

Analysis of the acute effects of mental fatigue on learning rope maneuvers in beginners of nature and adventure sports

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Abstract

The increase in the number of practitioners has led to a rise in the number of accidents in Nature and Adventure Sports (NAS). To mitigate risk factors, it is essential that the teaching-learning process is effective and adapted to new practitioners, considering the risks associated with rope maneuvers. The objective of the present study was to understand the effects of mental fatigue on learning rope maneuvers in NAS. The design used in this study was a crossover. The study sample had a mean age of 21.9 ± 2.51 years, totaling 16 beginner individuals in NAS, divided equally and randomly into two groups. Group 1 received instruction for CAT maneuver 1, followed by 30 minutes of mental fatigue induction through the Stroop task, and subsequently performed the maneuver test. On the same day, a second group (Group B, $n=8$) underwent the same procedure, using CAT maneuver 2 and changing the mental fatigue condition to the control task, resting for 30 minutes. After exactly 7 days, a new data collection was performed, crossing the groups. The results indicate that execution time was longer in the mental fatigue condition than in the initial condition ($+1.1\%$ and $p=0.737$), while without mental fatigue it decreased (-21.3% and $P<0.001$). Execution quality was lower by about -1.6% in the initial condition than in the mental fatigue condition ($p=0.571$), but increased by $+2.6\%$ without mental fatigue ($p=0.279$). Finally, the Final Score was higher in the mental fatigue condition than in the initial condition ($+6.3\%$ and $p=0.469$), but significantly higher without mental fatigue ($+30.8\%$ and $P<0.001$). In summary, the results of this study suggest that mental fatigue had negative impacts on the learning of rope maneuvers in NAS, considering that beginners did not improve under this condition. However, when comparing the initial condition with the condition without mental fatigue, a significant improvement in execution time and Final Score was observed.

Keywords: nature and adventure sports, rope maneuvers, assessment, observation instrument, demonstration.

Introduction

Nature and Adventure Sports (NAS) have gained increasing prominence as activities that provide unique and challenging experiences in natural environments (Durán-Sánchez et al., 2020; Melo & Gomes, 2017). Among the various practices within this context, rope maneuvers play a fundamental role, requiring specific technical skills to overcome obstacles and explore the potential of these sports (Betrán & Betrán, 2016).

In various countries, the uncontrolled increase in the number of practitioners has led to increases in the number of accidents in NAS (Nerin & Morandeira, 2005). To reduce risk factors, it is essential that the teaching-learning process is studied, defining concrete and high-quality procedures (Mário Silva et al., 2014), with the objective of preparing new practitioners for the risks associated with NAS involving rope maneuvers (Silva, 2008). Currently, assessment instruments have been developed enabling the characterization of the participants' technical level (Sarmiento et al., 2019) and some studies have been conducted on the teaching-learning process in rope maneuvers (Sarmiento, Brandão, et al., 2021). The study of mental fatigue

In this sense, some authors have explored how mental fatigue affects the learning of fine and complex motor skills, such as surgical skills, manual dexterity (Duncan et al., 2015) and sports skills (González-Villora et al., 2022). According to the same author, this research investigates the effects of mental fatigue on precision, speed, motor coordination, and decision-making during the execution of these skills. However, it is important to note that the effects of mental fatigue can vary depending on the complexity of the task, the type of motor skill, and individual characteristics (Pageaux & Lepers, 2018). The results of these studies are varied, but generally suggest that mental fatigue can have negative effects on the learning and performance of motor skills (Díaz-García et al., 2023; Habay et al., 2021; Le Mansec et al., 2018).

In this context, it is crucial to understand the effects of mental fatigue on the execution of rope maneuvers in NAS. By exploring this theme, we seek to provide a solid scientific basis that can contribute to the

development of more effective strategies and approaches in the training, practice, and instruction of these sports (Carvalho et al., 2010). Understanding the effects of mental fatigue in this context can lead to targeted and personalized interventions, aiming to improve practitioner performance and promote safety during the execution of rope maneuvers (Brandão, Gonçalves, et al., 2018).

Furthermore, by focusing on execution speed and technical execution quality, we intend to better understand the cognitive and physical aspects involved in these activities (Eigenschenk et al., 2019). The analysis of these elements can contribute to the development of training materials and more efficient and targeted training strategies, aiming to improve practitioner performance.

In summary, this article aims to fill a gap in scientific knowledge, providing a more comprehensive understanding of the effects of mental fatigue on the speed and quality of technical execution in rope maneuvers in NAS. The relevance of avoiding mental fatigue in the teaching-learning process of rope maneuvers is directly related to the optimization of participant performance, the safety of practices, and the effectiveness of learning. It is expected that the obtained results will contribute to improving the practice and safety of these activities, promoting more enriching and positive experiences for practitioners.

Methods

Study design

A survey was conducted using a crossover design, in which participants were selected based on convenience criteria and subsequently distributed randomly and equally between the mental fatigue and control conditions. Then, the participants switched between the two conditions. To ensure randomization, a simple method was used, applying an automatic randomization software (randomization.com). This research approach was adopted in several similar studies to avoid any bias in the allocation of participants to the different experimental conditions.

Participants

The study sample has a mean age of 21.9 ± 2.51 years, totaling 16 beginner individuals in NAS. The following eligibility criteria were considered: i) having a maximum of 10 activities involving rope maneuvers; ii) being over 18 years of age; iii) availability to undergo the assessments with exactly 7 days interval. The study design, risks, and benefits of participation were communicated to the research subjects. The participants signed a free and informed consent form. The study followed the guidelines for research on human beings and the Declaration of Helsinki.

Experimental Approach

Data collection took place between February 2 and 10, 2022. The research was conducted during the time slot from 10 am to 4 pm, in an acoustically isolated laboratory with white background walls, with identical thermal conditions between the two tests. Participants were instructed to maintain a regular sleep schedule (at least 7 hours daily) and diet, refrain from exhaustive practices in the last 48 hours, and not consume caffeine, nicotine, alcohol, or engage in tasks with high cognitive demand in the moments preceding the test.

To analyze the effects of mental fatigue on the learning and execution of rope maneuvers in NAS beginners, maneuvers 1 – "approach to the anchor with placement and locking of the figure-eight descender on the rope" and maneuver 2 – "setting up a retrievable rappel with a dynamic knot" from the Canyoning Assessment Tool (CAT) were used, alternating the mental fatigue and control conditions. In a first group (Group A, $n=8$), instruction for CAT maneuver 1 was given, followed by 30 minutes of mental fatigue induction through the Stroop task, and subsequently, the maneuver test was performed. On the same day, a second group (Group B, $n=8$) underwent the same procedure, using CAT maneuver 2 and changing the mental fatigue condition to the control task, resting for 30 minutes (Figure 1). After exactly 7 days, a new data collection was performed, crossing the groups. As the research focuses on learning a maneuver, the maneuvers were switched between the groups to avoid collection bias. In this sense, Group A was instructed in CAT maneuver 2, followed by 30 minutes of rest (Control Group) and then assessment of maneuver 2. While Group B received instruction for CAT maneuver 1 and switched the condition to mental fatigue induction through the Stroop task for 30 minutes, before performing the test for maneuver 1. Regarding the selection of maneuvers, these choices were supported by the research of Sarmento and colleagues (2021), which identified that maneuver 1 is the simplest and most used in rope maneuvers and that it could lead to a learning transfer with CAT maneuver 3, due to the similarity of equipment and their use. As such, we opted for CAT maneuver 2, which does not present the problem of bias during instruction and uses one of the most commonly used knots in rope maneuvers, the dynamic knot and its respective locking (Sarmento et al., 2019). Finally, CAT maneuver 4 was not considered because it does not allow the simultaneous assessment of 4 subjects and presents a higher degree of difficulty compared to the others.

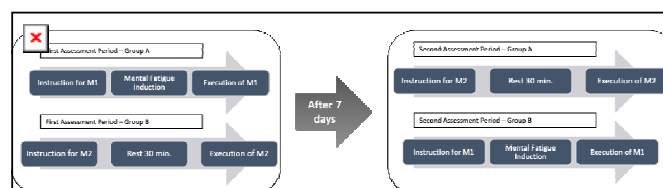


Figure 1 - Diagram of the data collection process.

Instruments

Mental Fatigue

The Stroop test was performed in a computerized version, using equipment with the same screen size for each subject (Coutinho et al., 2018). In the Stroop Test with colored words, four words were used (red, blue, yellow, and green), which were randomly displayed on a gray computer screen (Trecroci et al., 2020). Participants chose one of four computer keys, which corresponded to the color of the word and not its meaning. For example, when the word blue appeared in green color, the correct response would be the key corresponding to the color green. The task also contained 50% congruent trials (word and color matching) and 50% incongruent stimuli (no match between word and color) (Badin et al., 2016). To increase motivation levels, the subjects aimed to be as accurate as possible, trying to complete the highest number of correct stimuli compared to the other participants, within the 30-minute period (Coutinho et al., 2018).

Canyoning Assessment Tool (CAT)

For the technical assessment of rope maneuver execution, the validated instrument CAT (Sarmento et al., 2019) was used. The assessment of each of the 9 criteria for each maneuver focuses on 4 parameters: "Does not perform"; "Performs with errors"; "Performs without errors, but with hesitations" and finally, the best parameter "Performs without errors and without hesitations", on a scale of 0 to 3 points. The sum of the criteria results in the value of the Technical Execution Classification (TEC). The quotient of the TEC by the execution time (s) determines the value of the Final Score of the maneuver (Sarmento, Martins, et al., 2021).

$$\text{Score Final of the maneuver} = \frac{\text{TEC}}{\text{Execution Time (s)}}$$

Statistical Procedures

Descriptive statistics are presented as mean and standard deviation. Due to the sample size being less than 30, the non-parametric Wilcoxon test for paired samples was used for pairwise comparisons. Additionally, the standardized Cohen's effect size (d) was calculated for pairwise comparisons, using the pooled standard deviations. The statistical procedures were performed using SPSS (version 28.0.0.0, IBM, USA) for a $p < 0.05$.

Results

Table 1 presents the descriptive statistics of execution time and quality, as well as the overall Final Score for maneuver 2 performed under mental fatigue. No significant differences were found between the initial condition and mental fatigue in execution time ($p=0.737$), execution quality ($p=0.571$), and Final Score ($p=0.469$).

Table 1. Descriptive statistics (mean and standard deviation) of maneuver 2 performance under initial and mental fatigue conditions.

	Initial	Mental Fatigue	Wilcoxon test for paired samples	d
Execution time (s)	165,6±41,5	167,5±64,5	$Z=-0,336$ $p=0,737$	-0,040 95%CI [-0,529;0,451]
Execution quality (A.U.)	24,8±2,0	24,4±2,8	$Z=-0,566$ $p=0,571$	0,160 95%CI [-0,336;0,650]
Score Final (A.U.)	0,16±0,05	0,17±0,08	$Z=-0,724$ $p=0,469$	-0,238 95%CI [-0,723;0,263]

A.U.: arbitrary unity;

95% CI: 95% confidence interval

Table 2 presents the descriptive statistics of execution time and quality, as well as the overall Final Score for maneuver 1 performed without mental fatigue. Execution time was significantly shorter in the condition without mental fatigue than at the initial condition ($p < 0.001$), while the Final Score was significantly higher ($p < 0.001$). No significant differences were found between the conditions in execution quality ($p=0.279$).

Table 2. Descriptive statistics (mean and standard deviation) of maneuver 1 performance under initial and no mental fatigue conditions.

	Initial	No mental fatigue	Wilcoxon test for paired samples	d
Execution time (s)	195,3±58,5	153,7±45,8	$Z=-3,310$ $P < 0,001$	1,218 95%CI [0,553;1,859]
Execution quality (A.U.)	23,3±2,9	23,9±2,2	$Z=-1,083$ $p=0,279$	-0,282 95%CI [-0,777;0,223]
Score final (A.U.)	0,13±0,05	0,17±0,07	$Z=-3,258$ $p < 0,001$	-1,108 95%CI [-1,725;-0,469]

A.U.: arbitrary unity;

95%CI: 95% confidence interval

Figure 2a reveals that execution time was longer in the mental fatigue condition than in the initial condition (+1.1%). Considering Figure 2b, it is possible to observe that execution quality was lower by about -

1.6% in the initial condition than in the mental fatigue condition. Finally, in Figure 2c, it is possible to observe that the Final Score was higher in the mental fatigue condition than in the initial condition (+6.3%). Regarding the comparisons between the initial condition and the condition without mental fatigue, Figure 2d reveals that execution time decreased by -21.3% in the condition without mental fatigue, while execution quality increased by +2.6% (Figure 2e) and the Final Score increased by 30.8% (Figure 2f).

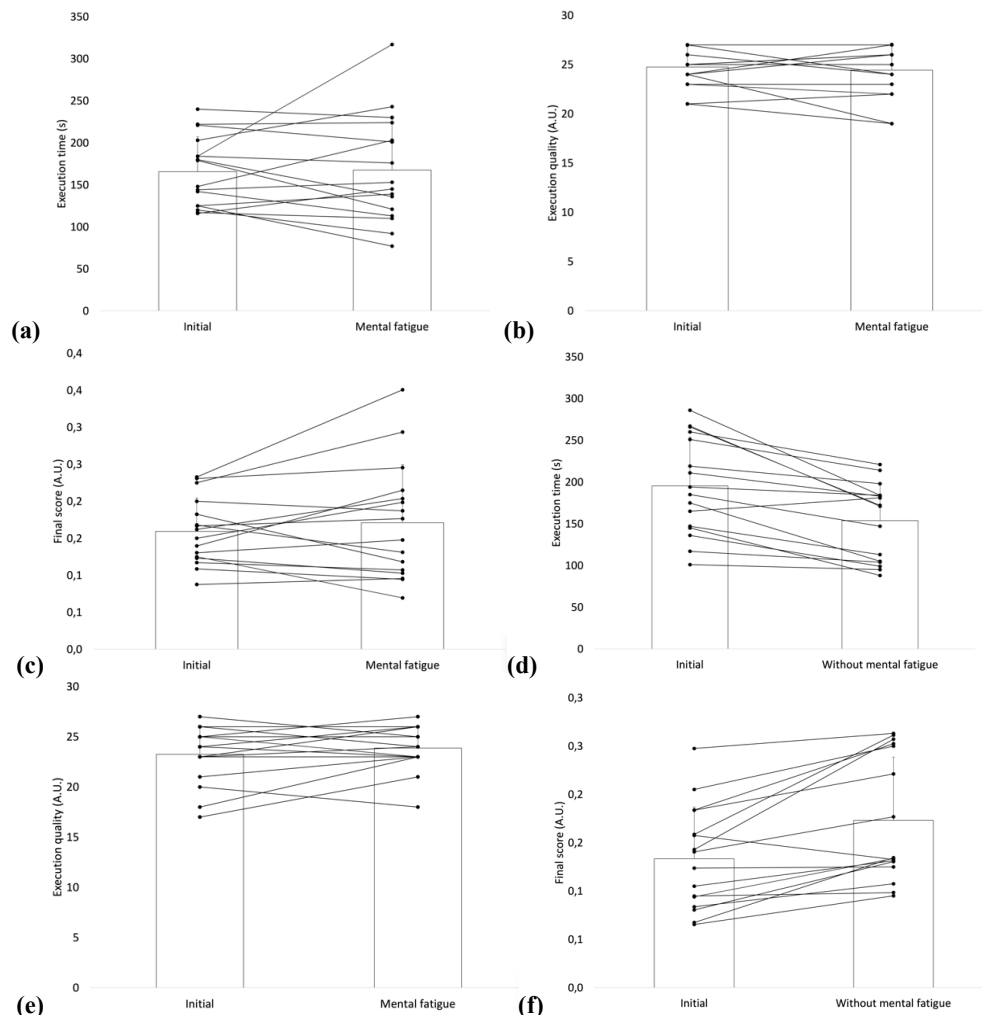


Figure 2. Intra-individual variations in maneuver performance for (a) execution time (initial and mental fatigue); (b) execution quality (initial and mental fatigue); (c) final score (initial and mental fatigue); (d) execution time (initial and no mental fatigue); (e) execution quality (initial and no mental fatigue); (f) final score (initial and no mental fatigue).

Discussion

The present study aimed to analyze the acute effects of mental fatigue on learning rope maneuvers in NAS. The results obtained in this study indicate that mental fatigue had negative effects on the learning of rope maneuvers in NAS. When comparing the initial condition with the mental fatigue condition, we observed that no significant differences were found in execution time, execution quality, and final score. These results suggest that the participants executed the maneuvers with the same efficiency and precision when they were under mental fatigue, demonstrating that the subjects did not improve or worsen their executions. However, when comparing the initial condition with the condition without mental fatigue, the results revealed significant differences. Execution time was significantly shorter in the condition without mental fatigue, indicating that the participants learned to execute the maneuvers faster and more efficiently. These results corroborate the study by Le Mansec et al. (2018) which indicates a negative effect of mental fatigue on the speed and accuracy of motor skills. The Final Score was also significantly higher in the condition without mental fatigue, which indicates that the participants were able to execute the maneuvers with greater precision and success. Furthermore, although the differences in execution quality between the conditions did not show statistically significant differences, it is important to note that even small variations can have a significant impact on practitioner safety. Several studies indicate the technical component as the greatest factor influencing

accidents (Brandão, Marques, et al., 2018; Ennes, 2013), precision and efficiency in the execution of motor skills are crucial to avoid risks and accidents (for example, a poorly executed knot can lead to an accident, but the reflection in statistical terms would be only 2 Arbitrary Units.).

Considering this aspect, it is possible to observe that in the mental fatigue condition the execution quality was lower by about -1.6% and in the condition without mental fatigue it increases by 2.6%. In this sense, it is important to value the effect of mental fatigue and find mitigation strategies during the training of new practitioners, since, according to Liu et al. (2020), mental fatigue is one of the main factors leading to human errors. This evidence is consistent with the hypothesis that mental fatigue affects the learning of specific motor skills. Mental fatigue can negatively affect practitioners' ability to concentrate (Boksem et al., 2006), make decisions (Badin et al., 2016), and process information effectively, which results in compromised performance (Boksem & Tops, 2008). These negative effects can be especially evident in activities that require precise and complex motor skills, such as rope maneuvers (Pageaux & Lepers, 2018; Trecroci et al., 2020).

The results of this study suggest the importance of managing mental fatigue during the practice and training of NAS. Strategies to minimize mental fatigue, such as regular breaks, adequate rest, and recovery techniques, can be implemented to optimize the learning and performance of the specific motor skills involved in these activities (Veness et al., 2017; Xu et al., 2022; Zeuwts et al., 2021).

In summary, the results of this study suggest that mental fatigue had negative impacts on the learning of rope maneuvers in NAS, considering that beginners did not improve under this condition. However, when comparing the initial condition with the condition without mental fatigue, a significant improvement in execution time and Final Score was observed. These results emphasize the importance of managing mental fatigue to optimize learning and performance in these activities, as referred by Russell et al. (2019).

However, it is important to note that this study had some limitations. The sample size was relatively small and the rope maneuvers assessed were specific to the study's context. For this reason, it is recommended not to generalize the evidence, refraining from definitive conclusions about the results found. Therefore, future studies with larger samples and a wider variety of maneuvers can provide a more comprehensive understanding of the effects of mental fatigue on learning motor skills in NAS.

Practical Implications By analyzing the effects of mental fatigue in the context of nature and adventure sports, this study can contribute to the development of more adequate training and practice strategies, as well as to the promotion of accident and incident prevention measures. The identification of the potential impacts of mental fatigue on rope maneuvers will allow the adoption of measures aimed at minimizing risks and optimizing the performance of young practitioners, making this sporting practice even safer and more enriching.

Conclusion

The results of this study suggest that mental fatigue has negative effects on the learning of rope maneuvers in NAS. In contrast, under the condition of no induced mental fatigue, a significant improvement in the execution of the maneuvers was verified. Mental fatigue can negatively affect concentration, decision-making, and information processing, resulting in compromised performance, especially in activities that require precise and complex motor skills, such as rope maneuvers in NAS. Although the conclusions of the present study should not be generalized due to the small sample size, strategies to minimize mental fatigue, such as regular intervals, adequate rest, and recovery techniques, are suggested to be implemented to optimize the learning and performance of specific motor skills in these activities.

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