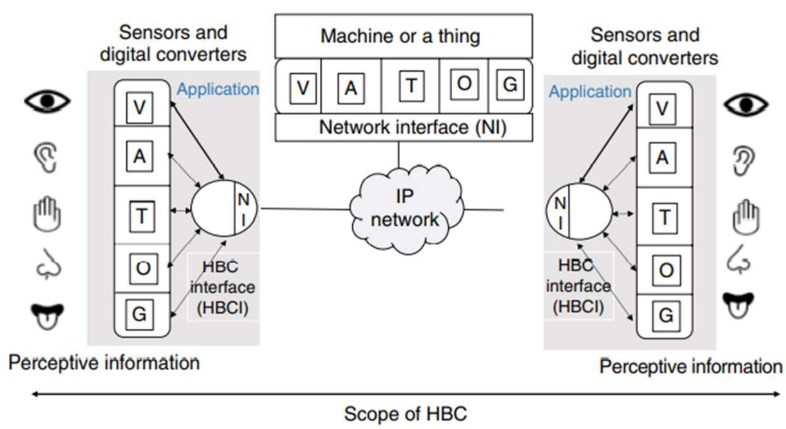

Figure 1 A systems level representation of HBC system (Dixit & Prasad, 2017)

Immersive technology encompasses a spectrum of devices from super imposing virtual images onto real world spaces and objects such as with augmented reality (AR) to virtual reality (VR) where users are exposed to a full "artificial environment… experienced through sensory stimuli" (Scavarelli, Arya, & Teather, 2020, p. 258). Mixed reality (MR) incorporates a mixture of AR and VR technologies. The degree to which the immersive technology delivers multiple "sensory modalities" similar to those experienced in the real world, the greater the sense of immersion (Scavarelli, Arya, & Teather, 2020, p. 259). For example, viewing an image of Yellowstone National Park is less immersive than actually being in the park.

Presence is a response to immersion where one is aware of their own thoughts, feelings, and physical surroundings. It is perhaps, most easily understood by its absence (Kleinman, 2017, p. 2466). For example, the feeling of not being in the moment when listening to a conversation is an absence of presence. In virtual environments, presence is an authentic reaction to becoming immersed in the virtual space with similar real world "cognitive processes and behaviors" (Barreda-Ángeles, Aleix-Guillaume, & Pereda-Baños, 2019, p. 290). When an individual feels presence in a virtual environment, they accept the illusion the environment is both genuine and plausible (Scavarelli, Arya, & Teather, 2020, p. 259). The more one experiences immersion, the greater the feeling of presence.

Presence involves all five senses, which "interact in interesting ways to become complete knowledge for human species" (Dixit & Prasad, 2017, p. 1). The ideal form of communication involves the complete transmission of sensory information. The human bond communication (HBC) concept (Figure 1) is an approach to "transmit the features of a subject in the way humans perceive it" requiring all five senses [visual, auditory, touch, olfactory, gustatory] and "includes both humans and machines as end points" within its scope (Dixit & Prasad, 2017, pp. 13-14). While technology has not reached the level of this ideal, "the interaction between the five senses enriches the information content tremendously" (Dixit & Prasad, 2017, pp. 11-12). As immersive technology incorporates sensory information across the five senses, the more users perceive the experience as real. Thus, experiences with immersive technology create more powerful interactions with the technology and lasting impressions within our memories like with real-world encounters.

Immersive technology's ability to provide similar real-world experiences has led to more meaningful work and improved performance. This is because the technology can "deliver the right information at the right moment and in the ideal format, directly in workers' line of sight, while leaving workers' hands free so they can work without interruption" (Abraham & Annunziata, 2017). This capability enhances existing working knowledge while reducing cognitive cycles required to manually integrate multiple data sources. In doing so, human work augmented by smart machines results in "dramatically improved performance, greater safety, and higher satisfaction" (Abraham & Annunziata, 2017). Additionally, enabling presence facilitates inclusion by adopting to various adult learning styles and improves the effectiveness of learning through the immersive experience (James W. , 1995, p. 29). Leaders who understand the benefit of immersive technology can then leverage how holistic connections with the surrounding environment enables experiences leading to the creation of new knowledge "in personally meaningful ways" (Yardley, Teunnissen, & Dornan, 2012, p. 163).

EXPERIENTIAL LEARNING

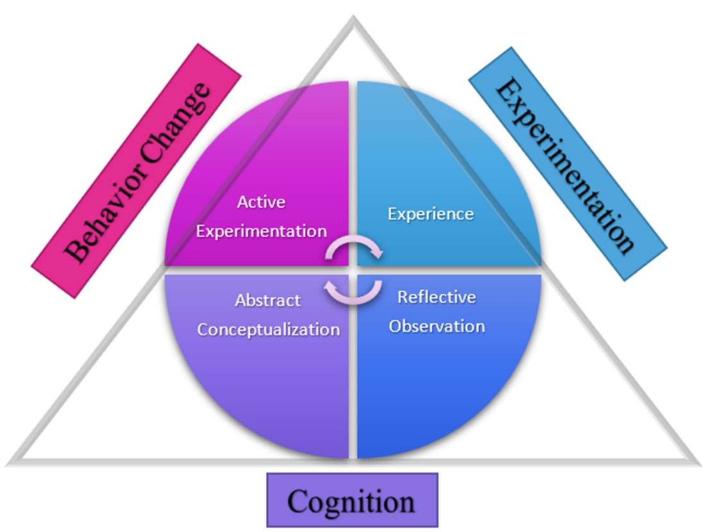

Figure 2: Experiential Learning Theory and Experiential Triangulation Concept (Clayton)

Experiential learning (Figure 2) is a type of holistic adult learning where learners apply “pre-existing knowledge, apply it to a new scenario, and” through social collaboration develop new knowledge that may be applied toward future experiences (Clayton, p. 1). Experiential learning theories explain how an individual’s learning and perception influence their reaction to experience and accumulation of knowledge (Yardley, Teunnissen, & Dornan, 2012, p. 161). In addition to experiential learning applied to academic settings, the model is applicable to active learning in the workplace as well. For example, medical students apply experiential learning through authentic workplace experiences as they “progress through clerkships and residency;” combining previous knowledge and experiential learning into their daily activities through the course of their careers (Yardley, Teunnissen, & Dornan, 2012, p. 162). This combination of previous knowledge and experiential learning extends to operations centers as well.

Operations centers are designed to bring together and assimilate massive amounts of data for commanders to make decisions in reaction to real time stimuli. They provide command and control, continuity of operations, and resources required to sustain operations. The scope of responsibility often requires a large support staff of knowledge workers (KWs) dedicated to processing a significant amount of time sensitive data. KWs utilize their high levels of “expertise, education, and experience” to provide value to operations centers (Óskarsdóttir, Oddsson, Sturluson, & Sæmundsson, 2021, p. 1). The complexity of the environment as well as expertise required to perform the mission require KWs to engage in similar active, experiential learning methods medical students practice during their careers. Experiential learning in operations centers occurs when KWs derive “knowledge and meaning from real-life experience” (Yardley, Teunnissen, & Dornan, 2012, p. 161). KWs in operations centers may gain their working knowledge through various means such as joint publications and standard operating procedures. It is likely many will begin to develop their knowledge through practical application while conducting their work (Jones, 2008, p. 112). For example, KWs such as planners may complete local training with established theory on how to develop an Air Tasking Order (ATO), but it may take a few attempts with experienced planners reviewing their work before they feel comfortable on their own.

Experiential Learning Applied To The Joint Air Tasking Cycle (JATC)

The experiential learning model (Figure 2) contains four phases: Experience, Reflective Observation, Abstract Conceptualization, and Active Experimentation. An examination of how these phases apply to the Joint Air Tasking Cycle (Figure 3) follows:

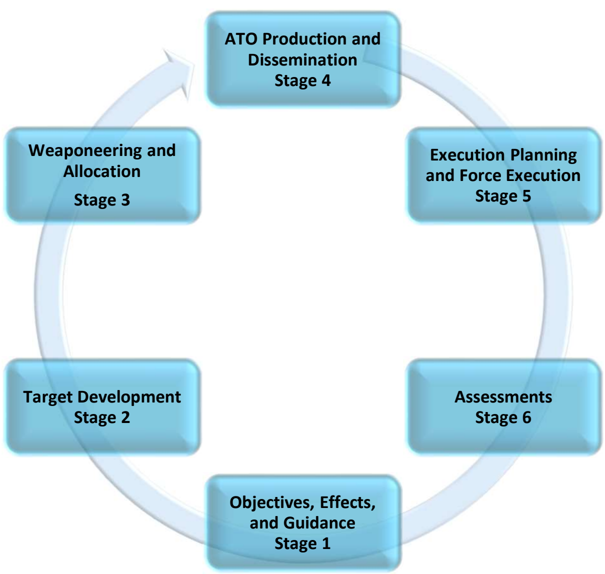

Figure 3: Joint Air Tasking Cycle (JP 3-30, 2021)

Experience: Learners may engage in concrete activities utilizing their senses, activities where their individual perception influence response, abstract activities applying theory, or social activities where each member learns from observing others (Clayton, pp. 3-5). Air Tasking Order (ATO) Production and Dissemination (Stage 4) of the Joint Air Tasking Cycle provides the instruction necessary for components to “plan and execute all their air missions listed in the ATO.” This feeds into the Execution Planning and Force Execution (Stage 5) phase where the Joint Air Operations Center and its commander provide instruction, sometimes in response to dynamic stimuli, during the execution of the ATO (JP 3-30, 2021, pp. III-25). Both stages utilize the planning team’s combined concrete, individual, abstract, and social experience to meet planning objectives during execution.

Reflective Observation: Learners may reflect on any combination of the content, process, and premise (i.e. what, how, and why respectively) of a problem (Clayton, pp. 5-7). Stage 6 of the Joint Air Tasking Cycle, Assessments, is a continuous process that determines how effective the mission was conducted at strategic and tactical levels. Reflective observation transitions from stage 6 to beginning of the tasking cycle, stage 1: Objectives, Effects, and

Guidance, where the results of previous operations influence "strategic direction and future plans" (JP 3-30, 2021, pp. III-21, III-26).

Abstract Conceptualization: The learner and educator conceptualize the experience and reflective observation to develop new goals or techniques (Clayton, pp. 7-8). Stage 2 of the Joint Air Tasking Cycle, Target Development, is where analysts utilize intelligence reporting to identify and nominate new targets that, once attacked, produce the desired effects (JP 3-30, 2021, pp. III-23).

Active Experimentation: Learners demonstrate their ability to apply knowledge from previous experience to future activities (Clayton, p. 8). Stage 3 of the Joint Air Tasking Cycle, Weaponeering and Allocation, is where desired effects are weighed against the collective knowledge of the group and a decision for the best "employment of all available means, to include air, maritime, land, space, cyberspace, and information-related activities" is made to inform Stage 4, ATO Production and Dissemination (JP 3-30, 2021, pp. III-23, III-24). Active Experimentation then transitions back to the experience phase of the experiential learning model.

The experimental triangulation model within Figure 2 simplifies the experiential learning model where experimentation leads to cognition and a behavior change.

OODA Loop and Experiential Learning

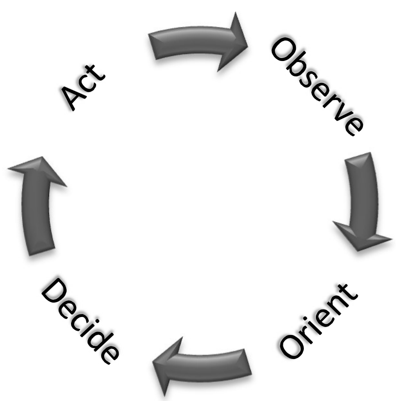

Figure 4: OODA Loop (Fadock, 1995)

The experiential learning model resembles Colonel John Boyd's OODA Loop. OODA is an acronym representing four stages: Observe, Orient, Decide, and Act (Figure 4). The following sections linking the OODA Loop to the Experiential Learning model will examine each phase through the lens of disaster management as a practical example of the type of activity executed within operations centers.

Experience: During the Observe stage, operations centers "must process vast amounts of multidisciplinary, often poorly organized, disparate data and information and convert it into relevant and useable knowledge" (Von Lubitz, Beakley, & Patricelli, 2008, p. 566). The next phase of the loop is informed through and during the observation phase.

Reflective Observation: During the Orientation stage, planners get their bearings through "cognitive grouping of the… environment into cohesive and easily recognizable blocks, and then realigning these blocks into even larger and better organized mental assemblies" (Von Lubitz, Beakley, & Patricelli, 2008, p. 571). Operations centers, especially while managing crisis, must quickly assimilate and order information in order to turn it into actionable data.

Abstract Conceptualization: Through cognition, new mental models inform the Decision stage enabling operations centers to develop products that feed into orders. The quality of assessments during the JATC process "leads to substantial enhancement of all processes within the Orientation stage… and increases the speed and the efficiency with which the Decision stage can be reached" (Von Lubitz, Beakley, & Patricelli, 2008, p. 571). Operations centers that efficiently align themselves with stimuli in accordance with guidance and the changing environment empower Commanders to make decisions with greater speed and agility.

Active Experimentation: During the Action stage, the operations center's "planned activity is fully implemented" (Von Lubitz, Beakley, & Patricelli, 2008, p. 571). At this stage all weapneering is complete and the ATO is published.

Following each phase of the OODA Loop more quickly and efficiently than an adversary causes the opponent to fold "back inside himself" making the opponents reactions irrelevant to the experience (Fadock, 1995, p. 16). Each OODA Loop phase directly maps to the four phases of the experiential learning model. This mapping highlights the agility of the experiential learning model by illustrating learning-action loops occurring through variable periodicity. This contributes to the OODA Loop's integration with military planning and connection with the JATC.

Combined Model For Operations Centers

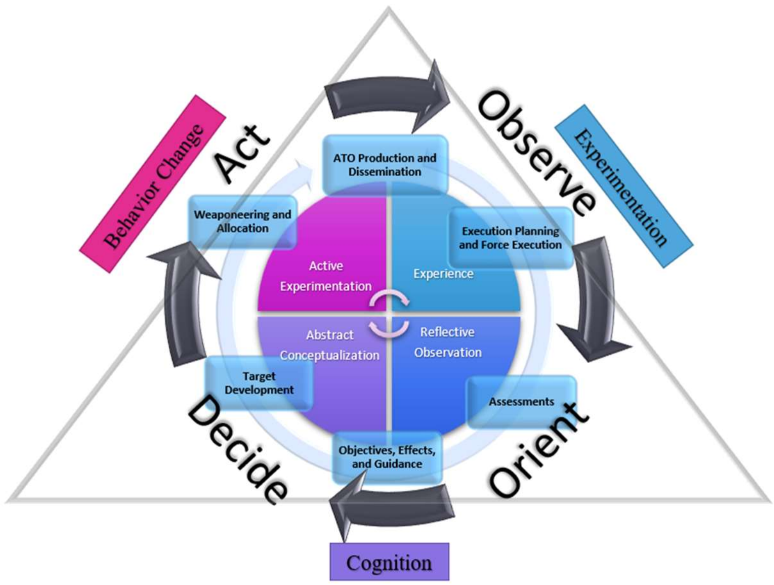

Figure 5: Combined Model

Experiential learning through immersive technology aid the JATC process by merging the benefits of learning in real time to more agile staff communication and product development. The combined model (Figure 5) demonstrates operations centers must enable planners to "accurately develop mental images, or schema" to manage the range of threats (both lethal and nonlethal) in their environment (Fadock, 1995, p. 16). In many ways, each of the three models (Experiential Learning, Joint Air Tasking Cycle, and OODA Loop) feed into and enhance each other. As individuals learn from experience, they are more easily able to retain their knowledge, and apply it to future scenarios. This benefit ultimately leads to responsive decision making and maneuver in the battle space while increasing efficiency between each OODA Loop cycle.

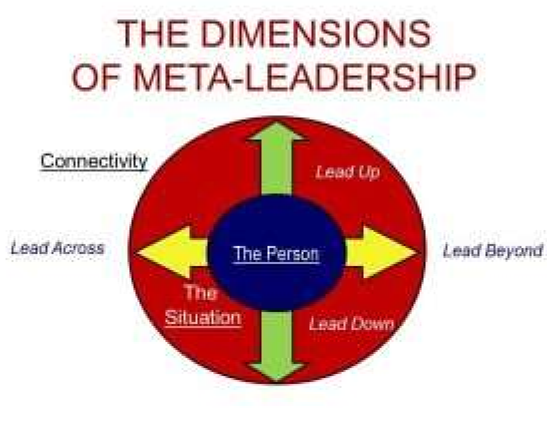

Figure 6 Meta-Leadership (NPLI, n.d.)

Leaders in operations centers following the concept of meta-leadership can use the combined model as a tool during high-stress operations. The meta-leadership model (Figure 6) developed by the National Preparedness Leadership Initiative (NPLI) at Harvard was designed to equip leaders with options to "act and direct others" during a crisis. The model contains three dimensions: person, situation, and connectivity (NPLI, n.d.). The combined model contains processes through the experiential learning, JATC, and OODA Loop models that: elevate "higher levels of thinking" (person); proactively lead decision makers to options for action and next steps (situation); and operationalizes decisions so that they may be communicated (connectivity) down the chain of command, up to leadership and stakeholders, across to peers and collaborative units, and beyond to third parties (NPLI, n.d.). Immersive technologies implemented within operations centers should consider meta-leadership in conjunction with the combined model when developing solutions generating collaborative environments.

ARTIFICIAL INTELLIGENCE (AI)

AI is exceptionally great at pattern recognition and can be used to "identify and categorize unstructured data into specific classifications" (Schmelzer, 2020). An example of this is performing a word search to find a photograph on a smartphone. The built in AI on the phone uses pattern recognition to identify pictures containing content associated with the search criteria. Use of AI in technology used to augment operations centers reduces the cognitive load on planners required to sift through and develop products from significant quantities of unstructured data. For example, the inclusion of AI during disaster management processes considered AI "particularly important in reducing stress-induced human errors" (Von Lubitz, Beakley, & Patricelli, 2008, p. 571). The smart application of AI within solutions utilizing immersive technology has the potential to improve efficiency, drastically reducing the time to act within an operations center's OODA Loop cycles.

IMMERSIVE TECHNOLOGY FOR OPERATIONS CENTERS

Immersive technology offers Commanders the ability to relate to and understand the data their team presents from their own perspective in ways never imagined before. Commanders no longer need to receive information siloed and carefully curated through traditional four quadrant slides. Instead, teams can show their Commander exactly what they are working with using intuitive, holistic displays presenting information through a shared experience that cuts through the barrier of subject matter expert level understanding of the material. Whether it is a complex idea or a first-person experience on the battlefield, the Commander has the option to view the experience and concepts as if they are actually present. Immersive technology also offers a superior approach to illustrate concepts requiring spatial awareness. For example, students pursuing medical education found spatial awareness using VR/AR was key to learning anatomical models and led to enhanced contextualization and retention of the models (Scavarelli, Arya, & Teather, 2020, p. 264). Immersive technology allows operations centers to analyze complex data sets holistically in ways only available in virtual environments unconstrained by the nature of physical real-world spaces.

Interactive, Augmented Reality Sand Table

Figure 7 ARES (PMC, n.d.)

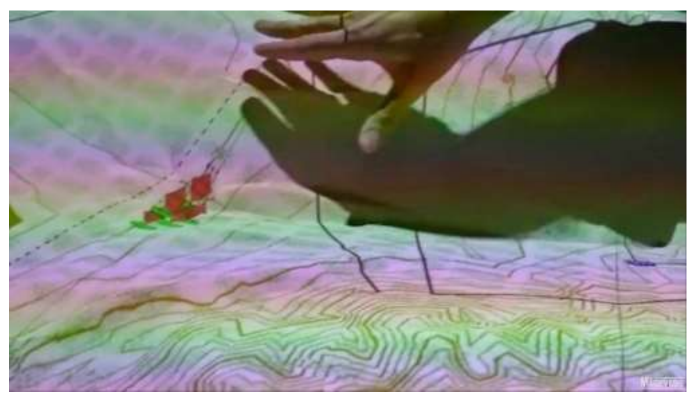

Figure 8 ARES (Mufson, 2014)

The Army Research Lab developed an interactive Augmented Reality Sandtable (ARES) (Figures 7 and 8) to visualize terrain quickly utilizing software and a projector on sand (PMC, n.d.). Sand tables like ARES empower users to describe physical elements in situations where experience, language, or other skills like drawing may have otherwise inhibited the transmission of knowledge. Additionally, this "video game" like view of realistic terrain facilitates "tactical thinking" (Mufson, 2014). In theory, a planner interacting with a physical sand table as an input source (like mouse and keyboard) to a virtual sand table can share ideas in real time (similar to white boarding) with a wider virtual audience.

Virtual Common Operating Picture (COP)

Virtual sand tables like the one from vST (Figure 9) merge multiple sources of data and media to present a COP (vST, 2018). These types of views enable a shared understanding and awareness of operations among personnel.

Figure 9 Virtual Sand Table (vST, 2018)

For example, the 3D map may reveal the location of a unit in the field while support personnel view media streamed in real time, aiding the personnel engaged in the activity. These support personnel may not have the real-world experience to relate to everything going on, yet the immersion enables an active understanding as an enabling function shortening the time to apply their expertise to the situation. This inclusion of subject matter experts does not need to occur within the physical space of an operations center floor either due to the inclusive nature of immersive technology. This enables a wider range of perspectives and expertise without the limitation of physical space available on the operations floor.

Space Operations Visualizations Leveraging Augmented Reality (SOLAR)

Figure 10 DARPA Hallmark Program (Daigle, 2019)

Immersive technology in combination with AI has the capacity to consume, assess, and display complex data sets using holistic, intuitive displays. The challenge of displaying large, complex data led the United States Air Force to collaborate with the Defense Advanced Research Project Agency (DARPA). Together, these agencies developed the SOLAR application (Figure 10). The application enables space operators to quickly develop "space situational awareness and course-of-action development workflow to arrive at decisions faster, with greater confidence" through a combination of immersive technologies (Daigle, 2019).

Augmented Reality Mission Operations UseR eXperience (ArmourX)

Figure 11 ArmourX Display (Berardino & Tucker IV, 2020)

Figure 12 ArmourX Collaboration (Berardino & Tucker IV, 2020)

Johns Hopkins Applied Physics Laboratory (APL) developed the ArmourX visualization tool (Figure 11) in partnership with the US Army to better visualize "the complex, invisible and nonlethal aspects of the operational environment" as well as "geographically distributed AR for remote viewing and briefing of the operational overlays or layers within the user-defined display." The team at Johns Hopkins APL is expanding the tool to visualize data from all warfighting domains supporting "the Army's multi-domain transformation" and Joint All-Domain Operational Tool Suite (JDOTS) development (Johns Hopkins APL, 2021). The tool is capable of visualizing hundreds of models simultaneously and successfully demonstrated the benefit of a collaborative work environment (Figure 12) among geographically separated users using AR with and without the use of a head mounted display (Berardino & Tucker IV, 2020, pp. 246, 247, 251).

Training

As virtual spaces are developed to augment real environments through replication or something entirely new and novel, virtual and physical worlds become "interwoven into parallel realities that affect each other and every individual within them in strange and exciting ways" (Scavarelli, Arya, & Teather, 2020, pp. 271, 272). Immersive technology offers Commanders the flexibility to maintain an operational and training environment in the same space. Training scenarios on the operations floor now offer trainers using augmented reality headsets to interact with trainees in a virtual space that so perfectly overlays on top of the operations floor trainees believe they are physically in the operational space. Commanders could develop training with dual objectives allowing trainees to interact with real world data so that their training experience may also offer solutions Commanders can use to solve current problems. Training in this way could present options for Commanders to test high-risk theories using real time data while also providing training benefit to the staff. The US Army is investigating the use of immersive technology in training. In their Army Multi-Domain Transformation paper, the Army wrote: "There is no substitute for exercises in the dirt, such as at our combat training centers, but we must add to that training with augmented reality and a synthetic training environment that will dramatically increase the quality of training without dramatic cost increases" (Department of the Army Headquarters, 2021, p. 33). One way training in virtual space reduces cost is through running simulations in real time without the cost of material and space to conduct the same effort in the physical domain. In addition to reduced cost, training in classified virtual environments may reduce the risk of exposing exquisite capabilities while offering trainees the benefit of unlimited opportunities to experiment, iterate, and become an expert on these capabilities.

Collaboration Within A Multi-Level Security Environment

The idea of leveraging parallel physical and virtual environments can be extended past training scenarios within operations centers. Multi-level security permits users with different security clearances, limited by their individual authorization, access to the same systems and network (Colonel Beers, 2022). In operations centers with a classified mission, immersive technology could enable multiple levels of access through existing access control mechanisms without having to lower the overall classification of the physical operations floor. For example, virtually present liaison officers physically located outside the operations center with limited authorization may view entirely different content on operations center displays compared with those physically in the operations floor with less restrictive authorization. This environment could significantly increase collaboration, efficiency, improve partnerships, and open the structure of operations centers to configurations that may have previously challenged operations security.

CONCLUSION

The power of immersive technology is in its ability to invoke a feeling of presence while interacting with technology. Presence strongly connects users with experiences and allows more natural, holistic learning to occur. This learning maps well to practiced and refined operational models like the JATC and OODA Loop. The combination of these models with meta-leadership offer operations centers limitless synergy and efficiency in communication, collaboration, and effectiveness. Immersive technology augments operations centers by presenting a more natural, active experience utilizing environments for training and operations capable of assimilating and presenting complex data sets with more holistic, intuitive displays.

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