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Factors to affect improvement in cyber officer performance

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Abstract

Purpose – The purpose of this study is to investigate how motivation – gained by understanding the purpose of specific cyber-oriented tasks – coping strategies and level of physical conditioning can affect cognitive abilities amongst cyber officer cadets.

Design/methodology/approach – Two cognitive tests (2014 and 2015) and coping strategy questionnaires (2015) were conducted during an annual military exercise involving increased levels of stress and hardship (physical and cognitive) over a sustained two-week period.

Findings – Motivation – gained by task explanations – and the conscious use of the "control" strategy can have a positive effect on individual performance in cyber tasks.

Research limitations/implications – The participants were all young adults with higher-than-average levels of physical fitness. From the outset, all participants were highly motivated and disciplined having entered cyber officer training after successfully completing a thorough selection process.

Practical implications – The results of this study are to be better implemented to the activities at the military academy.

Social implications – The closest civilian occupational equivalent is a computer network operations (CNO)-operator. The findings could be implemented into their daily work routines.

Originality/value – Cognitive tests used in this study are based on recognized general cognitive tests. However, modifications were made to suit the cyber task context, making the test original. The cyber officer is a contemporary concept currently lacking research.

Keywords Performance, Training, Education, Information security, Psychology

Paper type Research paper

1. Introduction

Recently, soldiers have to operate and maintain a large variety of devices connected to the cyber domain. This places a high demand on soldiers' cognitive abilities. The demand of cognitive and coping abilities increases when stressors such as context shifts, time pressure, environmental factors (such as heat and cold), noise and fatigue are present in the soldiers' operating space.

Existing research results have shown that physical activity and positive motivation have a positive effect on cognitive abilities (Fisher *et al.*, 2011; Gaillard, 2007; Gregory *et al.*, 2012; Reed *et al.*, 2013). In an earlier paper, "Effect of motivation and physical fitness on cyber tasks" (Helkala *et al.*, 2015b), we studied if the results from existing research can also be applied to cyber officer candidates taking part in a military exercise that included food and sleep deprivation under conditions of increased physical and academic activities. The results evaluated by Cohen's (1988) effect size supported those of the previous research.

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A significant amount of research has shown how people perceive threats, demanding situations and their coping strategies to adapt to these situations. Coping strategies are often identified tools and strategies that have the capacity to support managing or overcoming physical and mental stress. Research has shown that the capacities to cope and perform can be learned and trained (Eid and Johnsen, 2005; Wormnes and Manger, 2005). In a previous study (Helkala *et al.*, 2015a), coping strategies (that were later re-named to "performance strategies") used by the cyber officer cadets were examined.

This paper builds on a previous study on cognitive ability, motivation and physical fitness amongst cyber officer cadets at the Norwegian Defence Cyber Academy (NDCA; Helkala *et al.*, 2015b). The cyber officer cadets attend a four-year bachelor's program in Computer Science and Telematics, and their levels of physical fitness are good. We present the results of the cognitive experiment conducted during a military exercise in May 2015 and compared them with the results of the previous study (Helkala *et al.*, 2015b). A study on the performance strategies was also conducted simultaneously with the cognitive tests in 2015. The results are presented in this paper. The paper is divided into the following sections: in Section 2, the state of the art is introduced; in Section 3, the experimental context and setup have been described; the results are elaborated upon in Section 4, with the discussion in Section 5 and the conclusion and future work in Sections 6 and 7, respectively.

2. State of the art

Humans make errors. The nature of an error defines the damage a wrong decision or an action based on the error causes. In critical situations, a human error can have fatal consequences. Psychological factors divide human errors as intentional or unintentional. Unintended actions can cause errors as slips, attentional failures or lapses and memory failures, among others. Intended actions can cause rule- and knowledge-based mistakes, routine or exceptional violations and acts of sabotage (Angeles, 2004).

Education and training reduce knowledge- and rule-based mistakes, as well as violations. However, avoiding unintended actions, especially those occurring with environmental stressors, anthropometric and human sensory factors (size, shape, strength and senses; Angeles, 2004), cannot be achieved with pure academic education. Unintended actions can be a decrease of cognitive capacities or lack of cognitive abilities. Cognitive abilities such as perception, attention, memory, motor, language, visual-spatial processing and executive functions are mechanisms used to process and store information (Pascale, 2006). Our actions are then based on the processed information.

Cognitive incapability is often thought to be a problem for an older person. Even if clear generalities exist on age-related changes, the individual variance is large (Glisky, 2007), and age is definitely not the only attribute that changes humans' cognitive abilities. For example, fatigue (Hartzler, 2014), hunger (Gailliot, 2013) and stress (Harris *et al.*, 2007) can have a negative effect.

Physical activity, on the other hand, has shown to have a positive effect on cognitive functioning (Fisher *et al.*, 2011; Gregory *et al.*, 2012; Reed *et al.*, 2013). Also, environmental attributes (Dahlman *et al.*, 2012) and motivation (Gaillard, 2007) have shown to affect cognition. Some studies suggest that good physical condition has a positive effect on academic achievement (Koch and Hasbrouck, 2013; Lees and Hopkins, 2013).

Emotional arousal has also shown to have a positive effect on cognitive abilities and especially on memory processes. Positive or negative emotional arousal helps maintain a readiness to respond (McPherson, 2011) which helps them notice and recall incidents or details. Lee and Sternthal (1999) showed that a positive mood enhanced learning in relation to a neutral mood, when participants learned names of different brands. Dietrich *et al.* (2001) outlined the influence of emotional contents on recognition performance. Also, positive password sentences seemed to have a higher recall rate than sentences with negative content (Helkala, 2014).

Both adaptive and maladaptive coping strategies create emotions that influence self-perception (Wormnes and Manger, 2005). This, in turn, has an impact on future actions and performance. The study by Baumgardner and Crothers (2009) showed a strong correlation between self-perception and processing of information, regulation of emotion and motivation.

According to Bandura (1997), mastery experiences, physiological feedback, vicarious experiences and social persuasion contribute to self-efficacy. Self-efficacy contributes to learning, as it raises the probability of using and combining knowledge in new ways (Bandura, 1997; Zimmermann, 2000). However, as highlighted by Judge *et al.* (2007), high self-efficacy does not equal high performance levels because of strong individual differences. Regardless, performance prediction based on self-efficacy is more accurate in task-related situations (Judge *et al.*, 2007). Therefore, the task- and solution-oriented approach for coping (*situational understanding, accept the situation, use of knowledge and tools, ability to be proactive, finding alternatives and solutions, ability to prioritize, ability to control, ability to influence, self-confidence and belief in oneself and ability to handle uncertainty*) can be considered to be usable in learning process and affecting performance (Helkala *et at.*, 2015a).

3. Experimental context and setup

All experiments and data collection (in 2014 and 2015) took place during exercise cyber endurance. This is a two-week long military exercise held annually during spring. During the exercise, students lived in an outdoor base exposed to the elements, and their nutrition and sleep patterns were disrupted, and because of the hard physical and cognitive nature of the exercise, their levels of exhaustion were far higher than normal. Throughout the exercise, the students were tasked to integrate military- and civilian-based information communication technology (ICT) systems to solve varying operational requirements.

The cognitive ability experiments in 2014 and 2015 were conducted three times during the exercise period: once just before the exercise began and twice during the exercise. The performance strategy questionnaire was distributed after the second and third cognitive ability tests in 2015. There were 75 participants from both years ($n = 40$, 2014; $n = 35$, 2015).

In 2014, the participants were randomly divided into two groups. The control group was given the test with neutral instructions, and the experimental group conducted the same tasks, but this time, the purpose of each task was explained to them as an event or incident occurring in the cyber domain. In the analysis phase, both control and explanation groups were further divided into two smaller groups based on the students' physical fitness level by means of a median split (HL: high level; LL: low level).

In 2015, all participants ($n = 35$) conducted the test with the task explained. They were also divided into the HL and LL groups as in 2014.

Physical requirements of the HL group for men (women) in tests were: 3,000 m; 10 min 55 s (12:05); sit-ups: 53 (53); push-ups: 34 (20); and hang-ups: 10 (15 – hang-up type varies between men and women). The more detailed description of the exercise and the experimental setup is given in Helkala *et al.*'s (2015a) study.

3.1 Cognitive test

The cognitive test was based on the Montreal Cognitive Assessment test and a test set used in Leiberman *et al.*'s (2006) study. However, the tasks were modified so that they reflected cyber operations or incidents. No prior knowledge of cyber operations was needed to conduct the tasks. The test consisted of five tasks which required 30-40 min for completion.

Task 1 measured sustained attention through a visual vigilance test and similar to the Leiberman *et al.* (2006) test. The test demanded that students detect bars taller or equal to 3,000 in a continuously moving diagram (Figure 1). The bars appeared for 7.5 s with 0.25-s intervals with random heights. The explanation groups were told to monitor network traffic data and raise an alarm when a traffic peak was taller or equal to 3,000. The task lasted 20 min and the number of "alarm" bars varied between 115 and 120. Detection was correct if the bar was visible on the screen. Task 1a measured the correct alarms, whereas Task 1b the false alarms.

Task 2 measured sustained attention and short-term spatial memory. In this task, we combined two tasks from Leiberman *et al.*'s (2006) study: four-choice reaction time and matching-to-sample tasks. In our task, a single-colour or two-colour basic geometric figures were presented for 1 s (Figure 2). Then, a 2 × 2 matrix appeared and the students had to identify and locate the figure in the matrix. The matrix was visible for 3 s. In total, 75 single-figure and corresponding matrix pairs were presented. The task lasted 5 min. The explanation groups were told that the purpose of the task was to detect different states of different network devices in a very unstable environment.

Task 3 measured short-term memory and the ability to learn by trial and error. The task was a variation of the task used in Leiberman *et al.*'s (2006) study. In our task, a student had to memorize a random 12-digit-long sequence (Figure 3). The digits from

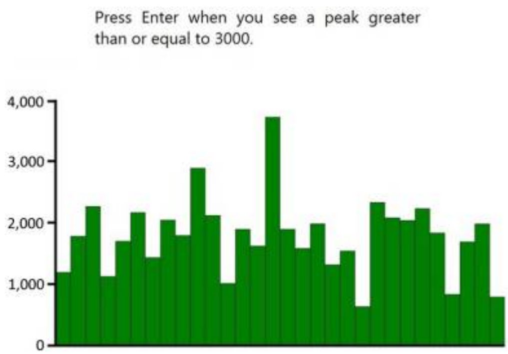

Figure 1.
Visual vigilance task (Task 1)

one to five were used to form the sequence. An empty 1 × 12 matrix was shown to the students. A digit was entered into the first square and "enter" was pressed. If the digit was correct, it stayed visible, and the cursor moved to the next square. If not, the digit vanished. Using the trial-and-error method, the student filled the whole 1 × 12 matrix. When the last digit was correct and "enter" key pressed, an empty 1 × 12 matrix appeared again. The same sequence had to be completed again. This was repeated 15 times. The explanation groups were told to memorize an encryption key. In each of the three test runs, the student had a different sequence to learn. We recorded the number of incorrect digits for each 1 × 12 matrix.

Task 4 confirmed if the 12-digit-long sequence really had been memorized. The students only had one chance to type the sequence. We recorded whether the sequence was correct.

Task 5 measured visual–spatial, executive memory and language abilities. The students were required to memorize three Norwegian (students' mother tongue) sentences consisting of 13-14 words, and a picture of five single-colour basic geometric

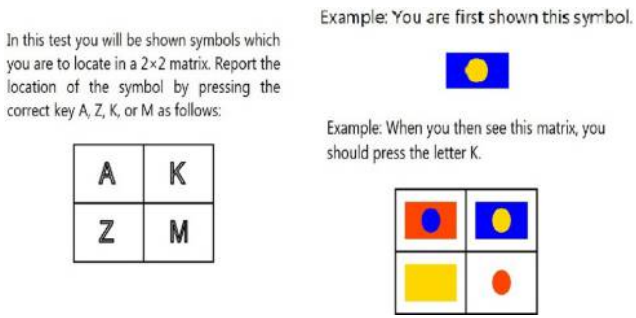

Figure 2.
Matching-to-sample task (Task 2)

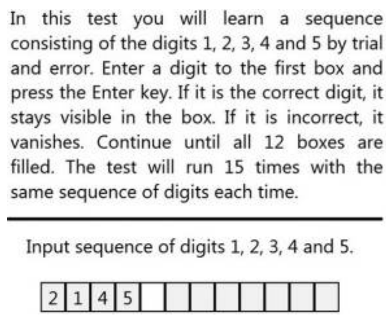

Figure 3.
Trial-and-error method (Task 3)

Figure 4.
Example of memory task (Task 5)

figures in 1 min (Figure 4). Subsequently, they had to write down the sentences and draw the figures with coloured pencils. The sentences and the figures were different in each test run. The correct words, forms and colours were counted. The word was correct if placed in the correct place in the correct sentence. The form was correct if it had the correct shape and was positioned in the correct place in the figure. For the colour to be correct, it had to be in the correct place in the figure. The explanation groups were instructed to memorize coded messages sent from a terrorist group.

4. Results

A comparison of performance rates was conducted between the control group from the 2014 study (Cont. 14) and explanation groups from both the 2014 and 2015 studies (Expl. 14 and Expl. 15). We hypothesized that the average performance rate is higher among explanation groups than in the control group because of the extra motivation that task explanation and its importance brings. However, in general, the military students are highly motivated to conduct any given task well in this particular exercise, and therefore, the data were chosen to be analyzed by one-tailed *t*-test.

Additionally, a comparison between HL and LL subgroups in both the control and explanation groups was conducted.

4.1 Effect of motivation: control group versus explanation groups

4.1.1 Task 1a: visual vigilance, correct detections. Table I shows that in 2014, the explanation group had higher performance averages than the control group in all tests (with close to 10 per cent significance level). However, the difference is not significant when the explanation group of 2015 is compared to the control group.

4.1.2 Task 1b: visual vigilance, false alarms. Explanation groups in both 2014 and

Task	Test	Cont. 14	Expl. 14	*p*-value Cont. 14 vs Expl. 14	Expl. 15	*p*-value Cont. 14 vs Expl. 15
Task 1a	1	97	*98*	*0.10*	*97*	0.24
	2	96	*98*	0.13	*97*	0.24
	3	87	*93*	0.14	*92*	0.17
Task 1b	1	43	*37*	0.11	*30*	*0.004*
	2	20	29	–	26	–
	3	30	33	–	44	–
Task 2	1	90	90	0.47	*95*	0.21
	2	95	*97*	0.14	94	–
	3	85	*89*	0.21	80	–
Task 4	1	68*	*95*	*0.02*	*92*	*0.02*
	2	95	85	–	89	–
	3	85	80	–	*95*	0.16
Task 5	1	83	*86*	0.22	*93*	*0.01*
	2	84	*89*	0.17	*96*	*0.01*
	3	82	*84*	0.40	*89*	*0.09*

Note: Low performance in Task 4* was because of misunderstanding of the task leading to biased *p*-values

Table I. Performance rates (%) and *p*-values of one-tailed *t*-test for the tasks

2015 had significantly fewer false alarms in the first test run than the control group (Table I). However, the significant difference vanishes in the last two tests, where in fact it is the control group that has fewer false alarms.

4.1.3 Task 2: matching-to-sample. The first performance rate in 2014 (first test run) for both groups is slightly biased because three control group and four explanation group students did not stop to read the given example, and therefore ended up pushing wrong keys in the beginning of the task. Furthermore, the *t*-test analysis does not show any significant differences between the control group and the explanation groups in the second and third test runs (Table I).

4.1.4 Task 3: motor learning. Error curves for the control and explanation groups in each of the test runs in 2014 are shown in Figure 5. The error curves show the number of errors the students made when guessing digits for each 15 matrices. There was a significant difference between the test groups in 2014 (p-values from the fifth iteration and further were 0.06, 0.08, 0.14, 0.11, 0.14, 0.07, 0.03, 0.03, 0.05, 0.05 and 0.04), indicating that task understanding gave the students extra motivation. However, it does not have an effect later on. Comparison between the control group of 2014 and explanation group of 2015 gave similar results than those shown in Figure 5.

4.1.5 Task 4: sequence control. The purpose of this task was to assess if the students had really learnt the correct sequence from Task 3. In 2014, this type of learning was unfamiliar to students, and two students from the control group did not understand that the sequence asked for in Task 4 was the sequence they had attempted to learn in Task 3. This lowered the recall rates in the first test run in 2014. Therefore, p-values can now be misleading because of the misunderstanding in the first test run (Table I). However, the results support the finding of the first test run in Task 3. The explanations of the tasks do not seem to have an effect in later test runs, neither in 2014 nor in 2015.

4.1.6 Task 5: visual-spatial and executive memory and language ability. The explanation groups in both 2014 and 2015 had higher average performance results in

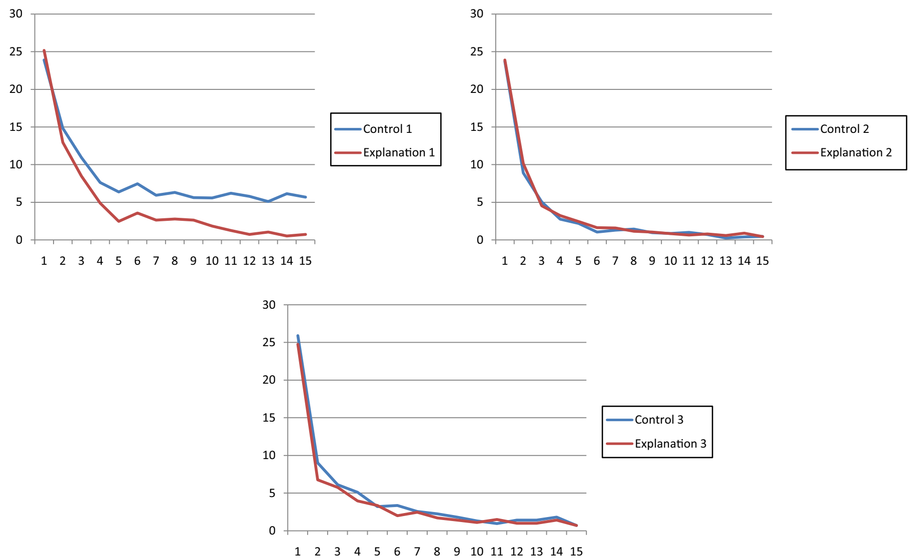

Figure 5.
Error curves of motor learning (Task 3)

memorizing three sentences and a coloured figure in all test runs. In 2014, the difference was not significant, but it was very significant between the control group and the explanation group of 2015.

The confirming experiment in 2015 supports the findings of the 2014 study (Helkala *et al.*, 2015b), indicating that the motivation gained by the explanation of the importance of the task has a positive effect on performance in cyber tasks, especially when the task is done for the first time.

4.2 Ability to control versus performance in cognitive tasks

The military exercise followed the same structure and format in both years, with only slight changes in content. We were interested to find out whether the changes we introduced to the preparation phase – providing greater opportunity for the students to apply the ten coping strategies across contexts – had any effect on performance.

An earlier study that focused on the use of coping strategies by cyber officer cadets (Helkala *et al.*, 2015a) showed that the first strategies used when a situation or incident occurs are: "situational understanding" and "acceptance of the situation". After a situation has been understood and accepted, only then can the actual performance start. Further on, the study showed that the "ability to control" strategy alone had high influence on performance in all cases.

The students who participated in the cognitive test in 2015 were also asked which coping (performance) strategies they used in the second and third cognitive tests and how they self-evaluated their own performance. The results showed that those who had used the ability to control and self-confidence strategies also had a highly significant self-evaluated performance rate in cognitive tests.

Further on, we compared the actual cognitive test results of the students who had used the "ability to control" strategy against the students who had not used this strategy. The results indicate that the use of "control" has a positive effect on performance results in cyber tasks, as shown in Table II. Results of the similar comparison regarding self-confidence did not show differences among the students' performance rates. However, 90 per cent of students who felt they had control over the situation were also self-confident.

The students only completed coping strategy questionnaires for the second and third cognitive test runs. Therefore, there are no data available from the first test. The averages shown in Table I vary slightly from the averages shown in Table II. This is because of the fact that one student participated only in the cognitive tests but not in the coping strategy questionnaires. In addition, one student failed to deliver the questionnaire regarding the usage of coping strategies in the third cognitive test.

Test	Comparison groups	Task 1a	Task 1b	Task 2	Task 4	Task 5
2	Control	*98*	*24*	*97*	*89*	*97*
	No control	95	36	82	86	93
	p-value	*0.06*	0.19	*0.09*	0.41	*0.12*
3	Control	*92*	*37*	*84*	*95*	*90*
	No control	91	54	77	92	89
	p-value	0.32	*0.04*	0.16	0.37	0.41

Table II. Performance rates and *p*-values for comparison for "used" ability-to-control group and "not used" ability-to-control group

4.3 Effect of physical fitness level

In 2014, we found indications that good physical fitness had a positive influence on cognitive tasks in the control group in the last test run when the participants were the most exhausted (Helkala *et al.*, 2015b). However, the test groups were too small that significant differences could be seen, but the *p*-values were closer to the significant level in the control group than those in the explanation group of 2014 (Table III). In 2015, the only difference between HL and LL groups can be seen in Task 5.

5. Discussion

The results indicate that motivation given by explaining the goal and importance of a task has a positive effect on the execution of cyber tasks. This is in line with the finding that information awareness education will be more effective if the reasons behind each security action are explained (Parsons *et al.*, 2014). According to motivation theories, a new task can alone act as motivation, as it gives a feeling of personal growth and learning (Ramlall, 2004). When a task is connected to a real-work situation, responsibility becomes a motivational factor. Emotions towards contents of tasks might also have an effect (McPherson, 2011).

It shows that using the performance strategy, the "ability to control" is connected to the well-recognized psychology term of *self-efficacy*. According to Bandura (1997), people with high self-efficacy – defined as an individual's belief about his capabilities to complete a task and reach goals – believe that they have the abilities to meet situational task demands. Our performance strategy, the "ability to control", is defined as:

> Having the ability to gain control of a situation or a task means that a person has a manageable level of oversight concerning available resources, areas of responsibility, risk and own capacities and capabilities (emotional and practical) in the given context to effect change. The ability to control also requires the person to be aware of the relative power and agency of those around them (both internal and external) (Helkala *et al.*, 2015a).

This is an indication that our research has measured situational self-efficacy, and our results support earlier research showing that self-efficacy predicts performance in task-related situations (Judge *et al.*, 2007).

The results also show minor indications that HL had a positive effect on cognitive abilities in neutrally explained tasks when a person is under sleep deprivation, is lacking nutrition and is not under (heavy) time pressure. The result supports earlier research (Fisher *et al.*, 2011; Gregory *et al.*, 2012; Luque-Casado *et al.*, 2013; Reed *et al.*, 2013), as well as Bullock and Giesbrecht 's (2014) findings about physical improvements in activities on attentional resources. The small or non-existing difference between physical fitness groups in the explanation groups support findings of Baumeister *et al.*

Table III. Third test's performance rates (%) of physical fitness groups with *p*-values of one-sided *t*-test

Test 3	Contr. 14			Expl. 14			Expl. 15		
Task	HL	LL	*p*-value	HL	LL	*p*-value	HL	LL	*p*-value
1a	*96*	72	*0.04*	*96*	90	0.17	*92*	91	0.31
1b	31	29	–	*32*	35	0.39	43	42	–
2	*86*	83	0.36	88	90	0.41	80	81	–
4	*92*	75	0.19	*82*	78	0.42	94	95	–
5	*87*	75	0.15	*86*	82	0.29	*92*	87	*0.09*

(2006), indicating that motivation might have a stronger effect than pure physical fitness.

6. Conclusion

In this study, we designed a cognitive test set to measure students' cognitive abilities. Attention, short-term memory, visual-spatial memory, execution of language skills and ability to learn were all tested at three separate occasions during a two-week exercise. The exercise was physically demanding because of sleep deprivation and reduced nutrition with increased physical activity.

We found that it is beneficial to give the explanation of the cyber task and its importance, as it can motivate the cyber operator to perform better. Also, the results show that applying the "ability to control" strategy has a positive effect on performance in cyber tasks. In addition, physical condition might have a positive effect, especially in cases where a person has been in a physically demanding environment for an extended period of time and the task they are undertaking lacks a clear explanation. However, to qualify this requires further investigation.

The study encourages us to build on the integration of cognitive cyber tasks, with structured military style physical training at our academy. Maintaining, operating and defending networks are not only tasks for military personnel. Civilian infrastructure and ICT networks are also maintained, operated and defended in similar ways. Based on the results of this study, as far as possible, clear explanation of tasks and good physical training should not be neglected or seen as unnecessary in civilian Computer Emergency Response Teams. Good physical condition could support analysts' ability to maintain performance when operating under stress for sustained periods.

This research is important, as we gain greater appreciation for the self-efficacy factors that affect cyber officer cadet performance across contexts and in different physical and mental states. Consequently, the NDCA can adapt the pedagogic platform to support the institutional framework for educating cyber officers. This leads to re-investment in areas of development such as mentoring, physical training and a more research-based, integrated curriculum.

7. Future work

We intend to find out how to manipulate and improve the working environment to affect self-efficacy and build on performance. More research is required to investigate how to increase metacognitive accuracy of one's own performance, identifying environmental factors that influence situational self-efficacy and how individuals can be trained to enhance their self-efficacy through reflection. Simultaneously, it is important to investigate the boundaries between beneficial self-efficacy and detrimental effects of over-confidence in the cyber context.

There is also a need to further investigate the effects of physical training and self-efficacy on performance, and to find the right type of physical training to support belief and behaviour that can lead to improved self-efficacy for performance.

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