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TWO HEADS ARE BETTER THAN ONE: BALANCING THE INCREASED COGNITIVE BURDEN OF DIGITIZATION

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AIM

1. This paper will inform the Chief of Staff Army Strategy of the need for a collaborative and unifying capability development strategy to address Army Hard Problem # 6 – Cognitive Overload. The Canadian Army (CA) must coordinate capability development with supporting programs from the Science and Technology (S&T) community. The paper reviews recent activities undertaken in absence of a larger strategy and suggests that the Army problem of cognitive overload can best be solved by mutually leveraging S&T activities exploring the technological challenge of cognitive burden and CA projects delivering digitized command support systems within a collaborative unifying strategy.

INTRODUCTION

2. There is a lack of clear understanding of the cognitive burden that digitization will impose on commanders at all levels. Similarly, it is unclear how successful our new digitized systems will be at meeting our command support requirements. Finally, a lack of appreciation for the cognitive capacity of future leaders makes it difficult to identify any specific deficiencies. These elements combine to add unacceptable risk to modernization projects. Two of these projects, the Integrated Soldier System Project (ISSP)[1] and the Land Command Support System Life Extension (LCSS LE)[2] are delivering digital capabilities aimed at improving the situational awareness (SA) and decision-making of commanders at multiple levels from section (Sect) to brigade headquarters (HQ). These objectives are to be met by increasing the connections

[1] Canada. Department of National Defence. "Statement of Operational Requirement: C.002383 Cycle 2 – Integrated Soldier System Project." Ottawa, ON: 2018.
[2] Canada. Department of National Defence. "Project Charter: 00002760 Land Command Support System Life Extension." Ottawa, ON: 2007.

between the commander, subordinates, information sources, and information products. The projects' deliverables are themselves rich with information in multiple forms. The volume, variety and velocity of information that a commander will face when using future command support systems could be overwhelming. Recognition of this potential and the dilemma of command support capabilities undermining the human command capabilities they are meant to support led the CA to declare cognitive overload an Army Hard Problem.[3]

3. Appreciating the problems posed by the technological complexity of digitized command support systems, and their potential exacerbation of cognitive burden, the S&T community has been investigating the implications on the Army's future operating concept. Informed by CA doctrine and concepts, and guided by Director General Science and Technology Army (DGSTAR), Defence Research and Development Canada (DRDC) has explored and assessed emerging technologies and experimented with command and control considerations for the Army of Tomorrow (AoT). These activities have contributed significantly to the body of knowledge associated with new technology. Regrettably, the absence of a collaborative unifying strategy means there will continue to be missed opportunities to learn and adapt. This paper will first show that the question of cognitive burden remains unanswered. Recent key activities in both the S&T and CA capability development communities will then be reviewed showing interdependencies. From these it is concluded that a collaborative strategy will synchronize S&T research and experimentation with CA iterative capability development. Ideally, the latter will be informed by principles derived from the former so that projects in both communities can be prioritized and resourced to meet the CA's operational requirements for the AoT.

[3] Canada. Department of National Defence. "The Army Hard Problems List (Draft)." Ottawa, ON: 9 November 2016.

DISCUSSION

4. Network-enabled Command. The AoT is described by CA capstone documents, notably Advancing with Purpose: The Army Strategy and the Force Employment Concept (FEC) Close Engagement: Evolving Adaptive Dispersed Operations. The FEC envisions a network-enabled force employing more effective command support systems.[4] A distinguishing feature of the AoT is the "robust, persistent information network linking soldiers, sensors, combat platforms and commanders".[5] The nature of command will not change, but command will be enabled by networked command support systems.

5. Command Support Systems and Cognitive Burden. As technology advanced, command support systems became digitized and presented a challenge: would the information they could process, store, and exchange eventually overwhelm the user? This outcome was colloquially termed *information overload* and in the scientific community is known as cognitive burden. An applicable definition of cognition is drawn from a United States Naval Post-Graduate School thesis: "cognition is the complex mental ability that makes communication, decision-making, reasoning, problem-solving, and other complex mental processes possible".[6] Clarke and Knudson's review of the research on cognitive burden found that we can be overwhelmed when too much information must be dealt with concurrently. Allied S&T activities are pursuing the

[4] Canada. Department of National Defence. *Land Operations 2021: Adaptive Dispersed Operations – The Force Employment Concept for Canada's Army of Tomorrow*. Kingston, ON: Army Publishing Office, 2007.
[5] Canada. Department of National Defence. *Land Operations 2021: Adaptive Dispersed Operations – The Force Employment Concept for Canada's Army of Tomorrow*. Kingston, ON: Army Publishing Office, 2007, 21. The revision of this concept is in draft form at the time of writing (see Bibliography) but the network concepts remain unchanged.
[6] Clarke, Alan J., and Daniel F. Knudson III. "Examination of Cognitive Load in the Human-Machine Teaming Context." Master's Thesis, Monterey, California: Naval Postgraduate School, June 2018, 25.

question *how much is too much,* building on earlier work looking at the effects of physical burdens and other stressors on cognitive performance.

6. Allied S&T. A recent study by the United Kingdom Ministry of Defence noted that much like physical performance, cognitive performance also decreased as physical load increased – in some cases earlier than the physical performance decrease. One of its open-ended conclusions was that "further reductions in cognitive performance" could result from "additional stressors of the operational environment".[7] Exploring that angle, a Canadian study of the risks of operational stressors to cognitive ability showed that some cognitive performance increased during operations but, more concerning, decision-making and reflex control showed below-average levels.[8] These mission command attributes have been studied extensively by our Allies.

7. The United States Army Research Lab (ARL) examined the effects of increased cognitive burden in network-enabled command support systems and mission command. Mission command was chosen as the model since it presents the greatest intrinsic cognitive burden. Mission command requires subordinate commanders to gain and maintain three key attributes: understanding the commander's intent, enriched situational awareness, and mission-focussed initiative.

8. Over the past 5 years, significant work by ARL has shown that the intrinsic complexity of mission command necessarily results in high cognitive burden, but extrinsic factors (design,

[7] Armstrong, Mrs. Nicola, Mr. Darren Doyle, Dr Sarah Smith, Dr Debbie Risius, Dr Sophie Wardle, Dr Julie Greeves, Dr James House. "A preliminary study of the effects of load carriage on cognition during a simulated military task in male and female soldiers." *Journal of Science and Medicine in Sport*, (November 2017).
[8] Makhani, Asad, Farzad Akbaryan, and Ibolja Cernaka. "Cognitive performance improvement in Canadian Armed Forces personnel during deployment." *Journal of Military, Veteran and Family Health,* Vol. 1, Issue 1 (February 2015): 59-67.

integration, and training) needlessly exacerbate it.[9] Specific mitigations were derived from a careful review of these factors, asserting that the "failure to address network-enabled [command posts] as systems of systems that support mission command as an integrated warfighting function" compounded the cognitive burden. These systems would have to be better designed and integrated, and users better trained, in order for them to be effective in supporting mission command.

9. High levels of cognitive burden are found across the levels of command, with many commanders having difficulty gaining and maintaining situational awareness essential to mission command. One ad hoc solution was to maintain analog map boards so that the commander could "get the gist of the tactical situation" more quickly than by using digital command support systems.[10]

10. A reliance on analog systems could be supported from the perspective of redundancy, or as a response to operating in a degraded or denied electromagnetic spectrum. This would require the commander to gain and maintain situational awareness in both the analog and digital environments, seemingly doubling the cognitive burden. ARL raised further questions faced with this duality which can be combined as: what makes the analog tool better than current digital

[9] Hawley, John K., "Human-Systems Integration (HSI) and the Network Integration Evaluations (NIEs), Part 2: A Deeper Dive into Mission Command Complexity and Cognitive Load." Aberdeen Proving Ground, Maryland: Army Research Lab, March 2015. Report No.: ARL-TR-7238.
[10] Hawley, John K., and Michael W. Swehla. "The New Equipment is Here, Now Comes the Hard Part: Cognitive and Sociotechnical Challenges in Network-Enabled Mission Command." Aberdeen Proving Ground, Maryland: Army Research Lab, March 2018. Report No.: ARL-TR-8322, 17.

tools at helping the commander think through certain problems?[11] Are they complementary or competing for a commander's attention?

11. ARL observations over many years of research on the cognitive burden of network-enabled mission command have been widely recognized by the United States Army and are appearing in its doctrine. Future warfare will be increasingly complex and the commander's information exchange requirements will have to be supported by an integrated command support system. The draft Command Post 2025 Concept of Operations (CONOP) states: "Current Army command posts are the result of unsynchronized requirements and efforts of multiple programs and are not integrated as a system."[12] For complexity and cognitive burden to be successfully managed, the three factors of design, integration, and training must be synchronized in capability development. There is broad consensus that network-enabled mission command has a degree of intrinsic complexity that cannot be reduced and must be managed.[13] Simple solutions will not succeed, echoing Cohen and Gooch's model of a failure to learn and adapt.[14] The ARL foreshadows this potential aggregate failure, by concluding: "As long as the Army equates force modernization solely with equipment change and not organizational transformation, success in modernization initiatives will be elusive."[15]

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[11] Hawley, John K., and Michael W. Swehla. "The New Equipment is Here, Now Comes the Hard Part: Cognitive and Sociotechnical Challenges in Network-Enabled Mission Command." Aberdeen Proving Ground, Maryland: Army Research Lab, March 2018. Report No.: ARL-TR-8322, 18.
[12] Hawley, John K., and Michael W. Swehla. "The New Equipment is Here, Now Comes the Hard Part: Cognitive and Sociotechnical Challenges in Network-Enabled Mission Command." Aberdeen Proving Ground, Maryland: Army Research Lab, March 2018. Report No.: ARL-TR-8322, 19.
[13] Hawley, John K., and Michael W. Swehla. "The New Equipment is Here, Now Comes the Hard Part: Cognitive and Sociotechnical Challenges in Network-Enabled Mission Command." Aberdeen Proving Ground, Maryland: Army Research Lab, March 2018. Report No.: ARL-TR-8322, 19.
[14] Cohen, Eliot A., and John Gooch. *Military Misfortunes.* New York: The Free Press, 1990.
[15] Hawley, John K., and Michael W. Swehla. "The New Equipment is Here, Now Comes the Hard Part: Cognitive and Sociotechnical Challenges in Network-Enabled Mission Command." Aberdeen Proving Ground, Maryland: Army Research Lab, March 2018. Report No.: ARL-TR-8322, 28.

12. Canadian S&T. As Canada's peer organization to the ARL, and as directed by the CA, DRDC runs S&T research programs to inform force modernization in light of the perplexing questions surrounding network-enabled command. The expected outcome of the command support program states:

> "The Army will have a distributed, integrated and interoperable network across soldiers, sensors, weapons, platforms and headquarters to collect, analyze and manage information, and support decision-making and command & control of assets in the future operating environment."[16]

13. A Unit Commander on the Move experiment was conducted in collaboration with the CA to identify and validate the key command and control requirements for that situation. Participants reported that the systems "were not creating an excessive cognitive load" but this may only have been achievable with a "battle adjutant" whose job was to operate the systems, thus alleviating the burden on the commander and allowing him to "maintain focus on the battle".[17] Contrasting this feedback, participants also noted that gaining and maintaining advanced situational awareness may create a condition described as "paralysis by analysis" wherein command reaction times would worsen as the commander was presented and processed more information.[18]

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[16] Canada. Department of National Defence. *Canadian Army Science and Technology Outcomes*. Ottawa: ON, May 2013.

[17] Couillard, Michel, Marie-Eve Jobidon, Katherine Banko, Maj. Edward Underhill, Maj. John Bosso. "The Unit Commander on the Move Experiment: Information and Communication Requirements for Effective Command and Control in a Dispersed Battlespace." 21st International Command and Control Research and Technology Symposium, 13.

[18] Couillard, Michel, Marie-Eve Jobidon, Katherine Banko, Maj. Edward Underhill, Maj. John Bosso. "The Unit Commander on the Move Experiment: Information and Communication Requirements for Effective Command and Control in a Dispersed Battlespace." 21st International Command and Control Research and Technology Symposium, 13.

14. Simple, robust, and integrated command support systems that are easy to use and reduce cognitive burden is the vision of DRDC's Soldier System Effectiveness Project (SoSE).[19] SoSE is studying CA future systems to assess their effectiveness and assist in reducing cognitive burden to the soldier. The Project Charter reinforces the requirement for the soldier to gain information through observation and communication in order to gain and maintain situational awareness. Already overburdened by weapons, equipment, and supplies, the soldier will increasingly be burdened by information.[20] Considering the ISSP in particular, the Charter characterizes it a "technological enabler [that] is expected to reduce cognitive overload" but warns of risks such as how its information will be represented, exchanged, and managed along with information from other digital systems – including the soldier's personal weapon. The ISSP, like the command support systems studied by the ARL, could become a source rather than a relief of cognitive burden.

15. To address this concern, DRDC participates in multinational technology assessment and demonstration programs. The BOLD QUEST coalition capability experimentation and evaluation exercise recently assessed the ISSP and other battle management systems and determined that the ISSP improved situational awareness and enhanced performance but at a human cost that may not be worth the present operational advantage.[21] With data captured on a variety of human factors including team integration, situational awareness, and cognitive burden,

[19] Canada. Department of National Defence. "S&T Project Charter, 02AB Soldier System Effectiveness (SoSE) Project, 02 Army S&T Portfolio / 02B The Soldier Program, Version 3.5." Ottawa, ON: February 28, 2014, 6.
[20] Canada. Department of National Defence. "S&T Project Charter, 02AB Soldier System Effectiveness (SoSE) Project, 02 Army S&T Portfolio / 02B The Soldier Program, Version 3.5." Ottawa, ON: February 28, 2014, Anx B.
[21] Banko, Dr. Katherine. "Assessing Dismounted Infantry Battle Management Systems: The Integrated Soldier System Suite (ISS-S) and Sitaware Edge, BOLD QUEST 17.2 Technology Assessment and Demonstration." Defence Research and Development Canada, Ottawa, ON: September 2018. Scientific Report, DRDC-RDDC-2018-R202.

results showed the system was heavy and restrictive to mobility. While useful for specific aspects of navigation, it was less useful for dismounted command. The company level HQ found it most useful while the soldiers at section level who are the intended primary beneficiaries were least satisfied.[22] Despite this rebuff, the data also showed that the ISSP did not aggravate cognitive burden.

16. CA Capability Development. The CA is pursuing command support capability development in parallel to S&T activities. ISSP and LCSS LE are being developed in line with Army concepts, to "support commanders in the application […] of mission command and manoeuvre warfare"[23] by delivering modernized command support systems. Operational requirements will be met through agile capability development – an iterative process of delivering and integrating equipment sequentially and successively so that the system annually incorporates evolving technologies and lessons learned.

17. ISSP is delivering capabilities in three cycles in keeping with the agile principle. LCSS LE is delivering Capability Packs (CP), the next of which is CP TOPAZ which includes the Tactical Battle Management System (TBMS). Activities in support of CP TOPAZ represent a unique opportunity to demonstrate how S&T outcomes can positively influence iterative capability development. Two examples, one recently completed and one ongoing, indicate the potential of enhancing capability development under a collaborative unifying strategy.

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[22] Banko, Dr. Katherine. "Assessing Dismounted Infantry Battle Management Systems: The Integrated Soldier System Suite (ISS-S) and Sitaware Edge, BOLD QUEST 17.2 Technology Assessment and Demonstration." Defence Research and Development Canada, Ottawa, ON: September 2018. Scientific Report, DRDC-RDDC-2018-R202, 21.

[23] Canada. Department of National Defence. *Land Operations 2021: Adaptive Dispersed Operations – The Force Employment Concept for Canada's Army of Tomorrow*. Kingston, ON: Army Publishing Office, 2007, 22.

18. The CA recently completed a capability validation exercise (CVE) for CP TOPAZ. The two-week trial with the 1st Battalion, The Royal Canadian Regiment (1 RCR), demonstrated that CP TOPAZ improved situational awareness, reduced voice traffic on the radio, and enabled mission command.[24] The observations and feedback provided by 1 RCR are needed by DRDC for further study into cognitive burden in network-enabled command support systems. Key points paraphrased from the CVE include:[25]

a. Data management is essential to avoid confusion and maintain operational focus;

b. Inherent design flaws clutter messaging and slow down tactical and operational processes; and

c. The lack of interoperability between mounted and dismounted soldiers, and the digital divide between the battle group and the company impedes effective command.

19. Referencing situational awareness in both the analog and digital environments, the report speaks at length on the employment of TBMS as effectively sharing the commander's field message pad (FMP) with anyone on the system. Soldiers had to learn how the commander sketched and chatted as they had once learned how he commanded by voice. The commander himself noted the challenge of "striking the correct balance between using TBMS and staying present 'in the fight'" and how they quickly developed tactics, techniques, and procedures (TTPs) to address these issues.[26] The FMP issue scaled up to maintaining overall situational

[24] Canada. Department of National Defence. "The Duke of Edinburgh's Company Exercise Capability Pack TOPAZ 2017." Petawawa, ON: November 2017, 1.
[25] Canada. Department of National Defence. "The Duke of Edinburgh's Company Exercise Capability Pack TOPAZ 2017." Petawawa, ON: November 2017, 4-6.
[26] Canada. Department of National Defence. "The Duke of Edinburgh's Company Exercise Capability Pack TOPAZ 2017." Petawawa, ON: November 2017, 7.

awareness, with the assertion that maps and traces marked with pens and pins be retained for simplicity and redundancy. A new procedure was needed so that both analog and digital systems could be maintained and matched. Although not explicitly stated in the report, these observations indicate an increased cognitive burden that warrants further study.

20. 1 RCR brought CP TOPAZ overseas for an operational trial, a second example of capability development that can benefit from synchronized S&T activities. The trial is being conducted from July 2018 through January 2019 with the intent to "support all aspects of capability development, including providing feedback on the system and software, development of TTPs and identification of training and force structure requirements".[27] The solicited feedback mirrors ARL's design, integration and training factors. Thus, the trial directive effectively identifies the need for a collaborative unifying strategy for the agile development of CP TOPAZ.

CONCLUSION

21. The imperative of reducing cognitive burden is expressed as a leading challenge facing the CA and requiring particular attention by the S&T community. The soldier and commander of the future will face more information and more stressors affecting cognitive ability. We haven't concluded if the stressed human brain can handle all this analog and digital information and still command and control effectively. Participants at a recent conference hosted by the Canadian Army in conjunction with Queen's University, the U.S. Army War College and the NATO Defence College commonly remarked on the lack of data about soldiers' physical and cognitive performance in operational environments.[28]

[27] Canada. Department of National Defence. "Trial Directive Capability Pack Topaz Operational Trial – eFP". Ottawa, ON: July 2018, 4.
[28] "What's your cognitive shoe size?" Canadian Army Today, Fall 2017, 66.

22. It is not clear when the increase in information provided through digitized command support systems will exceed human cognitive ability. It has been consistently shown by, with, and through activities in both the operational and research communities that the challenge of cognitive overload can be met through collaboration. An iterative development of new CA capabilities closely informed by S&T research is the best methodology to assure the smooth and balanced integration of new command support systems.

RECOMMENDATION

23. To truly benefit from the design, integration, and training deductions emerging from rigorous research into command support and cognitive burden, the CA must establish and maintain a closer collaboration with S&T. CA modernization projects depend on the results of DRDC research projects. A collaborative and unifying strategy that mutually leverages the S&T activities exploring the technological challenge of cognitive burden and CA projects delivering digitized command support systems is our best opportunity to mitigate the Army problem of cognitive overload.

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