Developing and Validating Virtual Reality Tool for the Evaluation of Cognitive and Physical Performance During Simulated lengthy field March

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Abstract**—Athletes, soldiers, and rescue personnel are often required to perform intensive and prolonged physically demanding activities while remaining cognitively focused. The combined effect of physical and cognitive tasks is of great interest, as both efforts share central nervous system reserves. Amid a larger study that is aimed to create an ecologically validated virtual reality (VR) - based experimental protocol to explore the effect of high-load physical and cognitive efforts on young individuals, the present report focuses on comparing new cognitive tasks presented in the context of simulated military missions with physical load to already established cognitive testing battery. Twelve young participants performed a 10 Km loaded march on a treadmill in VR settings with or without additional cognitive tasks (VR-COG). Each experimental day, subjects underwent pre- and post-evaluation, in which cognitive (trail making test – the color trail test CTT version, and SYNWIN battery for multitasking evaluation) and physical tests (time to exhaustion test – TTE) were conducted. In general, strong or moderate correlations were found between VR-COG performances and the cognitive tests. The VR-COG tasks, together with CTT components, were able to successfully predict the effect of the combined physical and cognitive load on the multitasking performance. Multitasking was evaluated by the SYNWIN score. We believe that our protocol allows optimal conditions for measurement of the effect of high-load physical and cognitive efforts for an extended period of time, thus contributing to the motor-cognitive interaction model knowledge base. It is apparent that virtual environments are ideal set ups for studying military activities, as they enable the participants to experience a particular situation within a controlled area.**

Keywords— virtual reality, ecologic environments, cognitive load, SYNWIN, CTT, Arm forces, military

I. Introduction

Athletes, soldiers, and rescue personnel are often required to perform intensive and prolonged physically demanding activities while maintaining cognitive focus. They must do so in order to make rapid decisions and process information from multiple sources using different sensory modalities [1-2]. These combined efforts can add a significant burden and may cause physical and cognitive exhaustion, and thus, poor performance. For example, when exposed to a stress stimulus, individuals may experience "perceptual narrowing", paying attention to fewer perceptual cues, making decisions based on incomplete information or ignoring alternatives [3].

It has been previously hypothesized that cognitive and physical efforts share central nervous system resources and therefore, when both functions are needed simultaneously, there is a reciprocal 'cost' expressed in the performance of both functions [4-6].

Understanding physical-cognitive interactions is of special interest in the context of military activity. For example, what

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are the ramifications of pre-mission physical and cognitive efforts on the performance during the mission itself? What is the optimal balance between the two in order to preserve the soldier's function and health?

Usually, studies examine the pre and post effects of exercise on physical [7-10] or cognitive [1, 11] performance separately. The exercise protocol is either an acute, short bout of exercise [10] or prolonged exercise protocols in which fatigue comes into consideration [7-9; 11-12]. For example, [12] evaluated the effects of load carriage and physical fatigue on cognitive performance. Participants walked for two hours with or without load while performing two cognitive tasks (auditory go/no go task and a visual target detection task). It was found that with time, the performance of both cognitive tasks decreased [12].

These results indicate a need to study these effects, addressing additional executive functions, and more importantly, studying the effects in more ecological settings.

For this purpose, we built an ecological platform and a controlled protocol that allows us to study the combined effect of highly demanding physical and cognitive tasks on the physical and cognitive performance for prolonged duration (2 hours). We used an advanced, fully immersive virtual reality (VR) system in order to maximize the simulation of real life conditions.

The **objective** of the present study was to develop and validate a VR -based experimental protocol (i.e. 'ecological') that sets the stage for meticulously exploring the effects of high-load physical and cognitive efforts on the participant. We systematically introduced context related (i.e., simulated military mission) cognitive tasks addressing the following competencies: (1) memory; (2) computation; (3) navigation (i.e., spatial orientation), and object detection. These tasks were compared to 'gold standard' cognitive assessments.

II. METHODS

The study took place at the Heller Institute of Medical Research (The Institute for Military Physiology) and the Center of Advanced Technologies in Rehabilitation (CATR), located in Sheba Medical Center (Tel Hashomer, Israel).

Rational:

Amid a larger protocol that was aimed to evaluate the feasibility of VR environment – based protocol, introducing simultaneous exposure to high physical and cognitive demands, we herein focus on comparing new cognitive tasks presented in the context of simulated military missions with physical load to more conventional validated cognitive tests. For the larger scope, to address the potential use of the set up and understand the ramifications of physical-cognitive load, the trials were conducted in cross over scheme. The participants participated in three visits, each visit consisting randomly of one of the following: simultaneous physical and cognitive load (Phys+Cog condition), solely physical load (i.e., Phys condition), or rest. To address the specific aim of the present study, the defined outcome is the correlation between the new VR-based cognitive tasks (during the Phys+Cog condition; see *Protocol* below) and cognitive testing battery that was presented prior and following the Phys+Cog condition.

A. Participants

Twelve healthy, male civilians that met the following inclusion criteria were recruited: (1) Males; (2) Age 21-30; (3) Served in a combat position during their military service in which they experienced with load carriage marches 4) Self-declared capability of enduring 10-km rushed walking while carrying substantial load using a backpack. 5) Above-average aerobic ability (VO_2max above 45 ml/kg/min). Individuals were excluded if they had any orthopedic or health issues.

The average values of those included were: age: 23.9±2.0 years; weight: 72.0±7.5 kg; height: 170±5 cm; BMI: 24.9±1.8 Kg/m^2; maximal oxygen uptake (VO_2max): 58.3±7.9 ml/kg/min.

All participants provided informed consent prior to their participation in the study. The study was approved by the Human Studies Committees of the Sheba Medical Center (SMC-2664-15).

B. Apparatus

We used the Computer Assisted Rehabilitation Environment (CAREN; Motek Medical©, Amsterdam, the Netherlands) high-end system. The system consists of a moveable platform (3m diameter) with six degrees of freedom of movement (translations and rotations). A dual-belt instrumented treadmill is embedded within the platform. This installation is placed in a dome shaped space. A virtual visual scene is projected on the interior surface of the dome using eight projectors, creating a 360° visual display that provides a sensation of full immersion and visual depth perception. A surround sound system provides auditory stimuli congruent with the scenery. The visual flow is synchronized with the speed of the treadmill.

C. Protocol

Firstly, the participants were invited to a preparatory visit, in which they underwent a physical examination, anthropometric measurements (height, weight, and body fat percentage), backpack size and weight adjustments, and VO_2max test. In addition, the participants were familiarized with one of the baseline cognitive evaluations. During each of the three visits, they performed one of the following protocols (randomly presented): Phys+Cog, Phys only, and rest. The physical element was a 10-km treadmill march (see details below). The 'rest' visit consisted of two hours of rest (sitting in a closed room without any kind of disturbance). The time interval between individual visits varied between 7 to 14 days, based on the participant's availability.

Each visit consisted of: a. Baseline assessment (pre; see below); b. Exposure to two hours of exercise/rest; c. Post exposure assessment (post; see below). Pre assessment included cognitive evaluation and post assessment included cognitive and physical evaluations. During each visit, the participants' heart rate (HR) was continuously monitored using

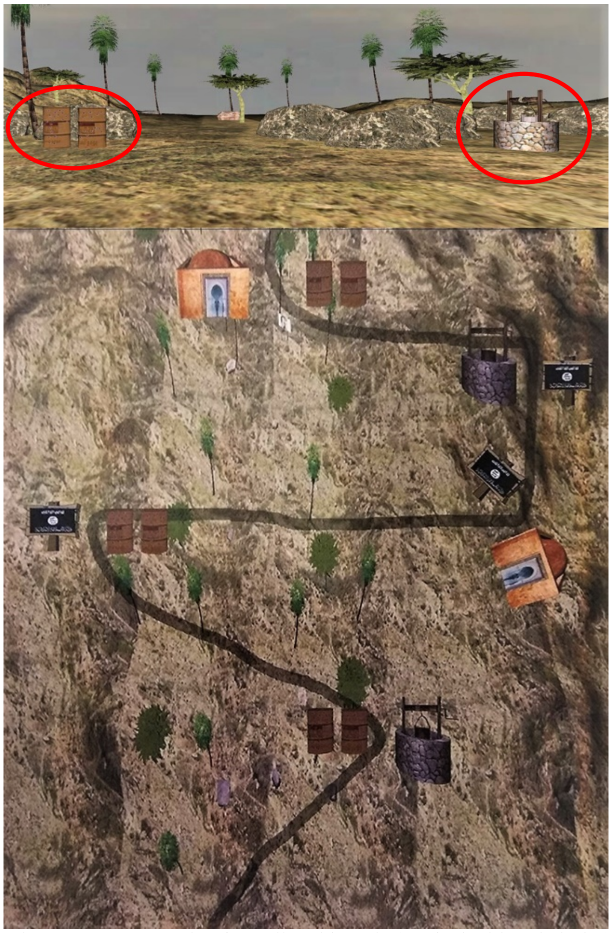

Fig. 1: A. An example of a well and barrels (marked with red circles) demarking the first turn; B. Schematic map of the march route.

a Polar RS800 watch with chest belt (Polar Electro, Finland), which measured the R-R time intervals.

a. March Settings

The participants were asked to arrive to each visit with shoes and clothes suitable for sports activities. By combining preset treadmill operation profiles (speed & inclinations) with congruent visual scenery, we simulated a 10 km "march" at a speed of 5 km/h and 1.15° slope (2% grade) in a Mediterranean hilly terrain with nearby and distant villages (Fig. 1a). To simulate diverse terrain, every 20 minutes the treadmill slope increased to 3.4° (6% grade) for 5 minutes and then returned to the original slope. The duration of the march was exactly two hours. The participants walked while carrying a backpack weighing 30% of their body weight. This profile is based on a prior study conducted at Heller Institute, in which cognitive and physical performance was evaluated after a road march [11].

The participants also carried a two-way radio (*walkie-talkie*). A drinking bag containing cooled water was placed near the treadmill and was not carried by the subject. The participants were attached to a safety harness for the entirety of the marching period. The harness did not cause discomfort while walking.

b. Context related cognitive tasks during the march

In the Phys+Cog visit, the participants, while marching, performed cognitive tasks that simulated military tasks, including: navigation, detection and reporting of the 'enemy,' of static and dynamic objects of interest, and memorizing the status of allied forces which they were exposed to via ongoing radio transmission.

Navigation

Prior to marching, the participants had two minutes to memorize the navigation route based on a map simulating aerial photos of the environment (Fig. 1b). Although the map was available to them during the march, they were encouraged to use their memory as much as possible and were notified that they will be scored accordingly. The route consisted of a number of straight walking intervals of different lengths, separated by 90° left and right turning points. The turning points were marked with noticeable landmarks such as wells, road boards, old barrels etc. These landmarks were also indicated on the map. The actual navigation occurred by choosing a direction to turn (left or right) once a landmark was identified (total of 5 navigation decision points). The actual signal to turn was done by pointing a stick with a reflective marker attached to it, captured by a motion capture system (Vicon, Oxford, UK; sampling rate 120 Hz). Immediately after the participant pointed to one direction, the visual scenery rotated accordingly to create the illusion of turning. If participants chose wrong, after 10 seconds, the visual scenery rotated by 180, and the participants were informed of their mistake. Using these methods, feedback was consistently provided, thereby preventing a cumulative effect from previous mistakes.

Scoring: each navigation decision was given a score of 1 (right decision) or 0 (wrong decision/ did not identify the turn/ looked at the map), thus considered a discrete parameter.

Detection and reporting of visual elements ('visual')

Prior to the march, the participants were told that while walking, different objects would appear in the sky and on the sides of the road, such as fighter jets, tanks, steel figure targets

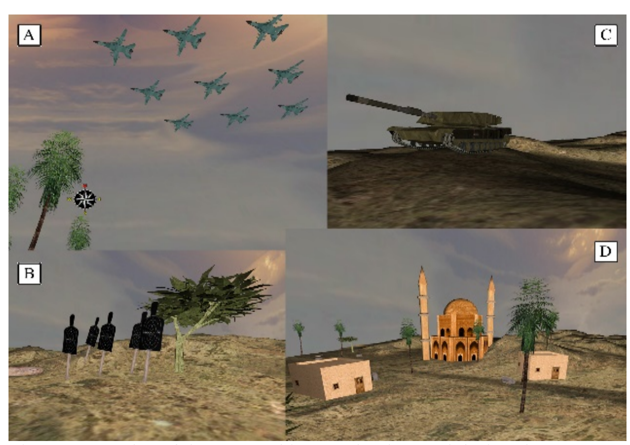

Fig. 2: Examples of the target objects to be detected during the march. A. Fighter jets with a compass rose B. Steel figure targets C. A tank. D. A typical Mediterranean village

(simulating enemy soldiers) and villages (see Fig. 2 for visual examples). In addition, the participants were told to identify these objects and memorize specific information about them i.e. the number of jets and their flight direction, the number of tanks and the side that they appeared in relation to them, the number of towers in the villages and the side they appeared on etc. To avoid misidentification of the target objects, the participants were shown pictures of them prior to the march. The jets' appearance was accompanied by a compass rose (projected on the screen in front of the participant's walking direction), making it easier for the participants to identify their flying direction. In addition, to alert the participants that jets are passing and to increase immersion, the jets were accompanied with actual recorded jet sounds. To evaluate the performance of the participants in these detection tasks, (in a pre-defined order), the experimenter used pre-recorded questions to ask the participants to report information, via the two-way radio, regarding specific objects seen previously. No feedback was provided as to whether the answers were wrong or right.

Scoring: each detection question was given a score of 2 (full correct report), 1 (partial correct report) or 0 (wrong report). Minimal possible = 0, maximal possible score=32.

<u>Memorizing the status of other allied forces</u>

The participants were informed that there were three 30-soldier units of allied forces walking in a parallel march, named as different colors: green, blue and red units. In addition, they were told that occasionally they will be given information (using the two-way radio) regarding the status of these forces. Each update report consisted of information about one of the units i.e. "three soldiers from the red unit were wounded and evacuated" or "5 new soldiers joined the blue unit". Periodically, the participants were asked to provide status reports regarding the current number of soldiers in each unit, thus, they had to perform immediate calculations and memorize the updated numbers continuously throughout the march. No feedback was provided as to whether these answers were right or wrong. To prevent carry-over effects from past mistakes, the participants' reports were judged (in a post evaluation) based only on the most recent responses.

Scoring: each report was given a score of 1 (correct report) or 0 (wrong report), thus considered a discrete parameter.

c. Pre and post marching cognitive assessments

We used the Trail Making Test (TMT) in its color version (i.e., color-trails test - CTT) to assess executive function, selective attention, visuoperceptual abilities and working memory [13-15].

We used the Synthetic Work Environment (SYNWIN) computerized tests battery to assess short-term memory performance, working memory, cognitive concentration, visual perception, multitasking, reaction time and data processing. The test consisted of four sub-tasks presented simultaneously for a 5-min session: a simple memory task, an arithmetic computation task, a visual monitoring task, and an auditory monitoring task. It has been used in many past trials to investigate the effects of various task and environmental factors on performance [16-20].

In addition, the participants did familiarization practice with this test in the baseline visit, which included repeating the test four times, to avoid learning effect in the test results [17].

d. Post physical evaluation

We used time to exhaustion (TTE) test only during the post assessment and after a 30-minute rest from the physical effort described above (the resting period includes the post-cognitive evaluation). The TTE is performed using a motor-driven treadmill as follows: after a 2-minute warm-up (5km/h, 2% slope), the pace and inclination was increased to match the subject's anaerobic threshold intensity (calculated from the VO_2max test) and was maintained for 15 minutes. If the participant managed to sustain this 15-min stage continuously, the pace was kept constant while the inclination was elevated by 2% every 4 minutes until reaching a subjective exhaustion. While performing the TTE test, a silicon mask was placed on the participant's face to measure respiratory values and adjust the intensity to match his pre-defined anaerobic threshold. Blood lactate was measured using a drop of blood drawn from the participants' fingertip prior to the beginning of the test and immediately after stopping the test. The primary outcome of the TTE test is the maximum running time that was achieved.

D. Outcome measures and data analysis

The study is designed as a feasibility study. We evaluated the correlation between the participants' performances during the validated cognitive tests using pre- and post-assessments, and our ecological cognitive assessment during the march in the VR environment (VR-COG). In addition, we examined the possible prediction of the post-exposure cognitive performance based on the VR-COG scores.

The CTT outcome measures are A part execution time that measures visual and perceptual tracking and sustained attention (CTT_A), and B part execution time that additionally measures working memory, divided attention, sequencing skills, inhibition control and cognitive flexibility (CTT_B) [13, 21-22]. For evaluating the exposure effect, the difference between pre and post (post-pre) for each test part was calculated (ΔCTT_A, ΔCTT_B,).

The SYNWIN outcome measure is a composite score based on the performance in the three sub-tasks (memory, math, and visual monitoring). In this study, we cancelled the auditory monitoring task due to technical issues, as participants were not able to appropriately hear tones produced by the software. For evaluating the exposure effect, the differences between pre and post SYNWIN total scores and sub-tasks were calculated (i.e., SYNWIN ΔScore, ΔMemory, ΔMath, and ΔVisual monitoring).

The VR-COG outcome measures are the total score of each cognitive task, i.e., navigating, detection and reporting (of both static and dynamic objects) and the memorizing tasks. In addition, a composite score was calculated based on all tasks using a weighted average (according to the number of task-related-questions that were presented to the participants).

E. Statistical analysis

The data is presented as mean ± standard deviation (SD). For validation of the cognitive performance, we used Pearson correlation between the VR-COG performance and the pre and the post results of the cognitive assessments scores. A multiple linear regression was calculated to predict the SYNWIN ΔScore based on the VR-COG and the pre-CTT score. Statistical significance level was set at α=0.05; and analyses was carried out on SPSS software (SPSS Ver. 24, IBM).

III. RESULTS

A. Correlations: VR-COG and CTT

Strong or medium statistically significant correlations were found between three out of the four VR-COG scores (total score and sub-tasks) and at least one of the CTT component scores (TABLE 1). The VR-COG total score showed a strong negative correlation with the pre and post CTT_A scores. The navigation score showed a strong negative correlation with the pre and post CTT_A scores and the pre CTT_B scores. In addition, the navigation score showed a strong positive correlation with ΔCTT_A (indicating an exposure effect). The visual VR-COG score showed a strong negative correlation with the pre and post CTT_A scores. The Calc&Mem scores did not show a correlation with the SYNWIN components.

Of note, no correlation was found between the VR-COG tasks and the difference between execution time of the CTT parts (CTT_{B-A}) as well as the ratio between the two parts.

B. Correlations: VR-COG and SYNWIN

Strong or medium statistically significant positive correlations were found between all the VR-COG scores (total score and sub-tasks) and at least one of the SYNWIN components' scores (TABLE 2). The VR-COG total score showed a strong positive correlation with the pre SYNWIN total score, with the post memory SYNWIN sub task score, and with the pre math SYNWIN sub task score. The navigation score showed a strong positive correlation with the pre SYNWIN total score and the pre math SYNWIN score. The visual VR-COG scores showed a medium positive correlation with the ΔVisual monitoring SYNWIN sub task score. The Calc&Mem score showed a strong positive correlation with the pre and post SYNWIN total scores, the post memory SYNWIN sub task score, and the pre and post SYNWIN math sub-task score.

C. Predicting post-exposure cognitive performance

A multiple linear regression was calculated to predict SYNWIN ΔScore based on the VR-COG tasks and the pre

TABLE 1: Pearson Correlation Between CTT Score in Pre and Post VR-COG.

	CTT_A			CTT_B		
Task Type	Pre	Post	Δ	Pre	Post	Δ
Total Score‡	**-0.75**[b]	**-0.70**[a]	0.48	-0.56	-0.52	0.18
Navigation‡	**-0.84**[b]	**-0.61**[a]	**0.69**[a]	**-0.59**[a]	-0.32	0.45
Visual†	**-0.61**[a]	**-0.72**[b]	0.28	-0.52	-0.57	0.08
Calc&Mem‡	-0.55	-0.54	0.34	-0.39	-0.48	0.00

[a] Correlation is significant at the 0.05 level. ‡ Discrete parameters.
[b] Correlation is significant at the 0.001 level. † Normally distributed (Shapiro-Wilk test, p>.05)

CTT scores. A significant regression equation was found ($F_{(5,6)}$=6.24, p=0.02, R^2=0.84):

$$\text{SYNWIN } \Delta\text{Score} = 1510.8 - 2.6{*}\text{Navigation} - 14.0{*}\text{Visual} + 5{*}\text{Calc\&Mem} - 3.8{*}\text{Pre } CTT_A - 7.3{*}\text{Pre } CTT_B \quad (1)$$

Visual (β=-0.98), Calc&Mem (β=0.93), and Pre CTT_B (β=-0.66) were significant predictors of the SYNWIN ΔScore (p=0.006, p=0.009, and p=0.04, respectively). Notably, the higher the SYNWIN ΔScore, the better the post-load score as compared to the pre-load score. Thus, the predictive model shows that better navigation and visual performances during the exposure reduce the post SYNWIN improvement, and additionally, better calculation and memory skills tend to improve the post SYNWIN performance post-exposure. In addition, longer pre CTT_A and CTT_B execution time (i.e., worse performance) tends to lower the SYNWIN ΔScore (reduce the post improvement). In order to evaluate if the prediction of the participants' cognitive performance is effected by their physical exhaustion, TTE score was added to the model. The addition of this component resulted in a non-significant model.

IV. DISCUSSION

In the current study, we created a validated protocol consisting of immersive environment VR scenery incorporated with real life conditions for exploring the combined effect of high-load physical and cognitive efforts for an extended period of time. To accomplish this, we used a VR-environment and props to simulate an actual military march combined with cognitive tasks that were designed to simulate actual military tasks. This paper shows the validation of these cognitive tasks. Virtual environments are ideal set-ups for studying the effect of such physical and cognitive loads because they enable participants to experience situations within ecologically-valid and controlled environments that can be tailored to their characteristics [24-25]. By using VR, specific scenery can be created for each cohort, reflecting its natural environment and professional requirements. We believe that these settings will most closely simulate natural environments, responses, and

TABLE 2: Pearson Correlation Between the Participants' Performances in the Pre and Post SYNWIN Battery and the VR-COG

	SYNWIN Score			Memory			Math			Visual monitoring		
Task Type	Pre	Post	Δ	Pre	Post	Δ	Pre	Post	Δ	Pre	Post	Δ
Total Score	**0.77**[b]	0.56	0.16	0.22	**0.66**[a]	0.17	**0.78**[b]	0.55	0.13	-0.25	0.23	0.46
Navigation	**0.67**[a]	0.50	0.16	0.13	0.44	0.13	**0.68**[a]	0.49	0.14	0.00	0.28	0.20
Visual	0.49	0.20	-0.19	0.28	0.40	-0.05	0.48	0.18	-0.21	-0.40	0.15	**0.58**[a]
Calc&Mem	**0.81**[b]	**0.71**[a]	0.37	0.18	**0.81**[b]	0.31	**0.83**[b]	**0.69**[a]	0.33	-0.24	0.18	0.41

[a] Correlation is significant at the 0.05 level (2-tailed).
[b] Correlation is significant at the 0.001 level (2-tailed).

actions, thus increasing the validity of the results. Our protocol can be modulated and used as a new assessment tool for all rescue personnel and athletes that are required to perform combined intense physical and cognitive tasks for an extended period of time. This protocol correlates with existing validated cognitive tests and constitute a more comprehensive tool for assessing participants' abilities in both physical and cognitive domains.

A. Summary of results

Strong or medium statistically significant negative correlations were found between the total score, navigation, and visual tasks of the VR-COG scores and the CTT_A score. Strong or medium statistically significant positive correlations were found between all the VR-COG scores and at least one of the SYNWIN components' scores.

The VR-COG tasks, together with CTT components, successfully predicted the effect of the combined physical and cognitive load on the multitasking performance, as reflected by the SYNWIN ΔScore.

Both CTT_A and CTT_B showed significant time effects, as the post-performance was better than the pre-performance.

B. Validation of the ecological VR environment

Overall, the ecological environment, using the different sub tasks, was successfully able to evaluate different cognitive abilities. The VR settings were built to assess various abilities expected from soldiers, rescue personnel and athletes: sustained attention, visual perception and information integration from multiple sources. These high cognitive abilities were evaluated while performing exercise and validated using two well-established tests and their matching components to the respective cognitive specific abilities.

A strong correlation was found between the VR-COG total score and CTT_A, based on spatial scanning and visuoperceptual abilities. Shorter CTT_A execution time indicates a better performance, while a higher score in the VR-COG, which is mainly composed of attention and perceptual function, might be relying on the same spatial skills [21].

A strong correlation was also found between the navigation and visual sub-tasks and CTT_A, which assess similar cognitive functions [13, 21]. The navigation sub-task was also correlated with the pre CTT_B, most likely due to their similar nature: making a decision based on visual input and the previous decision. The CTT_B test involves multiple demands (e.g., divided attention, cognitive alternation and inhibition control), and CTT_{B-A} minimizes visuoperceptual and working memory demands, providing a relatively pure indicator of executive control abilities. This can explain the non-correlative results of the other VR-COG components. The Calc&Mem sub-task involves different cognitive functions, such as math calculations, which are not evaluated by the CTT and therefore, are not correlated with the test.

Similar results were also found in the correlations to the SYNWIN test, in which VR-COG total score was strongly correlated with the SYNWIN components. While the total score, navigation and the Calc&Mem sub-tasks were correlated to the SYNWIN total score and to other sub-tasks, the VR visual score was correlated only to the visual monitoring task which relied on similar specific cognitive ability.

Although subjects were not tested for multitasking directly using the VR settings, the SYNWIN pre score, which represents the subject's overall cognitive performance in a multitasking environment, was correlated to most of the VR-COG scores. While performing exercise in the VR environment, the subjects were required to process information from multiple sources and memorize them until they were questioned while performing other cognitive tasks (i.e. navigation and calculation).

A strong relationship between working memory and multitasking was observed in the past [26-27]. Reference [26] concluded that working memory is most strongly related to SYNWIN performance. This conclusion points to a relationship between working memory and the VR-COG performance, suggesting that the application should be further evaluated in future work.

The performance in the cognitive tasks designed for the ecological VR environment was not correlated to the differences between pre and post SYNWIN score (separate from the visual sub-task which is similar in its nature). This indicates that the VR-COG tests cannot be used for evaluating post-exercise cognitive performance when compared to the baseline performance as reflected by the SYNWIN results.

C. Predicting post-exposure cognitive performance

In order to evaluate the physical and cognitive combined load effect on the cognitive performance, we chose the SYNWIN ΔScore as our examination parameter, as it most reflects the diverse cognitive abilities required from our population of interest. The significance of the regression components is due to the similarities of the cognitive demands from both VR-COG and the CTT_B, as explained above.

D. Limitations

A potential limitation of the current study design is that the VR simulation may not have caused high-cognitive load during the march. During military scenarios, soldiers are subjected to stressful environments in addition to cognitive load. Therefore, the interaction between exercise and cognitive performance with regards to armed forces should also be evaluated in more extreme scenarios that represent the real field, i.e., adding stress generating elements. Since this study was created as a pilot-study, the sample size was comparatively small. Finally, the study protocol was developed according to our previous pilot study, in which cognitive and physical performances were evaluated after performing a road march (using a treadmill) while carrying backload [11]. Therefore, the physical effort (i.e. pace, slopes and duration) had to be performed in the same manner for comparison proposes. Finally, our analyses correlating the VR-COG with the (post-pre Δ) was limited due to small sample size. However, it is noted that VR-COG approach can potentially assess the dynamics (i.e., comparing post to pre) of the cognitive performance under physical stress.

V. CONCLUSIONS

This protocol offers an ecological, highly immersive and controlled environment that can adequately simulate a military-related scenario embedded with military oriented tasks. The current study has the potential to create settings that allow the assessment of the combined effect of physical and cognitive efforts on later performances, and thus contribute to the motor-cognitive interaction model knowledge base. We propose that VR can also be used in order to conduct research on the soldier's function during field training by using simple and portable settings. A possible application of this kind of study can be combined cognitive and physical training to enhance soldier performance as well as an assessment tool for sorting processes in cognitively and physically demanding scenarios. The protocol, design, environment and tasks that were developed here can serve as future models for the creation of immersive, ecological VR environments for additional fields of interest (i.e., populations, cognitive and physical performances).

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