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A Constructive Approach to Organizational Learning in a Tactical Operations Centre

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ABSTRACT

Defence organizations conduct experiments to generate new concepts for fielding and employing military capabilities. These events typically involve people with different sets of expertise working collectively on complex real-world problems with the intent of generating new working methods. It is argued that constructivist learning theories are well-suited to conceptualizing defence experiments and that a constructivist approach provides useful insights to the conduct of defence experimentation. A defence experiment on the introduction of new airspace control software into a tactical operations centre is described and used to illustrate the application and benefits of a constructivist perspective. During the course of the six day long experiment, 19 military personnel operated a tactical control centre providing fire support to a simulated battle group. During the experiment the participants adapted their handling of unscheduled missions, their use of software features, and their briefing methods. Argote's (2002) Intra-Organizational Learning Framework was used to identify the newly generated knowledge pertaining to the skill requirements of the personnel, the functionality of the command and control software, and the tactics, techniques, and procedures employed in the operations centre. The practicality, responsiveness, and efficiency of the constructivist approach to defence experimentation are discussed along with its limitations.

Keywords: *command and control teams, learning, training, experimentation.*

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1. Introduction

Military command and control (C2) organizations provide direction to forces performing a mission. Their performance is critical to the success of the mission so consequently their personnel, technology, and processes are frequently altered in an effort to exploit advances in technology (Defense Information Systems Agency, 2009; Department of Defense, 2010; Pengelley, 2010) and to accommodate evolving circumstances. For example, changes to the

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composition of a coalition (Crebolder, Coates, Torenvliet & Stewart, 2009), the order of battle, rules of engagement (NATO, 2010), and enemy behaviour, led to C2 being performed differently in NATO missions in Iraq, Afghanistan, and Libya.

Military C2 organizations are complicated, and the effects of changes can be difficult to completely anticipate. To acquire a multi-faceted understanding of potential changes to a military capability, analyses, workshops, discovery experiments, and true experiments can be undertaken (Alberts & Hayes 2002; Alberts & Hayes, 2005; The Technical Cooperation Program, 2006). Campaigns of defence experimentation are undertaken to generate new knowledge, rather than transmit existing knowledge, such as might occur in a training event. This article describes the knowledge generation within a defence experiment from a constructivist perspective and uses the intra-organizational learning framework (ILF) (Argote & Ophir, 2002) to conceptualize the generated knowledge.

1.1 A Constructivist Perspective

A constructivist perspective on learning emphasizes the integration of new information with a person's existing mental constructs (von Glasersfeld, 1995). New knowledge may be compatible with the learner's existing mental constructs and be assimilated. If it cannot be assimilated, it may be accommodated with changes to current mental constructs or the creation of new ones (Piaget & Inhelder, 1954). Thus, the individual's prior knowledge is equally important as the new knowledge to learning. The intellectual development and prior learning of each individual create a unique set of mental constructs and therefore each individual's learning experiences will likewise be unique. Furthermore, mental constructs cannot be transmitted intact from an instructor to a learner; the learner must actively integrate new knowledge. Teachers, training media, and social interaction influence how knowledge is integrated, and may increase the amount or sophistication of the gains (Vygotsky, 1978).

Critics of constructivism have noted the failings of teaching approaches that attempt to foster the integration of knowledge structures by providing the learners with incomplete information or providing limited guidance. Mayer (2004) surveyed literature on comparisons of guided discovery learning, where students pursuing a learning objective were provided with guidance by a teacher, to pure discovery learning, where students were unconstrained is pursuing the learning objective. In examining the discovery of problem-solving rules, object conservation strategies, and computer programming concepts, experimental evidence showed guided discovery learning lead to better performance on new transfer problems. Mayer concluded that pure discovery learning was ineffective and that a viable constructivist learning theory cannot neglect the role of guidance and structured learning goals. In a similar critique of minimal guidance teaching methods, Kirschner, Sweller, and Clark (2006) wrote “Learners must construct a mental representation or schema irrespective of whether they are given complete or partial information. Complete information will result in a more accurate representation that is also more easily acquired (p. 78).” Moreover they emphasized the particular challenge this instructional approach poses for novices or weaker students.

These criticisms of minimally guided teaching methods are most relevant to the teaching of established bodies of knowledge. In these cases, the alternative of guided discovery is available. For people changing military C2 systems, however, complete knowledge of the future system is not available and guided discovery is not a certain approach. Creating and employing complex technology depends on a breadth and depth of specialized knowledge that rarely resides in a single individual. This development, or “domestication” of complex technology benefits from abductive reasoning and hypothesis generation (Patokorpi, 2009). Bitter-Rijpkema and colleagues have successfully used a constructivist approach to this kind of problem by emphasizing the importance of real operational contexts and interactions with external partners (Bitter-Rijpkema, Retalis, Sloep, Sie, Katsamani & van Rosmalen, 2010; Bitter-Rijpkema, Sloep, & Jansen, 2003; Bitter-Rijpkema & Crutzen, 2002).

A common element in defence experimentation (Alberts & Hayes, 2002; The Technical Cooperation Program, 2006) and social constructivist learning (Lundin, 2004; Vygotsky, 1978) is the importance placed on the situated nature of knowledge (Greeno & Collins, 1996). The development of ecologically valid knowledge is promoted when the actual people, tools, and problems are brought together. These events have a wealth of data that extends beyond what might be identified as a dependent variable in a pure experimental design. To capture all the knowledge generated, Argote’s (Argote & Ophir, 2002; McGrath & Argote, 2001) intra-organizational learning framework provides a means to understand changes to complex entities like C2 organizations. In the ILF, an organization is a socio-technical network comprised of three types of elements: members, tasks, and tools. Each is a repository of organizational knowledge. Obviously, individual members hold knowledge. Tasks express knowledge of what the organization does and how it does it. Knowledge is also instantiated in the function and customization of the tools. Applied to C2 organizations, knowledge, and therefore learning and adaptation, is embedded in personnel, processes, and information technology.

The ILF describes the relationships amongst and between elements as sub-networks. Using this theoretical construct, sub-networks can also hold organizational knowledge. The sub-network amongst members captures their knowledge of one another as individual people, and the sub-network amongst tools represents the integration of the information technology. A sub-network amongst tasks describes how the various work functions in a C2 organization are related. A tool – task sub-network shows how a piece of information technology is configured to support a particular work function, and so on with the other combinations of elements. Identifying ILF sub-networks in command and control can therefore provide a systematic method of finding and improving the adaptation of the system to the operation.

2. The Coalition Attack Guidance Experiment

Canada's Department of National Defence is conducting a campaign of experimentation to develop a model for joint fire support in coalition and national operations (Allen, Abdellaoui, Fraser & Wheaton, 2008). As part of that campaign, the Coalition Attack Guidance Experiment (CAGE) was conducted to refine a prototype tactical operations centre (TOC) for operations in Afghanistan. Military operators, C2 developers, and defence analysts joined together in an event where a command team used C2 tools to conduct six days of operations that were driven by computer simulations. The expected outputs included:

- Assessment of the concept of employment for airspace deconfliction systems
- Assessment of airspace deconfliction tactics, techniques, and procedures
- Technical and operational insight into the Integration of unmanned air vehicle tasking and intelligence, surveillance, and reconnaissance data into the operation centre's activity
- An improved understanding of joint fires management in coalition operations

2.1 The Participants

The primary participants were 19 military operators drawn from the Canadian Army, Navy, and Air Force and the US Army. Most had combat experience in Afghanistan and they ranged in rank from corporal to major. In addition to obtaining their informed consent, their participation was approved by their chain of command and the Defence Research and Development Canada Human Research Ethics Committee. Their primary goals were to gain experience with the new C2 systems employed in the prototype TOC and to develop suitable tactics, techniques, and procedures. They received remuneration of $12.16 per day.

The C2 system developers came from the Product Manager Air Traffic Control Systems. They developed two related C2 systems employed in the prototype TOC, the Tactical Airspace

Integration System (TAIS) and the Dynamic Airspace Collaboration Tool (DACT). The developers were experts with these systems as well as many of the other C2 systems in the experiment. Their role was to configure the systems into the existing TOC prototype and to support its use during the event. Their primary objective was to gain insight into the integration of TAIS and DACT with other coalition C2 systems and to observe how TAIS and DACT affected C2 performance and outcomes.

The analysts were operations researchers and human factors specialists from Canada, the United States, and Australia. Each analyst was assigned to observe a small section of the TOC to document how the members of the command team interacted with one another and the technology by making written notes of their observations during the experiment. The primary goal of the analysts was to support and evaluate changes to the C2 systems and the command team interactions.

2.2 Apparatus

The Tactical Operations Centre (TOC) prototype was located in a single room. Each member of the command team had a computer workstation with multiple screens. The workstations were arranged in rows, with five large screen displays at the front of the room that could be configured to display information of common interest such as briefing slides, imagery, and maps. The TOC was outfitted with the C2 systems listed in Table 1. To communicate, the command team had the messaging systems internal to some of the C2 systems, online chat, simulated radios, electronic mail, and face-to-face conversation.

AFATDS	Advanced Field Artillery Tactical Data System
ADSI	Air Defence System Integrator
AMPS	Aviation Mission Planning System
CPOF	Command Post of the Future
DACT	Dynamic Airspace Collaboration Tool
GCCS	Global Command and Control System
JADOCS	Joint Automated Deep Operations Coordination System
LCCS	Land Combat Support System
TAIS	Tactical Airspace Integration System
TBMCS	Theater Battle Management Core System

Table 1. Command and Control Systems Employed in CAGE

The command team was tasked with supporting brigade sized operations as Task Force Kandahar. A suite of simulations interfaced with the C2 systems drove a scenario that required the command team to oversee three different operations in its area of responsibility. The scenario prompted extensive fire support and casualty evacuation using coalition assets so that the TOC could be tested in these demanding activities.

2.3 Procedure

CAGE was conducted at the Canadian Forces Warfare Centre 3-14 May 2010. During the first three days, the participants received training on the technology and executed a test scenario to become familiar with the equipment, personnel, and processes involved. This also allowed the C2 developers to configure the systems to the initial preferences of the command team. Then two three-day runs of experimentation were conducted, separated by a day of rest and a day for demonstrations for high profile visitors. The last day was a review day. The two runs of the scenarios were the same, with changes to timings and locations of incidents so that the participants could not anticipate events. In the first run, the command team did not have use of the TAIS / DACT airspace control tools. These tools were introduced in the second run to evaluate their influence on the conduct of the TOC. Each exercise day followed the timings in Table 2.

Time	Events
0730 - 0800	Prepare for scenario execution
0800 – 1145	Execute scenario
1145 – 1200	Break for questionnaires
1200 – 1300	Lunch
1300 – 1530	Execute scenario
1530 – 1600	Break for questionnaires
1600 – 1615	Command team hot wash
1615 - 1630	Analyst and C2 developer hot wash

Table 2. CAGE Daily Schedule

The command team started the day with a battle update brief from the commander of the TOC. The brief provided the latest information on the scenario to the command team, simulating a hand-over briefing that would be provided by a preceding watch. The briefing also allowed the commander to review the operational plan, set priorities for the day, and solicit input from the other members of the command team. The scenario would then begin, with the command team performing their mission using their C2 systems, interacting with the forces driven by the simulations. The command team was able to solicit help from the C2 developers as required and have brief conversations with analysts during lulls. At the end of the scenario, the command team completed questionnaires assessing demographics, attitudes to decision making, trust in automation, situation awareness, team effectiveness, information sharing, and workload (described in Allen, 2011). They then conducted a debriefing on the conduct of operations During the debriefing the commander and leaders from each functional area of the command team reviewed the conduct of operations and provided insights into critical events in the scenario. The observations often addressed team performance, the procedures employed, and the functioning of the C2 systems, which was readily mappable onto the members, tasks, and tools constructs of ILF.

For the C2 developers, the day began with starting and initializing all the information and communications technology. In instances where major changes to the systems were performed, their preparation would actually begin the night before and resume the next day, earlier than the times listed in Table 2. During scenario execution, they monitored the systems and performed troubleshooting on problems that emerged during execution. They also provided individual assistance to members of the command team on the use of the information technology, such as explaining the function of specific system features or configuring the user interface. During questionnaire time and lunch the C2 developers performed system maintenance and short term fixes.

The analysts started the day at the same time as the command team. Each analyst followed the same members of the command team for the duration of the exercise, sitting where it was possible to look over the shoulders of the team members, observing their computer screens and hearing their conversations. The analysts maintained notes on the performance of the command team members, including their interactions with their systems and other team members. Conversations between command team members and analysts could be initiated by either side, and covered topics including the nature of the military operation, the strengths and weaknesses of the command system, potential changes to the systems, and extraneous, rapport-building topics. During the questionnaire time, the analysts administered the questionnaires.

Both the C2 developers and the analysts listened to the command team debrief, and their representatives had the opportunity to offer immediate observations or seek clarification. The C2 developers and analysts then conducted their own debriefings.

2.4 Observations and Results

The CAGE enabled the command team, the system developers, and the analysts to collectively work together to adapt command team dynamics and supporting C2 technologies for deployment in the near term. Some of the knowledge was generated concurrently with the simulated military operation. Knowledge was also generated outside of the simulation runs, during debriefs and planning sessions where systems were reconfigured and standard operating procedures changed. This newly generated knowledge pertained to the operation of specific C2 systems, the integration of C2 systems, and improved means to harness the power of the C2 systems to the command team's expertise. As described by the ILF, the knowledge was embedded throughout the network of people, tools, and task of the TOC. This section presents three examples adaptations created through constructive learning during the CAGE event and identified according to the ILF.

Adaptations for Unscheduled Missions. The first example of adaptation is the change to the handling of unscheduled missions, such as providing fire support to troops being ambushed or evacuating casualties. The simulation scenario would inject a report of a significant event though any of the TOC's various communications systems. Initially, the TOC's response was command – centred, where information and activity propagated through the chain of command. The report would first be passed to either the Chief of Operations (CHOPS), or the Chief of Fires (Fires), who would have their aides record the event in JADOCS. Fires or CHOPS would then create an appropriate functional activity entry in JADOCS, such as a casualty evacuation (CASEVAC) flight, and then pass it to the relevant functional area (in this example J3 Aviation) for detailed development and execution. This approach worked, but in the first morning the military operators quickly decided this approach in the fast-paced scenario placed too much workload on CHOPS and Fires. The TOC's response time could become slow and error prone when CHOPS and Fires serially initiated responses to multiple reports that had arrived in quick succession.

During the first day, the process was changed to be functionally – centred. When a report was received, the relevant functional area would create and develop the entry in JADOCS (such as the Fire Support Coordination Centre creating a Troops in Contact (TIC) entry), then executing the necessary action. CHOPS would monitor the incoming report, and provide his authorization and direction as required. This approach reduced the workload and bottleneck at the TOC Command, leading to quicker response times by the TOC and leaving more time available for CHOPS and Fires to monitor the overall battle. However, as an event unfolded, the JADOCS events created by one functional area did not support the data needed by other functional areas drawn into the event. For example, the entry used to provide fire support to the TIC did not contain the data fields needed to support a CASEVAC mission, which often followed a TIC. As a consequence, a new event would have to be created, re-entering data and optionally adding notes indicating its association with the earlier event. It was also observed that duplicate events were sometimes created by different functional areas. On the fourth day this multi-entry recording became more formalized, with high-level information on events being entered in the Significant Activity manager and the recording of individual events recorded in multiple engagement entries in other data managers.

Analysts and members of the command team felt that using several different entries to record related events was an imperfect adaptation of the tool. Tracing events was more difficult, workload increased, and it increased the potential for erroneous data to be introduced to the system. At the end of the third day, discussion between CHOPS and analysts proposed another change to the process. This process would be event-centred. In this process JADOCS entries would again be initiated by the initially relevant functional area and overseen by CHOPS or Fires. However, the tools would be altered to provide multi-facetted or tabbed entries. The entry would still pertain to one event, but different tabs would exist for each functional area. Command team members from the functional area initially creating the event would enter data needed for the first action. If subsequent action was required from another functional area, command team members from that area would add data to the relevant tab, where some fields would already be populated through links with the other tabs. This approach would enable continuity of records, save data entry time, and reduce data entry errors. Time and resources were not available to implement and evaluate this adaptation within the CAGE event.

The knowledge creation described above can be organized using the ILF perspective. Considering the people, tools, and task elements, the military operators acquired new knowledge on how to perform the tasks in ways that lead to quicker, more accurate performance. The proposed changes to the C2 tools express knowledge of how battlefield events growth or evolve. The changes to the mappings of tasks to people reflect improved knowledge of the rate of battlefield events and the workload capacities of the TOC.

Adaptations of the JADOCS Tool. A second example of adaptations made during CAGE was the interpretation of the mission indicators on the JADOCS C2 tool. Each mission record in the JADOCS database included a colored status indicator for each functional area of the TOC. The indicator could be set to red, blue, green, or yellow. As the command team worked with the system, the meaning and use of these indicators evolved.

On the practice day, the indicators were used as gates for action. CHOPS or Fires would establish a mission, setting the indicators colors to blue to signify which functional areas had to take action. Each functional area would then take action, first setting the indicators to yellow to signify receipt of the mission, then setting the indicator either to green to indicate that their work was complete and that the mission could proceed, or red to indicate that the mission could not go ahead. The intention was that a set of green lights would indicate that the mission was either ready or complete. This initial interpretation conflicted with the doctrine practiced in the TOC, however. The commander has the authority and responsibility to make decisions regarding the mission, yet this use of the indicator lights compromised that authority and responsibility by implicitly transferring them to the functional areas. This initial people – tool knowledge conflicted with the task knowledge, or military doctrine. By the end of the practice day, CHOPS stopped using indicators as gates for action.

On Day 1 of the scenario, the indicators were used as status signals to promote situation awareness. Each functional area would change the color of the indicator to signal that they were either working to complete their function in the mission (e.g. the Air Space Coordination Centre is clearing the airspace for a fire mission), that they had completed their function for that mission (e.g. the airspace is cleared), or that there was a problem preventing them from completing their function (e.g. the Air Space Coordination Centre cannot contact an aircraft in the airspace for the planned fire mission). This use of the indicators to signify status in execution was people – tool knowledge was consistent with knowledge contained in doctrine, but by the end of the day, this use of the indicator lights was abandoned as well. Although it was consistent with other knowledge in the system, the use of the indicator lights was found to be inefficient by the command team. Instead, they found voice communication to be more efficient. The whole team was co-located in the TOC, which was arranged to facilitate unaided voice communication, and the number and rate of incidents did not exceed their capacity to execute missions using voice. Subsequently the command team did not use the indicators.

Adaptations of the Battle Update Briefing Task. A third example of adaptation during CAGE was the change in the battle update briefings. The briefings used graphics, text, and speech to communicate results of combat actions, the disposition of friendly and enemy units, current progress toward mission goals, planned future events, and new priorities.

Initially, CHOPS used a dedicated tool, Microsoft PowerPoint, for the briefing. This was most clearly illustrated on Day 2 as CHOPS directed his aide to build slides throughout the day during lulls in the action and just before the briefing. This required taking screenshots of maps and inserting them into slides, adding text overlays, and copy & pasting text material from

JADOCS. During the briefing, the aide controlled the slides presented across all the large displays at the front of the TOC. CHOPS lead the briefing, with particular topics being addressed by the leaders of each functional area.

By Day 6, PowerPoint was used very little. Instead, CHOPS briefed using the JADOCS. To prepare the briefings, CHOPS worked with his aide to review the records in JADOCS, noting the event numbers of records that held information to be used in the brief. During the briefing, CHOPS then directed his aide to retrieve the relevant records from JADOCS by event number. The aide then recalled the record and displayed the associated text and maps on the TOC's large display screens. Again, the leaders of the various functional areas spoke to their specific sections of the briefs.

In terms of the ILF, the need to provide the same briefing content was stable, as were the roles of CHOPS and the functional area leaders. The task, members, and member – task network were unchanged. The tools changed, however, from JADOCS and PowerPoint to JADOCS only. The tool – tool sub-network was initially accomplished using the Microsoft Windows cut & paste function, screen capture, and the JADOCS save function combined with the Microsoft PowerPoint Insert Picture command. This involved multiple steps and required management of intermediate products. Later, the need to network separate tools was eliminated by using JADOCS alone to drive the briefings. This reduced the time and knowledge required to construct the briefing. CHOPS' aide no longer had to use PowerPoint, so that member – task sub-network was dropped, reducing the number of tools he needed to master.

3. Conclusions

Changes to complex socio-technical systems like a C2 organization can have pervasive effects that need to be anticipated and ameliorated, if necessary (Justice, 2008). Technology standardization (Davidson, 2008a, 2008b) and pre-deployment theatre and mission-specific training (e.g. Department of National Defence, 2001) help, but may not be sufficient, because changes to one sub-system of a larger socio-technical system may unexpectedly propagate to other aspects. Defence experimentation provides a method for gaining a more comprehensive understanding.

The CAGE took place to understand and adapt a TOC during the introduction of new C2 technology. Knowledge of how to conduct the mission with the new C2 tools was constructed through interactions amongst the command team, C2 system developers, and analysts. This knowledge pertained to, and was embedded within, the network of members, tools, and tasks. The resulting adaptations described in this paper are not proposed as optimal solutions to the problems of C2 in a TOC, however. Rather, they are offered as examples of incremental, evolutionary improvements attained using constructive learning approaches and identified using an ILF perspective.

The constructivist approach to knowledge development brought a number of benefits. Pragmatically, it made the event achievable. CAGE required substantial investments of time and money from the command team, C2 developers, and analysts. Accordingly, these stakeholders required that they obtain valuable results recognizable to their own communities' to justify their participation. The constructivist approach delivered this by providing each community with the opportunity to observe and alter a functioning TOC in a safe environment; something they could not obtain on their own. Dynamic interaction with the other communities made the experiences richer and more informative. Had each of the communities not been afforded the opportunity to achieve their own goals, they would not have participated.

Another benefit of the constructivist approach was that it was responsive. Given the freedom to make changes to systems and practices, the participants devised, implemented, and evaluated multiple changes during the event. Moreover, these changes were implemented in a working system conducting (simulated) operations, thus allowing the evaluation of changes to one element to include the cascaded effects on other elements in the organization. Fuller and Dennis (2009), in an experiment on the effect of technology fit to task demands, observed that teams can adapt even poorly suited technology in a few days, and ultimately attain a high level of performance. It is the responsiveness of this approach that the UK has exploited in the Niteworks partnership (Barton & Whittington 2010). Teams of operators, analysts, and developers conduct experimentation to support the management of C2 capability. Existing and proposed C2 systems are trialed and the results analyzed using sophisticated decision support tools. This responsiveness is especially relevant in light of Nissen's (2007) argument that no C2 system is best for all operations. Given the diversity of contemporary operations, there is value in the ability to rapidly refine C2 to particular circumstances. Currently deployed or soon to be deployed systems can be trialed and adapted to observed or anticipated conditions. Moreover, this efficiency was enhanced by adopting the ILF. The use of the framework provided both a systematic way find all the knowledge related to a particular adaptation as well as an organized way of reporting it.

Another attraction of this approach is that it effectively leveraged the collective expertise of the participants. Although not formally tested, it appeared that the simultaneous (i.e. within the interval of a constructive learning event) application of operational, information technology, and human factors expertise promotes comprehensively adaptive changes (Allen, Lichacz, & Wheaton 2010). The organization adapted the elements most in need of change and the other elements were changed in turn to facilitate the adaptation. This can be contrasted with situations where changes are imposed for the benefit of one community to the detriment of others. This may lead to maladaptive changes elsewhere in the organization, resistance, or “surface compliance” where people feign compliance with, but actually work around changes that undermine their work environment (Blandford & Adams 2008).

Not all the members of the command team that participated in CAGE will deploy as part of the next TOC. However, from the ILF perspective, a large turn-over in trained members need not result in a major loss in the knowledge gained from this event. Much of the knowledge is retained in other parts of the overall C2 organization. The new knowledge is embedded in tools, tasks, and remaining members. Also, the sub-networks (e.g. the modification of JADOCS to support the application of the rules of engagement) can retain much of the knowledge gained (Argote & Ophir 2002). Newly added members to the command team will inherit the benefit of these adaptations.

Finally, this constructivist approach may also provide a tool to manage changes to C2 systems being deployed. Recognizing that commanders will customize their command teams and processes to suit their concept of operations and individual requirements (Davidson 2008), conducting a constructive learning event appears to be a promising activity for pre-deployment preparations. The commander can implement, test, refine, and rehearse the TOC prior to actual operations. The CAGE event was completed within two weeks, not including facility set-up and tear down, making such events a practical, although not trivial, option for theatre and mission specific training.

3.1 Limitations

The short and intense duration of such constructivist events has drawbacks. The command team did not have enough time to become experts with the initial or adapted systems. It may be that the benefits and drawbacks of the adaptations may change with practice. The intensity of the event also prevented the participants from formally recording the task changes. Future events would benefit from the participation of a military expert, dedicated to recording the adaptation of tasks. These observations would be valuable for documenting the changes, obtaining endorsement for the changes, and the development of training materials. Similarly, the changes to the C2 systems made by the developers were sometimes done in an expedient fashion to enable the event to continue running. Permanent implementations will require time-intensive software testing and documentation to be performed following the event.

Constructivist events can be difficult to schedule. It requires that many highly qualified people be available simultaneously. In case of CAGE, experienced command team members, C2 developers, and analysts familiar with the activities in a TOC were scarce. As the number of team members increases, assembling them for training or experimentation becomes progressively harder, potentially undermining the value of the event (Magee, 2010).

Constructivist learning requires that experimental methodology be compromised. Independent variables are not manipulated orthogonally, so attributions of causality are more tenuous. The system is constantly adapting, so observations are taken of an unstable system and repeated observations under identical conditions are uncommon. Some planned scientific questions may not be addressed because the system evolves away from conditions needed to make the relevant observations. These are real drawbacks, but for CAGE the compromise was more hypothetical than real: There was little prospect of obtaining the participation of command teams and C2 developers for a series of rigorous hypothesis testing experiments.

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