Cognitive Performance Among Finnish Paratroopers During a 20-Day Winter Military Field Training Course and the Following 10-day Recovery Period

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ABSTRACT

We investigated the effects of winter military field training course consisting of strenuous physical stressors (e.g., physical activity, sleep deprivation and cold weather) on cognitive performance among Finnish soldiers. Fifty-eight male soldiers participated in a 20-day military field training course in Lapland as a part of their military service. Cognitive performance was assessed before, during and after the course with Sustained Attention to Response Task (SART), Baddeley's 3 minute reasoning task (BRT) and Change Blindness (CB) task in a tablet computer. We found that soldier's cognitive performance declined during the field exercise: reaction time increased and response accuracy to a target stimulus as well as visual perception and grammatical reasoning scores decreased. However, we also found that cognitive performance was recovered quite well after a 10-day recovery period. We concluded that to be able to optimize the planning of field training exercises or operational missions, it is important to know how cognitive performance, in addition to physical performance, is coping, moderating and recovering during the exercise or mission.

1.0 INTRODUCTION

Cognitive functions refer to a person's ability to perform various mental activities, such as perception, information processing, memory, language, reasoning, problem solving and executing actions. Paratroopers' field operations often involve cognitive and other stressors. Stressful situations have often been seen as a result of a prolonged and/or particularly intense fighting in which the burden is made up of several factors; such as lack of sleep, mental pressure, cognitive strain, malnutrition, and situational conditions (cold / heat, darkness, difficult terrain). In order to survive, soldiers must be able to act rationally and consistently in mentally and physically stressful situations. Cognitive disorders and problems with performance are usually a result of a situation where the demands of the mission exceed those of soldier's available resources and capacity.

It is highly important to understand the interactions between stressors and cognitive performance among soldiers to be able to optimize performance as well as to mitigate the potential problems for example in reasoning and decision-making during operations. However, even though there is increasing number of studies on physical stress, the understanding of the cognitive load and the effects of stress factors (such as physical strain, sleep deprivation and environmental factors) to cognitive performance in the military operations is less well understood.

It has been suggested that physical and/or mental stress may interfere cognitive performance. For example, it has been found that physical and mental stress may increase worker's vulnerability to mistakes and accidents [1] as well as reduce the effectiveness of decision-making [2]. In military context, in our previous study we found an interaction between physical stress markers (cortisol and IGF-1 levels) and cognitive executive function [3]. Decreased cognitive performance was related to high cortisol and low IGF-1 levels that were a result of cumulating physical stress.

In connection with environmental factors such as cold exposure, studies have shown equivocal effects on cognitive performance. Some studies suggest decrements in cognitive performance [4], [5] during cold exposure while others have found no effects [6].

In addition to executive function, it is important to study cognitive tasks which include higher levels of cognitive processing (e.g., visual perception and grammatical reasoning). Paratroopers' activity often involves, among other things, observing environment and detecting targets (perception), maintaining good situational awareness and adjusting plans and actions (reasoning) and decision to shoot or not to shoot to a target (executing or sustaining actions). Previous research has shown that losses of inhibitory control could be responsible for some friendly-fire incident [7]. Studies also suggest that problems with visual perception and reasoning might occur as a result of prolonged sleep loss and cold [8], [9], [10].

In the present study we investigated the effects of winter military field training course and recovery on cognitive performance among Finnish soldiers. We expected that the strenuous stressors (such as cumulative physical stress, lack of sleep and cold exposure) would result in decreased cognitive performance.

2.0 METHODS

2.1 Field Training

Fifty-eight conscript male soldiers participated to the training exercise. Soldier's average age was 19, 4 (±0.8) years, height 182 (±6.0) cm and weight 78, 5 (±7.2) kg.

The training exercise (and the research measurements) took place during winter (February/March) in Northern Finland. During the exercise, soldiers were exposed to winter conditions (moving, eating, sleeping etc. in outdoors) and performed different tasks, which included, among other things, skiing long distances with their 30-40 kg equipment. The exercise was planned to be progressively harder from the beginning to the end and proceeding from lighter training phase to a more strenuous field phase with accumulating stress (i.e., cold, physical load and sleep deprivation). The Figure 1 below illustrates the winter conditions.

The average temperature during the field exercise was -11, 3 °C and snow depth 107, 2 cm. The lowest temperature during the exercise was -31, 8 °C.

Figure 1: Winter military field training in Northern Finland (image source: Finnish Defence Forces).

2.2 Cognitive Tests

Cognitive performance was assessed with three cognitive tests that were performed before the exercise (PRE measurement), after seven days from the start of the exercise (MID), right after the field exercise end (POST measurement, 17 days from the beginning of the exercise) and after a 10 day recovery from the end of the field exercise (RECO measurement). Tests were the Sustained Attention to Response Task (SART; see [11], [12]), Baddeley 3-min reasoning grammatical task (BRT, see [13]) and Change Blindness task (CB, see [14], [15]).

SART was used to assess soldiers' inhibit and executive cognitive functions. It is a test that requires participant's constant attention and measures the speed and accuracy of soldier responses to a NoGO (inhibition) and GO (execution) stimuli. In the test, subjects were shown a constant stream of numbers at the centre of tablet screen. Participant's task was to monitor the screen and press response button as quickly as possible whenever other than number 3 was presented in the screen (i.e. one of the numbers 1, 2, 4, 5, 6, 7, 8, 9; GO stimulus) and refrain from pressing the button in the existence of number 3 (NoGO stimulus). One round of the test took about 5 minutes and contained 225 stimuli, of which the proportion of NoGO stimuli was 25. The number of commission errors (responses to NoGO stimuli) was used as a measure of lack of behavioural inhibition, whereas the number of omission errors (omitted responses to Go stimuli) and response time (in connection with correct responses to Go stimuli) was used as measures of execution performance.

BRT test was used to assess soldier's level of grammatical reasoning. It consisted of 64 statements about the order of letters A and B that were presented in the screen either in order AB or BA (e.g., "B follows A", "B is not following A", "B precedes A" etc.). The participant's task was to answer correctly as many questions as possible in the fixed 3-minutes period. The number of corrects answers and response rate was used as a measure of verbal reasoning performance.

CB was used to assess soldier's visual performance. In the test, participants were shown two set of 3-13 objects picture collages (for example, a clock, shoe, saw, chicken, etc.). In the latter picture collage one of the objects was replaced by a new object. Participant's task was to point out both the replaced and the replacing object from the set of response options. The test included 5 practice tasks and 28 actual test tasks. The number of correct answers in the test was used as a measure of the accuracy of perception.

Cognitive tests were adopted from the millisecond.com test library (https://www.millisecond.com) and performed in the PRE, MID (+7d), POST (+17d) and RECO (+27d) measurements using Inquisit stimuli presentation software (millisecond.com) and Panasonic FZ-G1L2114T3 tablet. The order of the execution of the tests was always the following: SART, BRT, and CB.

2.3 Statistical Analyses

Data for cognitive performance parameters (i.e., number of SART commission errors, number of SART omission errors, SART reaction time for GO stimuli, BRT test score and response rate and CB test score), each in turn, was analysed by the General Linear Model (GLM) Repeated Measures procedure in SPSS statistical program with Measurement (PRE, MID POST, RECO) as within-subjects. Contrasts (e.g., POST vs. PRE, RECO vs. POST measurement) were analysed to assess differences in cognitive performance after recovery and before and immediately after the field training.

3.0 RESULTS

THE GLM Repeated measures analysis revealed significant main effect for the Measurement (PRE, MID, POST, RECO) in all three tests as follows: in predicting SART omission error rate, $F(3,160) = 8,70$, $p<0,001$ and reaction time, $F(3,132) = 16,57$, $p<0,001$; In predicting BRT score, $F(3,130) = 20,06$, $p<0,001$ and response rate, F(3,135) = 16,35, p<0,001 and in predicting CB test score, F(3,133) = 13,51, p<0,001. Analyses showed no effect for the SART commission (false response to NoGO stimuli) rate.

As illustrated in the Table 1, contrast analyses between POST vs. PRE measurement revealed that SART omission errors (M_{PRE} = 1,2 % and M_{POST} = 4,0 %; p<.01), SART reaction time (M_{PRE} = 332 ms. and M_{POST} = 423 ms.; p<.001), and BRT response rate (M_{PRE} = 4612 ms. and M_{POST}= 5564 ms.; p<.01) increased and BRS score (M_{PRE} = 35,0 and M_{POST}= 30,1; p<.05) decreased. For CB test the difference between POST and PRE measurement was not statistically significant.

As also illustrated in the Table 1, contrast analyses between RECO vs. POST measurement revealed that SART omission errors (M_{RECO} = 0,6 % and M_{POST}= 4,0 %; p<.001), and BRT response rate (M_{RECO} = 4323 ms. and M_{POST}= 5564 ms.; p<.001) decreased and BRT (M_{RECO} = 38,9 and M_{POST}= 30,1; p<.05) and CB (M_{RECO} = 31,0 and M_{POST}=25,8; p<.001) decreased

In summary, results show that SART omission error rate, SART reaction time and BRT response rate was highest and BRT and CB scores lowest in POST measurement (i.e., right after the field exercise) therefore indicating that the strenuous exercise impaired cognitive performance in terms of reaction and error rate, grammatical reasoning and visual perception. Results also showed that omission error and BTR response rate decreased, and BRT and CB score increased from POST to RECO measurement, therefore indicating significant cognitive recovery in 10 days.

Table 1: Summary of the cognitive test results. * = compared to PRE measurement * = p < 0.05, ** = p < 0.01, *** = p < 0.001; # = compared to POST measurement # = p < 0.05, ## = p < 0.01, ### < 0.001.

	PRE (0)	MID (+7days)	POST (+17days)	RECO (+27days)
Test result				
SART omission error (%)	1,2##	0,6###	4,0**	0,6###
SART reaction time (ms)	332###	386***	423***	398***
BRT score	35,0#	35,8###	30,1*	38,9###
BRT response rate (ms)	4612##	4537###	5564**	4323###
CB score	27,6	29,0###	25,8	31,0###

Figure 2 illustrates the percentage change in test scores as compared to the “baseline” (PRE measurement). POST SART response rate was 27.3%, POST BRT response rate and test score were 20.6% and 14.1% and CB test score 6.7% lower than baseline. However, cognitive performance levels recovered near or better than baseline after the recovery period (except in the case of the SART reaction time).

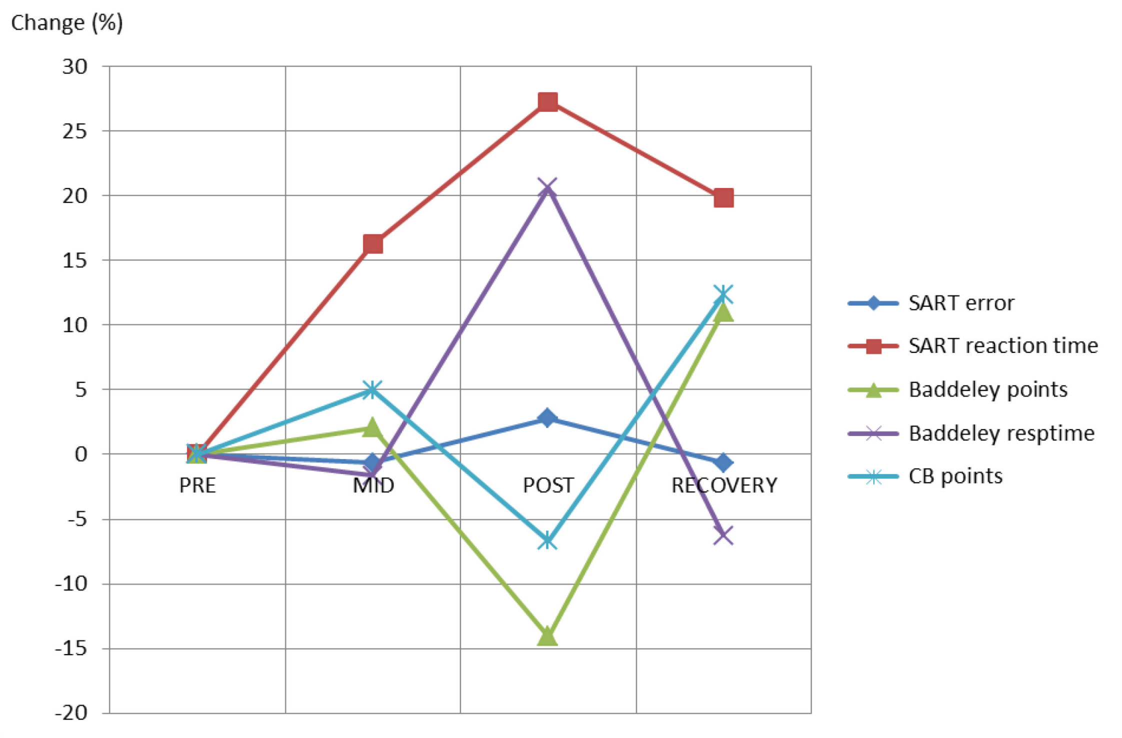

Figure 2: Percentage change in SART omission error rate and reaction time, BRT score and response rate and CB score in the measurements as compared to baseline (PRE measurement).

4.0 DISCUSSION

In the present study we investigated the effects of winter military field training course consisting of strenuous physical stressors (e.g., physical activity, sleep deprivation and cold weather) on cognitive performance among Finnish soldiers. We found that soldier's cognitive performance declined during the field exercise: reaction time increased and response accuracy to a target stimulus as well as test scores for visual perception and grammatical reasoning decreased. Changes in performance were in some measures as high as 20%. The results supported previous studies that have reported effects of prolonged exercises on cognitive performance and underline the necessity of understanding, preparing and supporting cognitive performance in operations in addition to physical and environmental factors. Support and recovery are especially important in long operations and in tasks that are done with short of personnel, because in these situations the stress factors tend to cumulate.

In the present study, field training consisted of several strenuous physical stressors. It was not possible to analyse the effects of each stressor (e.g., cold exposure) in isolation of another. To be able better support soldiers and mitigate problems, in further studies we plan to examine the role of different stressors that moderate cognitive performance. For example, we would expect that the physical stress should be considerable high to have an impact on cognitive performance as in our other (unpublished) study with moderately low level of physical activity we observed no effects on cognitive performance.

In connection with recovery, the results and some of our other studies [16], [17] suggest that sleep may be the most effective way to support cognitive performance, while other means such as nutrition or more active recovery methods such as nerve stimulation should be also explored. We are currently investigating the possibilities of Vagus nerve stimulation in enhancing and maintaining cognitive performance.

Environmental factors are also of interest, as in connection with cold exposure, the effects of cold exposure on soldier's cognitive performance are not well established. We are planning to examine the role of cold exposure in more detail in our future studies on shooting and survival exercises using our demonstrator system that was developed for measure and visualize cognitive stress. It uses Savox biometric system and router, movement and heart activity tracking with Suunto movesense, skin temperature measurements with Ruuvi tag and outside temperature measurements with integrated sensors. The system can also be integrated with so called secondary task paradigm (see [18]).

The operating environments and tasks for paratroopers are often in many ways highly challenging and stressful. Understanding the levels of cognitive performance and recovery as well as effects of various stressors on performance is highly important both for realistic training as well as for preparing and executing successful operations. This study showed some evidence of the negative impacts of long and strenuous field exercise on cognitive performance. Further studies could elaborate more the effects of different stressors (e.g., the role of cold temperature), the individual thresholds and differences related to stress and performance as well as larger variety of soldier relevant cognitive tasks.

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