Assessing Cognitive-Motor Interference in Military Settings: Validity and Reliability of Two Dual-Tasking Tests

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ABSTRACT

Cognitive-motor interference refers to the decrease in cognitive and/or physical performance occurring when a cognitive task and a physical task are performed concurrently (dual-tasking) compared to when they are performed in isolation (single-tasking). The aim of this study was to investigate the validity and test-rest reliability of two cognitive-motor interference tests in military settings. Twenty-four soldiers, officers and cadets attended four experimental visits (tests: Visit 1 and 2; retests: Visit 3 and 4). They performed a 10-min loaded marching, a 10-min Psychomotor Vigilance Task (PVT) and the two tasks combined (Dual-Task 1) at Visit 1 and Visit 3; a 5-min running time trial, a 5-min Word Recall Task and the two tasks combined (Dual-Task 2) at Visit 2 and Visit 4. Step length, step frequency, reaction time and number of lapses were measured at Visit 1 and 3; running distance and number of words recalled were measured at Visit 2 and 4. Significantly shorter step length ($t_{(21)} = -0.721$, $p < 0.001$) and higher step frequency ($Z = -3.523$, $p < 0.001$) were found during the loaded marching in the dual-task condition compared to the single-task condition. No significant differences were observed in mean reaction time ($t_{(21)} = 0.856$, $p = 0.402$) and number of lapses ($Z = -0.721$, $p = 0.479$) during the PVT. Significant impairments were shown on both running distance ($t_{(21)} = 5.600$, $p < 0.001$) and number of words recalled ($t_{(21)} = 3.227$, $p = 0.004$) in the dual-task condition compared to the single-task condition. Good to excellent reliability was found for all the cognitive and physical variables in both single and dual-task conditions, except for the number of lapses, which showed low reliability in both conditions. Overall, the present findings suggest that the Running + Word Recall Task test is a valid and reliable dual-task test that could be used to assess cognitive-motor interference in military settings. Further work is required to improve the validity and reliability of the Marching + PVT test.

1.0 INTRODUCTION

Cognitive-motor interference refers to the decrement in cognitive performance and/or physical performance that occurs when a cognitive task and a physical task are performed concurrently (dual-tasking) compared to when they are performed in isolation (single-tasking) [1]. A considerable number of studies have investigated cognitive-motor interference while walking, showing evident gait performance impairments [2] and higher cognitive workloads [3] under dual-task conditions. However, less research has been conducted on other physical tasks, such as running [4-7], swimming [8] and climbing [9]. In military contexts, the ability to perform more than one task simultaneously (i.e., multitasking performance) is essential [10]. However, errors and other performance impairments are often inevitable due to the higher workload that multitasks induce compared to single tasks, even in the most expert individuals [1].

Different strategies have been proposed to improve multitasking performance of military personnel [10]. However, objective assessment of multitasking performance is not commonly used in military settings. An attempt has been made by a team of rehabilitation scientists through the development of the Assessment of Military Multitasking Performance (AMMP). The AMMP is a battery of clinical dual tasks and multitasks intended to evaluate the return-to-duty requirements in the military population affected by mild traumatic brain injury [12]. Some studies have also investigated cognitive interference in gait stability following concussion and mild traumatic brain injury [13-15] and more recently a multi-modal database aimed at assessing mental workload during physical workload has been described [16]. However, more work is required to develop valid and reliable tests of cognitive motor interference in healthy soldiers and other military personnel. Here we describe a study aimed at investigating the validity and test-retest reliability of two cognitive-motor interference tests on soldiers, officers and cadets free of brain injury.

2.0 MATERIALS AND METHODS

2.1 Participants

Twenty-four healthy physically-active soldiers, officers and cadets (20 males and 4 females) (means ± SD: age 28.5 ± 6.0 yr, body mass 76 ± 10 kg, height 1.80 ± 0.08 m, VO_{2max} 53.1 ± 5.8 ml/kg/min) were recruited from the Royal School of Military Engineering (RSME) in Chatham and RAF College Cranwell. Participants with any illness, disability or injury that may have precluded safe participation in vigorous exercise, any sensitivity to flashing lights, mental illness or learning disability and pregnant women were excluded from this study. All volunteers received a Participant Information Sheet and signed the Standard Consent Form before taking part in the study. The study was approved by the Ministry of Defence Research Ethics Committee (MODREC) and conducted in conformity with the Declaration of Helsinki.

2.2 Study Design

A randomized cross-over experimental design was used. Participants were required to attend five visits, which included one preliminary visit and four experimental visits: Visit 1 and Visit 2 (Tests) and Visit 3 and Visit 4 (Retests). The Retest Visits were conducted after two weeks (See *Testing Procedures*). Both Test and Retest Visits were separated by a minimum of 48-hour recovery period and conducted over a period of 7 days.

Participants performed a 10-min loaded marching, a 10-min Psychomotor Vigilance Task (PVT) and the two tasks combined (Dual-Task 1) at Visit 1 and Visit 3; a 5-min running Time Trial, a 5-min Word Recall Task and the two tasks combined (Dual-Task 2) at Visit 2 and Visit 4. Step length, step frequency, reaction time and number of lapses were measured at Visit 1 and 3; running distance and number of words recalled at Visit 2 and 4. All variables were measured in both single and dual task conditions.

2.3 Testing Procedures

2.3.1 Preliminary Visit

Following the collection of the main anthropometric measurements, subjects were asked to execute an incremental test on a motorised treadmill for VO_{2max} determination. Following the test, participants were familiarised with the dual-task tests.

2.3.2 Loaded Marching + PVT Test (Visit 1 and 3)

Participants were required to walk on a motorised treadmill for 10 minutes at 5 km/h whilst wearing a rucksack with a weight corresponding to 30% of their body weight (Task 1). During this loaded march, participants' gait was analysed for step length and frequency using an optical gait analysis system with detectors fixed to the motorized treadmill. After 10-min rest, participants were asked to perform a standard 10-min PVT [17] (Task 2) whilst standing on the same but inactive motorized treadmill. Participants were instructed to respond as quickly as possible to the visual stimuli (a bullseye) which were presented randomly with an inter-stimulus interval of 1 to 10 seconds on a computer screen attached to a laptop. Reaction time (RT) was recorded using a hand-held response button attached to the same laptop via a response box. After another 10-min break, participants performed Task 1 and Task 2 at the same time (Dual Task 1). PVT performance was analysed as mean RT and number of lapses over the 10-min period. Gait was analysed as mean step length and frequency over the 10-min period. Tasks order was randomised and counterbalanced.

2.3.3 Running Time Trial + WRT Test (Visit 2 and 4)

This test was based on the protocol developed by Epling and colleagues [5]. Participants were invited to run as far as they can in 5 minutes on the same motorized treadmill grade 1% (Time Trial, Task 1). After 20-min rest, they performed the WRT in a seated single-task condition (Task 2). Then, they would perform the WRT whilst running again with the same goal of covering as much distance as possible in 5 minutes (Dual Task 2). Four 20-word lists from the Paivio et al. [18] word pool were used for the WRT. The words were provided to the participants via earphones connected to a smartphone via bluetooth. One word was played every 15 seconds so that participants were presented with 20 words in 5 minutes. At the end of this 5-min period, participants were given 90 seconds to write down all the words they remembered. The four word lists and the tasks order were randomised and counterbalanced.

2.4 Statistical Analysis

Data from participants who did not complete all the test and retest visits were excluded from the statistical analysis. The validity of the cognitive-motor interference tests was assessed on the test data (Visit 1 and Visit 2) as they included the maximum number of participants (N = 22). Validity was conceptualized as the ability to demonstrate a significant cognitive-motor interference. Statistically, validity was analysed using paired-sample t tests to test the effect of task condition (single task vs dual task) on various parameters of cognitive and physical performance. Reliability was assessed for each variable using intra-class correlation coefficient (ICC) test-retest, based on a two-way mixed model effect, absolute agreement, multiple measurements, and average measures. ICC values lower than 0.5, between 0.5 and 0.75, between 0.75 and 0.9, and higher than 0.90 were classified as poor, moderate, good, and excellent reliability, respectively. Lower and upper limit bounds of the 95% confidence intervals were also reported [19].

Unless otherwise stated, data are presented as mean ± SD. Significance was set at 0.05 (2-tailed) for all analyses.

3.0 RESULTS

3.1 Loaded Marching + PVT Test

Paired t-tests revealed a significant effect of task on both step frequency (Z = -3.523, $p < 0.001$) and step length ($t_{(21)} = -0.721$, $p < 0.001$) during the loaded marching (Figure 1). Step frequency was higher in the dual-task condition (114 ± 5 steps · min^{-1}) compared to the single task condition (113 ± 5 steps · min^{-1}). Step length was shorter in the dual task condition (73.3 ± 2.76 cm) compared to the single task condition (74.0 ± 2.89 cm). No significant differences were found on mean RT ($t_{(21)} = 0.856$, $p = 0.402$) and number of lapses (Z = -0.721, $p = 0.479$) (Figure 1D) during the PVT (Figure 1).

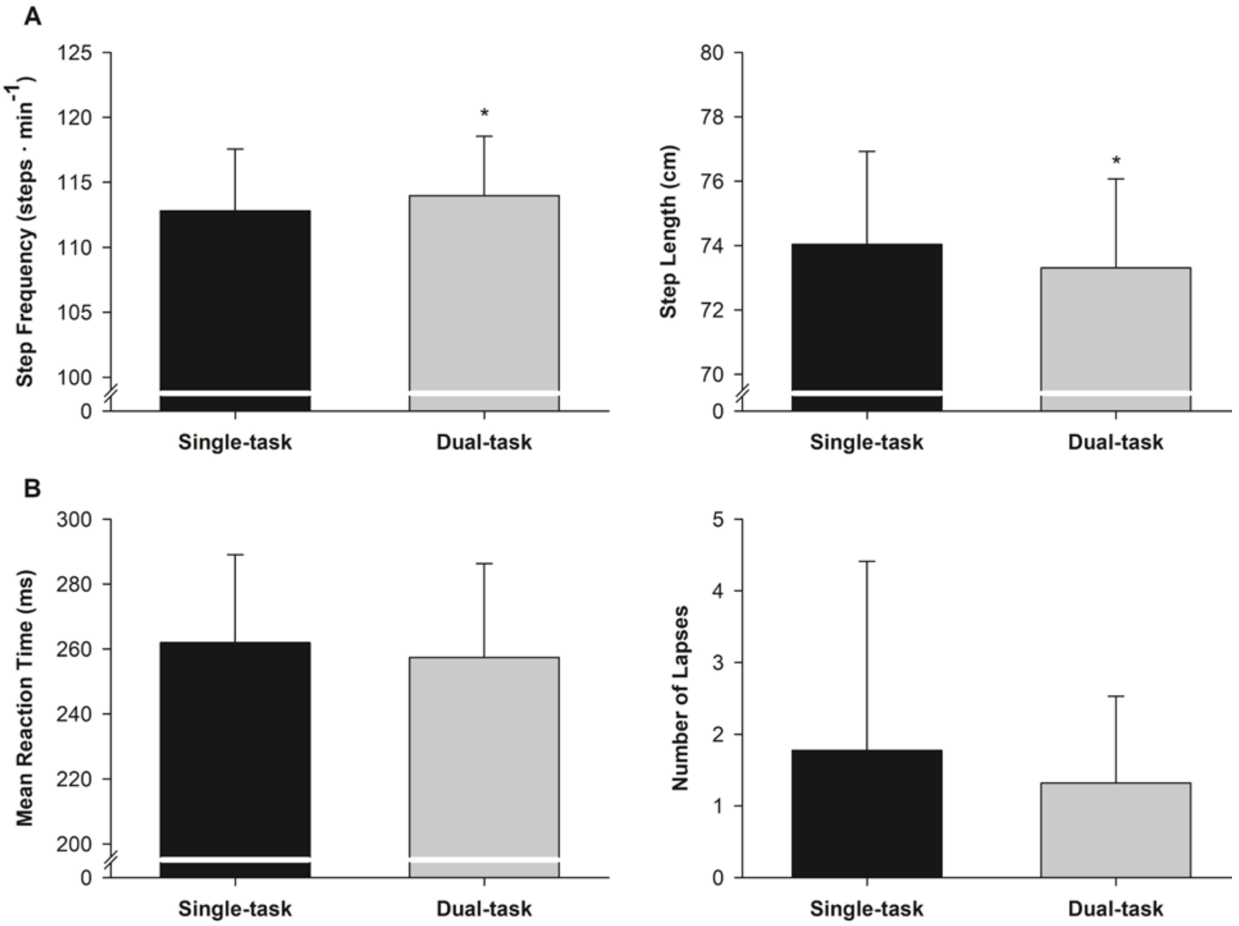

Figure 1. Loaded Marching + PVT Test. (A) Gait parameters. (B) PVT variables. Data are presented as mean ± SEM. N = 22. * p < 0.05

3.2 Running Time Trial + WRT Test

Paired t-tests revealed a significant effect of task on both running distance ($t_{(21)} = 5.600$, $p < 0.001$) and number of words recalled ($t_{(21)} = 3.227$, $p = 0.004$) (Figure 2). Running distance was shorter in the dual-task condition (1149 ± 154 m) compared to the single task condition (1245 ± 171 m). The number of words recalled was lower in the dual-task condition (13 ± 4 words) compared to the single task condition (14 ± 4 words).

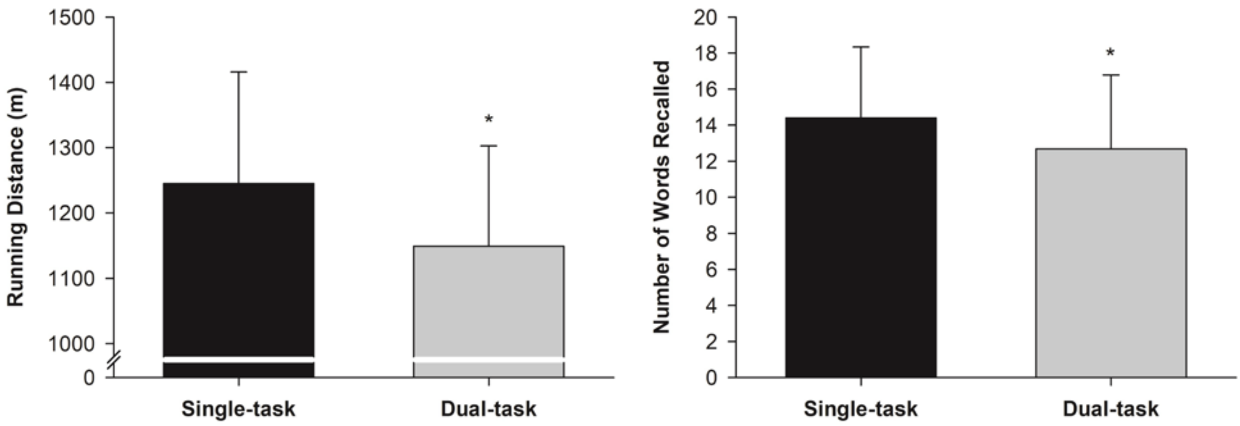

Figure 2. Effect of Task during the Running Time Trial + WRT Test. Data are presented as mean ± SD. N = 22. * p < 0.05

3.3 Test-retest Reliability

Good to excellent reliability was found for the vast majority of cognitive and physical variables in both, single and dual task conditions (Table 1). Only the number of lapses in the PVT showed low reliability in both conditions. Paired *t*-tests revealed a significant systematic change between test and retest for step length and step frequency during single task only ($p = 0.021$).

Table 1. Test-Retest Correlation and 95% CI of the Cognitive-Motor Interference Tests (N = 22)

Loaded Marching + PVT Test		Running Time Trial + WRT Test	
ST Step Length (cm)	r = 0.95 [0.87, 0.98]	ST Running Distance (m)	rho = 0.72 [0.41, 0.88]
DT Step Length (cm)	r = 0.92 [0.81, 0.97]	DT Running Distance (m)	rho = 0.78 [0.52, 0.91]
ST Step Frequency (steps/min)	r = 0.95 [0.88, 0.98]	ST Words Recalled (N)	rho= 0.85 [0.65, 0.94]
DT Step Frequency (steps/min)	r = 0.93 [0.83, 0.97]	DT Words Recalled (N)	r = 0.82 [0.59, 0.93]
ST Mean RT (ms)	r = 0.73 [0.43, 0.89]		
DT Mean RT (ms)	r = 0.65 [0.29, 0.85]		
ST Lapses (N)	rho = 0.11 [-0.35, 0.53]		

DT Lapses (N)	rho = 0.07 [-0.38, 0.50]

CI = Confidence Interval. Pearson's (r) or Spearman's (rho) correlation coefficient.
PVT = Psychomotor Vigilance Task. WRT = Word Recall Task. ST = single-task. DT = dual-task.
N = Number. Data are shown as means ± SD.

4.0 DISCUSSION

The current study has provided evidence that these novel tests are valid. Specifically, strong evidence of cognitive-motor interference was found during the Running + WRT Test, where both cognitive and physical performance were impaired in the dual-task condition. These results are in partial agreement with previous studies conducted in athletes and physically active individuals which showed significant impairments in WRT performance, but not significant decrements in self-paced running performance during dual-tasking [5,6]. It is important to highlight that, differently from Epling and colleagues [5], who ran the experiment in a 400-m track and participants were consequently aware of the distance covered, the 5-min running time trial performed in the present experiment was performed on a motorised treadmill and no feedback was given. Even though the workload during the dual-task was greater than the running task alone, participants' awareness of the distance covered, might have facilitated the physical performance and therefore decreased the interference of WRT on running. In addition to that, the resting time between tasks in the same study was not timed-set and this might have also contributed to different performance results.

The evidence for the validity of the Loaded Marching + PVT Test is weaker because significant cognitive-motor interference was found for physical performance only. A significant reduction in Step Length and a concomitant significant increase in Step Frequency was observed in the Dual-Task condition compared to the Single-Task condition. Decrements in Step Frequency and increments in Step Length have previously been shown when a cognitive task is added to walking [2]. In order to increase cognitive-motor interference, future modifications of this test are required such as increments in test duration to induce a state of mental fatigue or performing the same test under conditions of sleep deprivation. It might also be considered to increase the difficulty and the workload of the cognitive task itself by adding some internal interfering factors, such as mental tracking [20]. Virtual reality environments might also be used to change cognitive demands during loaded marching. On the other hand, increments in loading weight and/or in marching speed may enhance the physical demand during the PVT.

The test-retest results indicate that the Running + WRT Test can be considered a reliable cognitive-motor interference test for assessing multitasking performance in military environments. Only the number of lapses in the PVT showed poor reliability (ICC < 0.5) in both conditions. Furthemore, there were order effects (i.e. changes over time) in both Step Length and Step Frequency showing a learning effect between the first and second loaded march on the motorized treadmill which may be reduced by further participants familiarisation.

5.0 CONCLUSIONS AND PRACTICAL APPLICATIONS

The current study provides evidence that the Running + WRT Test is a valid and reliable dual task test and that it could be used to assess cognitive-motor interference in soldiers, officers and cadets. On the other hand, the Marching + PVT Test require further work to enhance its validity and reliability, especially in terms of cognitive performance. From a practical perspective, the Running + WRT Test may be used to assess multitasking performance of both soldiers and pilots and monitor any potential improvement induced by training. However, further research is required to assess its sensitivity to change and to increase its ecological validity in military environments.

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