


Slow Education and Cognitive Agility: Improving Military Cyber Cadet Cognitive Performance for Better Governance of Cyberpower

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ABSTRACT

Governance of cyberpower from a military perspective are focused on the efforts to control and influence events occurring in cyberspace. For the Norwegian Defence, this means educating cyber engineers, responsible for governing cyberpower effects, beyond technical skills and competencies. To match the complexity of modern warfighting necessitates adaptive high-order thinking skills. Building on earlier cognitive engineering and human factors research in cyber defence this article suggests how Slow Education has the potential to improve cognitive performance among cyber cadets. Slow techniques were applied to 37 cyber cadets during a three-year bachelor programme at the Norwegian Defence Cyber Academy. The quantitative data for this study was gathered during a two-week Cyber Defence Exercise. Combining and applying a novel pedagogic method with psychological techniques suggests reflective pondering, self-regulation and metacognition as being associated with cognitive agility. This study helps develop and make metrics available that are suitable to evaluate human performance in cyber defence.

KEYWORDS

Cognitive Agility, Cyber Operations, Cyber Security Education, Cyberpower Governance, Hybrid Space, Metacognition, Slow Education

1. INTRODUCTION

Cyberpower is an emerging phenomenon in the Defence realm. It is shaping attitudes, behaviours and decision-making as a result of its ability to: "...create advantages and influence events in all the operational environments..." (Kuehl, 2009, p. 38). Gray (2013) sees cyberpower as "the ability to do something strategically useful in cyberspace" (p. 9). This can be understood as giving agency to any actor, to support or undermine systems of governance, coordination, cooperation and competition (Nye,

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2010). As a productive power, cyberpower manifests through relationships and network convergence (Stevens, 2016). One can argue that governing cyberpower is essential to absolutely everything a modern military hopes to accomplish due to its utility to “influence tangible and intangible assets through digital means” (Knox, 2018, p. 11). For this reason, Defence forces need to advance their understanding of the cyberspace military context, in order to mitigate negative consequences when human agency, empowered by cyberpower, is influencing and driving change at rates traditional good governance systems, and codes of practice cannot control (Stevens, 2015).

In the following the changing face of military operations is presented; detailing the effects of cyberpower and the need for adaptations in educational methods to meet the cognitive challenges these effects present. Previous research is introduced to frame the current contribution in the context of operating with cognitive agility in hybrid environments. The concept of Slow Education is then presented, and the importance of metacognition is made clear. The methods section begins with detailing the Slow Education interventions that were applied at the Norwegian Defence Cyber Academy (NDCA) to embed, inform and maintain metacognitive activity. Next, the methods section details how quantitative data was gathered to operationalize and assess cognitive performance in a cyber defence training environment. First, participants completed three trait questionnaires (Response, Self-regulation, Metacognition) before a Cyber Defence Exercise (CDX). Then during the same CDX participants plotted their cognitive focus in the Hybrid Space application (Jøsok et al., 2018) allowing for the researchers to observe for individual use of flexible cognitive processes (Knox et al., 2017). The results section shows the associations between specific cognitive strategies and cognitive agility, represented as cognitive focus movements in the Hybrid Space. Further, we discuss the results in the context of improving performance in military cyberspace operations before the paper concludes and presents future work.

The complexity of cyberspace requires a higher level of understanding regarding own and adversary actions and interactions as information is pushed and pulled from multiple-centers of gravity (Alberts & Hayes, 2003). Educating military personnel to plan, operate and govern complex digital-battlespaces demands focus on the complex mental challenges presented at multiple layers of abstraction. Technological developments may lead to augmented cognition with novel techniques such as artificial intelligence, virtual reality, machine learning and nanotechnology. These emerging technologies are already changing the way of warfare and are demanding adaptations and constant revisions of how to maintain and improve daily operative performance. The digitized context of the future operating environment will subject tactical level decision making to increased levels of scrutiny as incorrect choices and actions can lead to geo-political consequences and unexpected collateral damage (UK MOD, 2014). For young military personnel to accurately govern themselves, technology, cyberpower effects and others in military cyberspace operations, will require the application of flexible cognitions through hierarchies, as well as improved understanding across domains. For example, it is important that military cyber personnel are capable of analysing, evaluating, synthesizing, interpreting and lastly articulating cyberpower effects in relation to wider geopolitical conditions, as well as relating to its application in multidomain military contexts (Knox et al., 2018). When attribution and deterrence in cyberspace are framed by uncertainty, shifting interpretations and applications of cyberpower, deciding what is a tactical attack or an advanced persistent threat becomes far more than a simple exercise in classification.

The authors define governance of cyberpower as legitimate efforts to make events by, with and through cyberspace happen in a productive direction. This definition allows for governance to be understood as a practice capable of occurring at lower levels in military hierarchies, as it meshes both the process and performance concepts of governance (Hyden, 2004). At this level, good governance is more representative of the techniques required to: “...impose a general framework of order on the disorder, to prescribe the general flow of action rather than to try to control each event” (FMFM1, 1989). Conceiving governance this way is similar to what has been described as situational leadership (Northhouse, 2009). Situational leadership is defined as leaders able to diagnose the demands of

their situation (Schermermore, 1997, p. 5). Where governance differs from this perspective is its suitability to go beyond diagnosing, to actually making things happen. The chaos, complexity and hybridisation of modern warfare (Bousquet, 2009) means adaptive modes of governance praxis may be more productive when appropriating and manipulating outcomes across multiple fluid networked situations, even if outcomes are uncertain.

It is possible that ‘standardization’ and ‘accountability’ common to traditional education models (Jenson, 2016) are barriers to achieving the education appropriate for military personnel who will be operating and governing operations in cyberspace. This research introduces how pedagogical interventions at the NDCA provide the context for new literacies that encourage cadets to exert control over their thinking. Developing such metacognitive strategies can support critical thinking, complex problem solving, expert communication and applied knowledge in real world settings (Pena-Lopez, 2016). At a cyber-personal and cyber-organisational level this implies the need to develop a range of flexible cognitive strategies capable enough to build relationship capital - the productive power - necessary for governing cyberspace operations.

The Hybrid Space (Jøsok et al., 2016; Figure 1.a) provides an ontology and common framework for cognitive processes that can contribute to improved performance, in the form of understanding and modes of governance. By visualizing a cognitive landscape in the intersection between cyber-physical and strategic-tactical dimensions, the Hybrid Space allows for the application of psychological concepts in assessment, training and monitoring the effects of pedagogical interventions and provide the context improved cognitive agility.

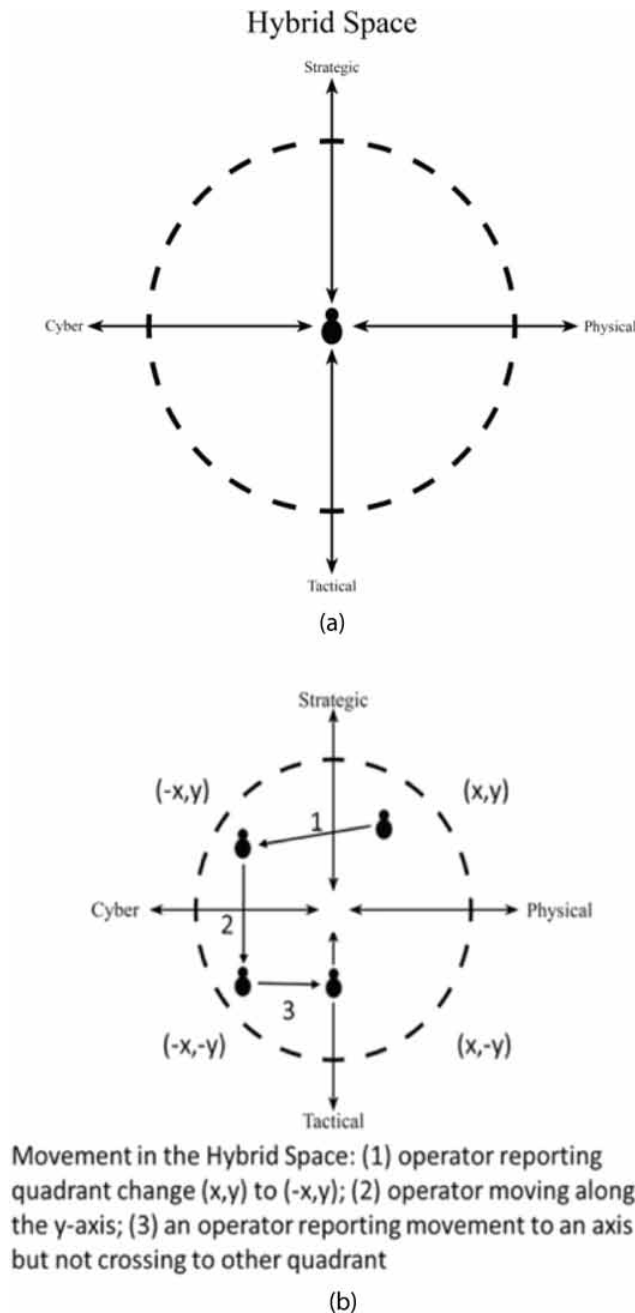
Previous research suggested that flexible cognitive strategies can support better performance in military cyberspace operations (Hoffman & Hancock, 2017; Knox et al., 2017). The authors define the outcome of understanding and adaptable goal directed application of flexible cognitive processes as cognitive agility. Cognitive agility is founded on strategies of metacognitive awareness and self-regulatory processes and is associated with performance in complex hybrid environments (Knox et al., 2017; Figure 1.b). Cognitive agility can be interpreted/defined as movements within the Hybrid Space and used as a tool to monitor, understand and support how individuals regulate flexible cognitive strategies for better communication performance in cyberspace operations (Knox et al., 2018).

2. SLOW EDUCATION FOR CYBERSPACE OPERATIONS

Slow Education is an adaptive non-standards based approach to education. It is categorised alongside Slow Movement philosophies and has its roots in student-centered education methodologies where self-expression, interests and capacities are prioritised (Holt, 2002). An outcome of this method is students gaining situational self-efficacy and empowerment as they engage in critical thinking (Bandura, 1997). This is valuable for cyber education as it leads learners to: “...displaying richer intertextual connections [...] and meanings beyond prescribed lesson content...” (Jenson, 2016, p. 35). Slow techniques may be more suitable for creating and deepening knowledge into the context of cyberspace operations as they have the capability to aid orientation and understanding for learners (Hannafin, 2010). Learners can build authentic real-world knowledge regarding political and legal limitations/frames, strategic guidance, governance, and risk analysis based on tactical, operational and strategic cyberpower effects.

Reflecting upon learner needs and cyberspace operational demands, we conclude that educating military personnel into the context of cyberpower and cyberspace operations, to secure expanded domain understanding, takes a *Slow* pedagogical approach. Slow methods tend to be seen as messy, inefficient and are rejected in favor of mechanistic, one-size-fits-all time and resource friendly instructional methods (Wright, 2018). There is though, evidence that constructivist pedagogical approaches are capable of accelerating learning and improving performance by building deeper knowledge grounded in metacognitive strategies such as reflective practice and self-regulation (Kember et al., 2000; Panadero, 2017; Piaget, 1964; Zimmerman, 2000).

Figure 1. (a) Jøsok et al., 2016; (b) Knox et al., 2017



3. THE IMPORTANCE OF DEVELOPING METACOGNITION

Having an understanding of how cognitions affect behavior requires individuals to reflect over relevant experiences and their outcomes. Reflecting can be done alone or with others (mentoring, feedback), but is an important process in consolidating experiences to long-term memory (Halpern, 1998). Being able to monitor and control encoding processes that arise from both negative and positive outcome after a meaningful experience, leads to better long-term retention (Barrick & Hall, 2005). The importance of developing such metacognitive skills is essential in functioning properly within the aforementioned Hybrid Space environment. For example, when training for cyberspace operations there is a requirement to focus on better grounding of communication along authority gradients. This is due to complex communication tasks occurring when domain-specific expertise

do not necessarily overlap, but need to work in collaboration for accurate decision-making. If a communication partner lacks cognitive regulatory resources then they may resort to hierarchical norms resulting in communication failure (Knox et al., 2018).

Encoding experiences for consolidation into long-term memory integrates both cognitive and emotional processes and strategies. Metacognition is defined as ‘awareness of one’s own knowledge - what one does and does not know - and one’s ability to understand, control, and manipulate one’s cognitive processes’ (Meichenbaum, 1985). Metacognition includes three components: knowledge of one’s abilities, situational awareness, and behavioral regulation strategies (Flavell, 1979). Metacognition involves the active process of being aware of and exerting control over one’s thinking to achieve present goals through planning, monitoring, and evaluating one’s cognitions, emotions and behaviors, and actively adapting to the situational demands. Examples of metacognitive knowledge skills include world, technical, and experiential knowledge, and personal knowledge and awareness of one’s own skills (e.g. self-efficacy), beliefs (confidence), and expected outcomes (situational knowledge).

Being aware of emotional and behavioral factors is key if they are to be controlled and adjusted so that they can be incorporated into adaptive situational decision-making, and problem-solving strategies (Gross, 1998). Emotional and behavioral factors also involve motivational aspects that explain differences in goal achievement. Individuals with higher metacognitive skills are accurate and confident in their judgments of their own performance in relation to task demands and are better able to accurately describe their strengths, weaknesses, and their potential to improve.

Metacognition was considered as having two dimensions: metacognitive knowledge and metacognitive regulation (Flavell, 1979). It has since been updated to include three facets where metacognition interacts with behavior at a personal-awareness level: metacognitive knowledge, experience and skills (see Figure 2; Efklides, 2008, 2011). Metacognitive knowledge includes declarative knowledge, and understanding strategies and goals, but is usually not accessible while experiencing present situation. Metacognitive knowledge is renewed through reflection when the situation has ended, which then has a top-down influence on future behaviors. On the other hand, metacognitive experiences are feelings and cognitions that arise during the situation and include judgements, emotion regulation strategies and self-efficacy.

Metacognitive experience operates through two feedback loops where one loop involves monitoring and evaluating one’s progress against set goals and its influence through emotional evaluation (positive or negative; Carver & Scheier, 2012). Efklides (2008) explains how at the nonconscious level, emotion and cognitive regulation strategies are accessed via previous rehearsed strategies that are triggered by situational perceptions. These nonconscious metacognitions are monitored and regulated at the personal awareness level. They can be adaptively regulated if one has had prior experiences where positive outcomes and/or previous experiences have been reflected upon (Efklides, 2011; Shea, Boldt, Bang, Yeung, Heyes, & Frith, 2014). Only after the situation has ended can one access the second loop at the social level (meta-meta level) where meta-judgements can be included in metacognitive development. The absence of meta-judgements at the personal awareness and nonconscious levels inhibits the consolidation of cognitive (self-efficacy development) and emotional experiences (emotion regulation strategies) and allows for declarative knowledge, where all aspects of the experience are formed (Halpern, 1998; Efklides, 2011; Shea et al., 2014).

Research has shown that developing metacognition helps academic achievement. Research on academic achievement showed that more experienced students who achieved higher grades were better at regulating (monitoring, evaluating, changing behaviour) than less experienced students (Young & Fry, 2008). Vrugt and Oort (2008) showed that students who had better metacognitive skill set achieved higher exam grades.

4. METACOGNITION AND SLOW LEARNING

Development of metacognition is reliant on a student-teacher interaction that promotes reflective discussions, giving support in scenario testing, and developing an understanding of causes of goal achievement and failure (Downing et al., 2009). Metacognition is also considered the most powerful predictor of learning (Veenman et al., 2006). Yet metacognitive development is dependent on metacognitive instruction that incorporates three principles:

- Embedding metacognitive instruction in the content matter to allow for consolidation into long-term memory;
- Informing learners about the usefulness of metacognitive activities to make them exert the initial extra effort;
- Prolonged periods of training to guarantee the smooth and maintained application of metacognitive activity.

Strategy instruction approaches has been associated with better metacognitive development and states that a transactional educational setting is necessary (Schraw & Gutierrez, 2015). Garrison & Akyol (2015) identify learning as a community of inquiry framework that consists of social and cognitive aspects, but also include the presence of the instructor in the process. Strategy instruction identifies a number of factors from an educational setting that support slow learning practices. Educational settings must (Schraw & Gutierrez, 2015):

- Combine several strategies to learn through several modalities, i.e. simulation, problem-based learning;
- Explicit modelling and instruction;
- Immediate feedback through small group discussion;
- Use more time for learning consolidation which also includes understanding how learned strategies can be transferred to new domains; and
- Instructors must be trained in understanding metacognition.

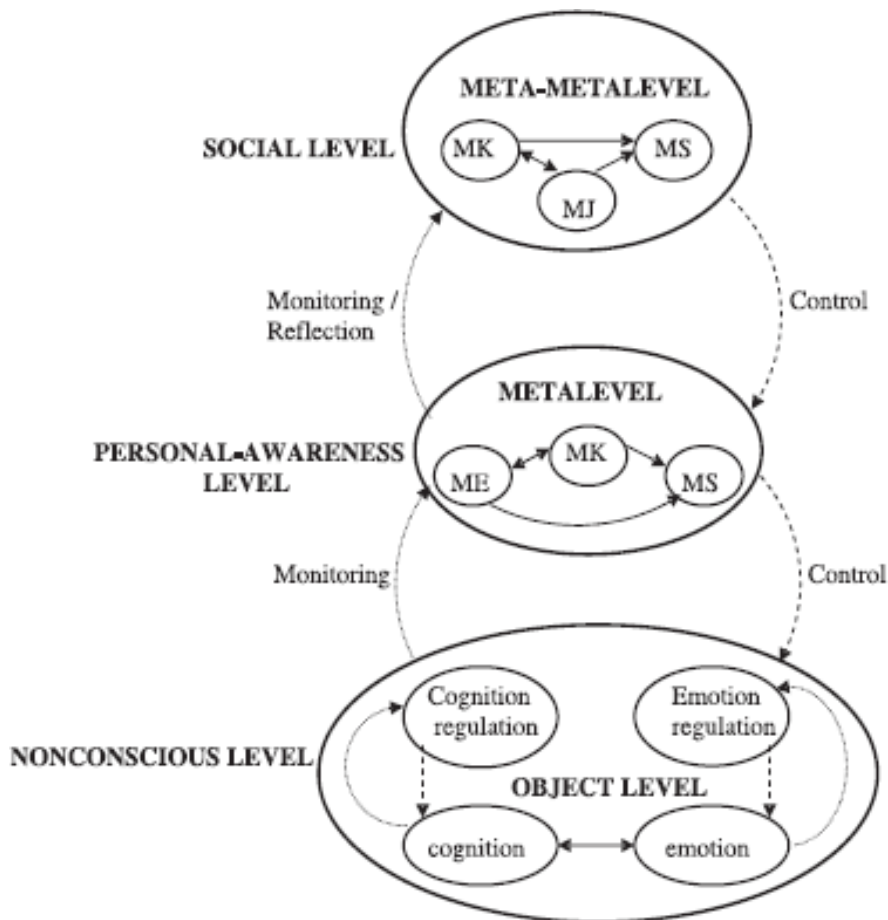
Metacognitive development happens when the student, alongside the instructor, monitors, debugs, and evaluates what is learned (Nietfeld & Schraw, 2002). Research has shown that students who undergo such training programs show better, deeper and more resilient learning (Nietfeld & Schraw, 2002).

A slow learning approach that incorporates such strategy instruction helps metacognition develop through the monitoring and reflective processes that brings experiential experiences up to higher levels of processing i.e., levels of metacognition (Efklides, 2008; see Figure 2). The student and instructor, over time, are able to learn, test, evaluate, monitor, and consolidate the knowledge acquired during training.

By implementing Slow Education measures at the NDCA the applied research hoped to see associations between specific cognitive strategies - metacognition, self-regulation and ruminative perseverative thinking, and cognitive agility. The intended outcome is to ensure military cyber personnel have sufficiently developed thinking skills to regulate behaviour(s) for good governance of power effects in and through cyberspace. Flexible cognitive strategies founded upon facets of metacognition are necessary for decision-making in complexity. This is especially true when digital-system-dependency and the cyberization of everything is: "...make[ing] it easier to subvert and harder to govern" (Betz and Stevens, 2011, p. 135).

Slow Education can create environments where learners gain insights on cognitive processes that could affect performance. The techniques provide access to role models and mentors and an environment where the mentors can help the learner understand adaptive and maladaptive problem-

Figure 2. A multifaceted and multilevel model of metacognition (Efklides, 2008)



solving strategies. Trait rumination (Nolen-Hoeksema, 1991) has been shown to be one such factor that can both inhibit and help performance (Watkins, 2008). While brooding, rumination focused on internal emotional processes, has been shown to be detrimental in decision-making. In several domains, rumination in the form of reflective pondering has been shown to help performance (see Lyubomirski, Tucker, Caldwell, & Berg, 1999).

Inspired by constructivism, and the Slow Education approach to learning, specific pedagogical interventions designed to improve higher-order thinking and understanding, such as self-directed workshops, flipped classroom, reflection logs, and cognitive task analysis, were introduced into the bachelor degree program at the NDCA.

The purpose of this study was to gain indicators of improved cognitive performance among novice cyber cadets. By introducing constructivist education techniques - that are known to develop metacognition - during a three year bachelor program, the intent was to encourage more positive performance related cognitive processes, measured during a CDX.

5. METHOD

Integrating the three principles (metacognitive instruction, metacognitive activities and prolonged periods of training) into the educational platform at the NDCA was achieved through Slow Education approaches in the classroom and during praxis and exercise periods. Figure 3. conceptualizes the process and Figure 4 details the different pedagogical approaches, inspired by Slow Education, that were applied to the research groups' educational platform.

Figure 3. A learning system of knowledge acquisition through a slow education philosophy. At individual level the process is linear, however at organisational level there can exist a feedback loop from the 'cyber defence exercise' to 'slow education'. This occurs when final year cadets play a mentor role for younger students.

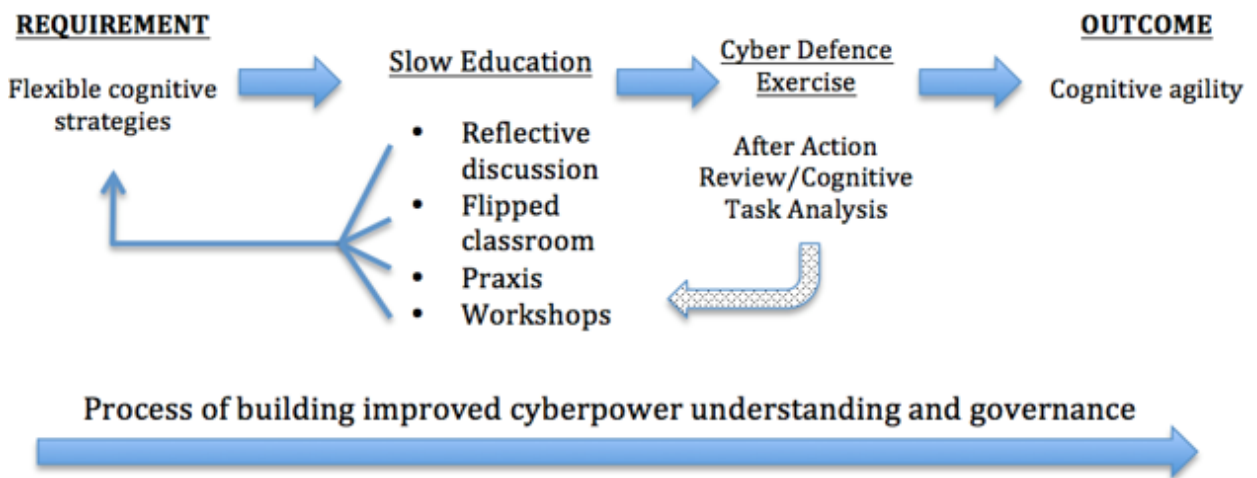


Figure 4. Slow education interventions designed to improve cyberpower understanding and governance among cyber cadets at the NDCA

Slow Interventions	Semester	Description	Goal
Cyber context reflective discussions	1	Cadet lead analysis, synthesis and interpretation of multiple cyber military topics introduced through an entire semester. Cadets document their ripening understanding.	Grounding understanding of the cyberspace military profession. Embedding metacognitive instruction through student-teacher interaction.
Praxis period with authentic real-world cyberspace challenges	4	Intense and enduring period of military cyberspace operations with close mentoring, available role models, focus on reflection and goal directed outcomes.	Gain insight into cognitive processes that affect performance. Help cadets understand adaptive and maladaptive problem-solving practices in complexity.
Flipped classroom	4	Traditional engineering subject taught in a learner-centered way. Skill development and concept practice via guided knowledge construction and application of high-order thinking skills.	Improve understanding through knowledge acquisition and construction of meaning.
Workshops	6	Cadets are grouped and design/deliver a one-day cyber related workshop to their peers. Workshops are developed over an entire semester. Cadets document their progress and are largely self-directed.	Build situational self-efficacy and empowerment through critical thinking, scenario testing and developing an understanding of causes of goal achievement and failure.
Daily After Action Review (AAR) including Cognitive Task Analysis (CTA) during a Cyber Defence Exercise	7	Mentor facilitated AAR and CTA process. Conducted in the evening after each cyber defence scenario. AAR completed with all teams present for knowledge and experience exchange. CTA completed in teams with individual contributions to populate a chronological reconstruction of events and decision making in all domains.	Focussed retrospection to accelerate learning based upon improved domain and multidomain understanding.

It was assessed that focusing on learner oriented, non-standards based pedagogic strategies during the educational program could support long-term development and application of cognitive agility. High-order thinking skills support building deep knowledge and adaptive expertise. They also have the ability to improve critical thinking in the form of truth-seeking, open-mindedness, self-confidence, and maturity (Miri et al., 2017). The authors view these skills and capabilities as necessary behaviors for cyber cadets who will be making legitimate efforts to make things happen in a productive direction, i.e., governance of cyberpower.

5.1. Measurements and Metrics: Cognitive Process Questionnaires

Reflective pondering was assessed via the Response Style Questionnaire (RSQ; Nolen-Hoeksema & Morrow, 1991) after removal of depression-related items (Treyner et al., 2003). The RSQ assesses perseverative cognition on the subscales brooding and reflective pondering. Both subscales consist

of five items to be answered on a 4-point Likert-scale (e.g., brooding: ‘What am I doing to deserve this?’ or reflective pondering: ‘I analyze recent events and try to understand why I am depressed.’). The scale showed good reliability for this study: Brooding Cronbach’s $\alpha = .86$; Reflective Pondering Cronbach’s $\alpha = .84$.

The Metacognitive Awareness Inventory (Shraw & Dennison, 1994) was used to measure metacognitive awareness. It is a self-report scale comprising of 52 items that includes several subscales assessing knowledge of cognition (declarative knowledge, procedural knowledge, conditional knowledge) and regulation of knowledge (planning, information management strategies, comprehension monitoring, debugging strategies and evaluation). Items are assessed on bipolar responses (true/false) and then ratios are computed from the subscales. Sample items include: ‘I find myself using helpful learning strategies automatically’ (procedural knowledge) and: ‘I ask myself if I have considered all options when solving a problem’ (comprehension monitoring). The test shows high reliability on all subscales (Cronbach’s $\alpha = .90$).

The Self-Regulation Questionnaire (SRQ) was used to assess the various self-regulatory processes through self-report (Brown, Miller, & Lawendowski, 1999). A sample item includes ‘I am able to accomplish goals I set for myself’. The SRQ is made up of 63 items, and each point is scored through a 5-point Likert scale (Brown, Miller, & Lawendowski, 1999). The form has good reliability (Cronbach’s $\alpha = .91$) and showed acceptable reliability score for this study (Cronbach’s $\alpha = .75$).

5.2. The Hybrid Space App

Cognitive agility represents an individual’s metacognitive ability to understand, monitor and regulate the use of flexible cognitive strategies that help performance. Cognitive agility is measured as movements in the Hybrid Space. The Hybrid Space is mapped in a Cartesian plane and movements are operationalised through four constructs that represent the dependent variables in the study. Four cognitive agility indices were created:

- **HSDT:** distance traveled in the Cartesian Plane measured by Euclidean distance;
- **HSQC:** Number of quadrant changes;
- **HSxM:** Movement along the cyber-physical domain (x-axis); and
- **HSyM:** Movement along the strategic-tactical domain (y-axis) (Knox et al., 2017).

Data was collected in the Hybrid Space where 0 is the centre, Y-axis range from -100 to +100, and X-axis from -100 to +100 (Jøsok et al., 2018).

The quantitative data used to accompany the pedagogical interventions for this study was gathered before and during a four day CDX. The CDX is an annual event designed to train cyber cadets in conducting military cyberspace operations. During the exercise the cadets operate in independent, but not opposing, cyber protection teams. The CDX contributes to developing the human and technical competencies necessary to govern the effects of own and adversaries’ cyberpower capabilities. Prior to the CDX, students filled out all the trait questionnaires (Response, Self-regulation, Metacognition). During the CDX the cyber cadets were arranged into four teams totaling 37 ($M_{age} = 22.7$ years, $SD = 0.71$) resembling a complete cohort undergoing a cyber engineer education. From the 37 cadets, 23 took part in the experiment. The CDX lasted four days and participants simultaneously marked the location of their cognitive focus in the Hybrid Space cognitive landscape framework every hour from 08:00-18:00 each day. This came to a total of 854 Hybrid Space measurements over the four days.

6. RESULTS

Descriptive statistics and correlations are presented in Table 1 and 2 respectively. Positive associations between hypothesized variables were significant in presumed directions (Table 2). Reflective

Table 1. Descriptive statistics (N=23)

	Mean	Standard Deviation	Minimum	Maximum
HSQC	17.39	6.92	6.00	30.00
HSxM	1539.17	740.41	456.00	3145.00
HSyM	1271.96	550.90	446.00	2595.00
HSDT	2225.09	934.71	723.00	4161.00
Self-Regulation***	214.33	12.06	199.00	236.00
Declarative Knowledge*	0.71	0.21	0.25	1.00
Procedural Knowledge*	0.63	0.30	0.25	1.00
Conditional Knowledge*	0.74	0.24	0.20	1.00
Planning*	0.50	0.25	0.14	1.00
Information Management*	0.64	0.16	0.30	0.90
Comprehension Monitoring*	0.61	0.27	0.14	1.00
Debugging*	0.86	0.16	0.40	1.00
Evaluation*	0.47	0.27	0.00	1.00
Brooding**	13.96	4.31	6.00	21.00
Reflective Pondering**	14.04	4.30	6.00	24.00
Total Rumination	28.00	7.25	16.00	40.00

*Meta Cognitive Awareness Inventory **Response Style Questionnaire ***Self-Regulation Questionnaire

pondering, self-regulation, and metacognition were all significantly associated with Hybrid Space movements (Table 2).

Collinearity checks were done for rumination, metacognition and self-regulation variables, and it was found that self-regulation and metacognition (declarative knowledge) were overlapping on HSDT ($r = .646, p=.009$). Self-regulation total was therefore used in this analysis.

To test the idea that variables associated with Slow Education, rumination, metacognition and self-regulation, would predict Hybrid Space movements, hierarchical regression analyses was performed to show how they influenced each Hybrid Space movement with rumination entered as a predictor variable in step 1, and metacognitive regulation and knowledge were entered in step 2 and 3 respectively (Table 3).

Regression analysis showed that reflective pondering and self-regulation were significant variables that influenced HS movements for DT and X-axis movements and almost significant for Y-axis movements. Self-regulation was the only significant predictor for distance travelled, X-axis and Y-axis movements.

7. DISCUSSION

Whether cyber is understood as a substrate for modern warfare (Dombrowski & Demchak, 2014), or as an independent operations domain (NATO, 2016); cyberpower effects are an emerging and globally

Table 2. Correlations (N = 23)

	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. HSDT	.858**	.946**	.874**	.685**	.412*	.174	.157	.168	-.172	.120	.043	.024	.099	.397*
2. HSQC	1	.766**	.809**	.543*	.432*	-.049	.232	.022	-.215	.002	.138	-.089	.154	.374*
3. HSxM		1	.676**	.675**	.501**	.223	.159	.213	-.133	.214	.077	.151	.107	.387*
4. HSyM			1	.588**	.183	.130	.137	.112	-.188	-.043	.021	-.163	.062	.362*
5. Self-regulation				1	.476*	.256	.212	.515*	.315	.145	.239	.197	.116	.428*
6. Declarative Knowledge					1	-.090	.268	.455*	.115	.086	.120	.155	.257	.291
7. Procedural Knowledge						1	.579**	.298	.252	.155	.080	.461*	-.101	.312
8. Conditional Knowledge							1	.292	.529**	.332	.109	.512**	.173	.242
9. Planning								1	.412*	.452*	.083	.538**	.356*	.345*
10. Information Management									1	.599**	-.102	.531**	.311	.134
11. Comprehension Monitoring										1	.214	.737**	.258	.210
12. Debugging											1	.210	-.237	.117
13. Evaluation												1	-.037	.144
14. Brooding													1	.419*
15. Reflective Pondering														1

** Correlation is significant at the 0.01 level (1-tailed). * Correlation is significant at the 0.05 level (1-tailed).

Table 3. Hierarchical regression on all Hybrid Space (HS) variables

Dependent Variable	R^2	F	ΔR^2	β	T
HSDT					
Reflective Pondering	.096	1.484		.310	1.218
Self-Regulation	.469	5.751**	.374**	.694*	3.026
HSQC					
Reflective Pondering	.090	1.388		.300	1.178
Self-Regulation	.297	2.744	.207	.516	1.955
Declarative Knowledge	.332	1.988	.035	.208	0.795
HSxM					
Reflective Pondering	.103	1.614		.321	1.270
Self-Regulation	.455	5.428**	.352*	.674**	2.897
Declarative Knowledge	.479	3.672**	.024	.170	0.736
HSyM					
Reflective Pondering	.073	1.102		.270	1.050
Self-Regulation	.345	3.430	.272	.593*	2.326
Declarative Knowledge	.409	2.766	.063	-.280	-1.135

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

shared phenomenon: "...posing more questions than answers" (Tapscott, 2014). This paper suggests that the answer to questions relating to what the right education model for governing cyberpower effects is, and may lie in alternative approaches. Adapting certain technical and non-technical subjects at the NDCA meant educators avoided following only instructionist models that are: "...largely ineffective at helping learners acquire the skills and knowledge needed for the 21st century" (Keith Sawyer, 2014). Instead, education practices founded upon methods that are able to: "...unlock powerful learning opportunities..." (Dede, 2014, p. 5) and require educator humility, creativity and critical thinking were introduced.

The Slow Education interventions at the NDCA showed partial support for the idea that reflective pondering and self-regulation predicted certain Hybrid Space movements, i.e., cognitive agility. All three independent variables (rumination, metacognition, and self-regulation) each showed positive associations with Hybrid Space movements, however when a collinearity check was done for metacognition and self-regulation, these two factors described the same association for total distance travelled (Table 3). Since metacognitive awareness and self-regulation were shown to be overlapping, only self-regulation was used in further analyses. The results indicate that Slow Education interventions may have led to more positive performance related to reflective cognitions, reflective pondering and self-regulation, as postulated.

Relating human performance in cyberspace operations to specific cognitive strategies provides an *a priori* argument for how military cyber cadet education should be modeled. Mastering the 'art' of cyber warfare goes beyond having the [false] impression of control over one's own information communication systems when faced with an advanced threat actor. So far even the most comprehensive preventive security measures have proven insufficient to stop advanced cyber-threats. The complexity of contemporary cyber-systems (Rescola, 2005) hands the advantage to the resourceful threat actors as they only need to discover one exploitable flaw to succeed, while the defender has to find them all to make sure the system is impenetrable.

Gaining and applying knowledge about the cyber domain and the opportunities it presents, to attackers and defenders, as a domain of operations requires investment in developing higher levels of understanding of the problem-solving at hand (Ward et al., 2013). For military cyber personnel extended knowledge of technology is a prerequisite of achieving real security. However, to increase prospects of maintaining the advantage in the rapidly evolving and continually contested cyber space, appreciation of technologies societal impact, the hostile actors operating by, with and through it, and how to employ the new instruments of power are also indispensable. This demands education adaptations that will ensure cyber personnel have the cognitive regulatory strategies to utilise cyberpower with prudence, knowledge and skill.

Adaptations to traditional educational models have been identified as a pathway to better performance among learners in the digital age (Pena-Lopez, 2016; Tapscott, 2014). The data from this study shows that a: "...novel educational model" (Jenson, 2016, p. 21) such as Slow Education can potentially deliver deep-learning experiences and enhance current instructionist education systems for cyber cadet education. The necessity to improve cognitive skills and capabilities among cyber cadets is founded on the complexity of the current military context. Educators must ensure cadets have been given the opportunity to sufficiently develop their metacognitive facets to regulate behavior(s) for good governance of power effects in and through cyberspace. Many cadets have advanced technical competence giving them an intuitive advantage concerning cyberspace understanding and tactical, operational and strategic considerations. This can mean they are open for accelerated learning due to the knowledge authority they possess relating to such things as electronic connectivity, system layering, information system architectures, as well as meshing of real-world and cyber relationships; the "virtual-human network overlap" (Kilcullen, 2015, p. 183). Officers with a non-technological military education lack this nuanced understanding and will have to engage in more basic programs to ground cyber-technical and socio-technical knowledge if they are to understand military cyberspace operations. This may compromise their leadership potential, as their ability to sense-make for tactical

and operational level understanding and decision-making will be limited. A consequence being their role will be restricted to one of officer-administrator or liaison-officer; rather than operative planner, leader and decision-maker. In this context, the cyber engineer will have increased responsibility to govern cyberpower effects as they are required to operate closer to the operational and strategic levels of planning and decision-making. This will require they are cognitively agile and capable of building relationship capital - the productive power - necessary for governing cyberspace operations. Being able to appropriate and manipulate outcomes across multiple fluid networked situations founded on their metacognitive skills that enable understanding, sensemaking, and collaboration in uncertainty.

The model and interventions (Figures 3 & 4) were designed to match the dynamic context of cyberspace, as they facilitate learning by empowering cadets to find information through interactions, and construct knowledge in a manner that reflects the innovation-age (Sawyer, 2005), where performance assessment requires students: “apply their knowledge and skills to real world contexts” (Dede, 2014, p. 1). Slow Education encourages positive rumination in the form reflective pondering as it allows the learner to profoundly learn and build a positive self-image through authentic experience; cultivating the necessary skills to participate in digital environments (Hannafin, 2010, Kellner, 2002). As the results of this study suggest, where education encourages the development of understanding and adaptable goal directed application of flexible cognitive strategies, the outcome can be associated with cognitive agility among cyber cadets. In practical terms, this can be presented as meaning better governance of cyberpower effects in complex Hybrid Space environments.

This study used simulation as a design to investigate the effects of slow learning on cyber cadet performance. Simulations are a crucial aspect within slow learning approaches and have been described as “activities that mimic reality and [...] help students learn [new skills] and allow them to demonstrate decision making, [and] critical thinking...” (Jeffries, 2005, p. 97). Simulations provide experiential contexts and outcomes similar to real specific situations in controlled environments. Simulations not only help technical skill development, but also help improve psychological aspects of performance such as increasing self-efficacy, and allowing metacognitive processing to reach higher levels (see Figure 2) when a mentor leads feedback. For simulations to improve metacognition, several aspects must be present: time for decision making and reflection, followed by expert follow-up and debriefing, where interaction with the mentor identifies opportunities and understanding how several paths of action could have been used for decision-making. The expert feedback that follows simulations must be immediate and is essential to help the learners reach the meta-meta level where the understanding of the reciprocal influence of metacognitive judgements, strategies and knowledge can be achieved.

The term deliberate practice describes the psychological approach to skill development and entails the practicing (simulating) of specific situations relevant to the domain in order to increase skills (Ericsson, 2008). Thus, similar to praxis in other domains, repeated simulation can be applied as a method for testing slow learning techniques across technical and non-technical cyber domain contexts, allowing for rapidized training as novice personnel acquire higher levels of proficiency from experiencing both trial and error of procedures, and expert feedback.

Simulation has been shown to increase self-efficacy through case studies (Sadri & Robertson, 1993). Simulations support the development of coping strategies for the participants that are embedded within metacognition. This includes handling of one’s personal physiological and emotional experiences, the development of cognitive strategies to handle the situation, increased confidence, and reduced stress levels (Leigh, 2008). A qualitative analysis revealed that communication skills development and more realistic simulations could further improve the confidence gained from the simulations. A systematic review shows that simulations such as the CDX exercise used here, are effective in establishing learning environments that help learning outcomes and improve confidence (Norman, 2012).

The current findings show how metacognitive development influences performance in an ecological setting, which can then be reflected upon in a debriefing setting. Having knowledge of one’s behaviour regulation and how it is influenced by the situation (simulation), one can adjust

both intra and interpersonal factors that are relevant in future simulations. Reflective pondering is an emotion regulation strategy that is situated at the non-conscious level, and this is regulated at the personal level of metacognition, but the social level is not accessed during specific situations. Being able to identify psychological factors post hoc, under expert guidance helps both processes (emotion regulation, behaviour regulation) to be accessed at the social level. In this instance, self-regulation was a significant predictor on three of the four dependant variables. To understand its influence on performance, debriefing after the simulation is necessary. The expert in this case guided participants in understanding how self-regulation works in this exercise, that being able to monitor one's behaviour, evaluate if the behaviour matched the goals intended, and operate adaptively through flexible thought processes. But to understand the meaning of decision-making, i.e., cyber-physical interactions and strategic-tactical decisions, can only be understood after the exercise through mentor interaction.

But slow learning is not a unidirectional process. It also provides feedback for instructors on the development of the learner's knowledge, which in turn can help design the next simulation. This requires the instructors see themselves as primary learners (Taylor and Soal, 2003) from the outset. Adopting this mindset allows for the instructors/mentors to design simulations based on current standards and tailor simulations to increase confidence (self-efficacy) by raising the level of difficulty that is commensurate with the skills of the learners. This follows the principles of Vygotskian scaffolding (Hmelo-Silver, Duncan & Chinn, 2007). With this tool, simulation design can set up challenges to behaviour regulation, to test slow learning approaches and further improve metacognition through the simulation-feedback loop.

Using a CDX to observe for cognitive agility allowed the researchers to validate Slow Education pedagogical interventions designed to accelerate learning and improve performance. Research has shown that rumination is a significant factor in performance, where reflective pondering is a more adaptive process over brooding (Lyubomirski, Tucker, Caldwell, & Berg, 1999). Applying Slow Education methods provides situations that can help develop and consolidate reflective pondering over brooding rumination. This is due to training simulations guided by mentors with substantial and appropriate feedback. Whereas traditional education approaches tend to move forward and leave the reflection to the learner, unintentionally supporting more maladaptive strategies (brooding). This supports the notion of using training to increase more adaptive cognitions (reflective pondering) to help consolidate metacognition (Veenmen et al., 2006). Slow Education is able to help metacognitive development (both awareness and regulation) due to more opportunities to inform, discuss, practice, and evaluate the effectiveness of implementing metacognitive strategies in learning. By providing opportunities, i.e., practice and targeted feedback, Slow methods are better equipped to support self-regulated learning strategies, which facilitate more adaptive regulatory behaviours. This study tried to address these aspects, and while not finding full support, did find that the variables had positive associations with performance.

Military cyber personnel need a developed cognitive repertoire if they are to effectively govern the effects of cyberpower. For example, when experiencing the feeling of lack of control in cyberspace operations it is absolutely critical that they have enough self-regulatory skills to be at their most motivated, even though they are most likely at their most uncertain. This condition mirrors the scientific work of John Boyd who saw uncertainty and ambiguity as an 'irreducible characteristic of being and nothing less than the very condition of possibility of change and creativity' (Bousquet, 2009, p. 193).

8. FURTHER RESEARCH

This was not systematic controlled research. The approach was a naturalistic, descriptive and correlative study in an applied setting. Based on our observations, this study provides first arguments that Slow Education approaches might be able to improve cognitive agility for understanding and governance in the cyberspace military context. Further systematic research should investigate and compare different pedagogic techniques and the comparative impact in objective measures of performance in larger

samples. Technologies are able to extend, augment, and even supplant individual cognitive processes (Iiyoshi, Hannafin, & Wang, 2005 in Hannafin, 2010). However, it is argued that metacognition and prior knowledge are needed for sensemaking (Land, 2000). In particular, when appreciation and understanding for political and legal limitations/frames, application of strategic guidance, governance of cyberpower effects, and risk analysis is no longer confined to higher ranking personnel.

9. CONCLUSION

This study is - to the best of our knowledge - the first to provide descriptive data on measures of cognitive performance in cyber defence. These data suggest that Slow Education interventions, capable of improving learners' cognitive repertoire, may help support good governance in military cyberspace operations and utilisation of cyberpower. Specifically, the cognitive strategies of self-regulation and reflective pondering correlated with cognitive agility, measured as movements in the Hybrid Space. As the goal of Slow Education methods is to improve high-order thinking skills, such as reflective cognitions, then these findings can be seen as positive outcomes for measuring performance.

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