Mental Load and Fatigue Assessment Instruments

Subjects: Anthropology

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Mental load and fatigue are important causes of performance decreases and accidents in different activities. Most of the existing instruments to analyze mental load and fatigue are subjective questionnaires and scales.

Keywords: cognitive fatigue ; mental health ; assessment procedure ; measurement ; validity

1. Introduction

Fatigue can be caused by excessive mental and/or physical demands, but the analysis of fatigue has focused on physical aspects [1]. Physical fatigue causes impairments in the traditional physiological variables (i.e., heartrate, blood lactate, or oxygen uptake). Contrary to physical fatigue, mental fatigue is not associated with these impairments, although the specific role of the brain has been demonstrated in mental fatigue [2]. Mental fatigue is apparently caused by excessive mental demands [3], and some authors have used the term “mental load” to refer to it [4]. Mental load and fatigue have been widely associated with specific performance decreases or an increase in the risk of accidents [1][5].

Mental fatigue represents a psychobiological state with subjective (e.g., an increase in feelings of tiredness), behavioral (e.g., motivation decrease or reaction time increase), and physiological (e.g., alterations in the electroencephalogram signal) derivations in humans [6]. This psychobiological state is caused by brain-demanding tasks (i.e., mental load), with a relevant role of emotional (e.g., anxiety or stress) and cognitive (e.g., working memory or cognitive flexibility) aspects [6]. This should be considered in the analysis of mental load and fatigue, although most of the studies performed have used the cognitive aspects of mental fatigue [6]. For example, the case of Simon Biles or the different episodes observed during the COVID-19 are examples of how emotional aspects may impair health and performance.

Specifically, it has been observed that mental load and fatigue may impair human physical performance [6]. Some authors have stated that this phenomenon occurs through the increase in the subjective Ratio of Perceived Exertion, whereas other performance indicators, such as accuracy, tactical decisions, or reaction time, may be impaired by excessive accumulation of mental fatigue [1]. These impairments have been observed in different contexts such as medical surgery, construction work, or athletic settings [1]. Although the accumulation of extracellular adenosine or impairments in cognitive functions are possible explanations of this phenomenon, more studies are necessary to clarify the causes underlying these impairments.

However, it is difficult to analyze the causes and consequences of mental fatigue. Several covariables influence the mental fatigue induced by task performance, such as task difficulty, engagement, duration, or enjoyment/aversion [7]. In addition, a large number of individual differences could explain why the same task does not induce the same level of mental fatigue in different subjects or why mental fatigue manifests with different derivations (i.e., subjective, behavioral, or physiological) among participants [8]. Van Cutsem and Marcora [7] strongly recommend the use of a combination of several derivations (i.e., subjective, behavioral, and physiological) of mental fatigue as the best approach to identify its presence. Changes in all three areas do not necessarily appear in mentally fatiguing conditions, and they could depend on the subjects’ individual characteristics. For example, cognitive performance does not necessarily decline in presence of mental fatigue due to the effect of the compensatory effort system [6][7][8][9]. Therefore, the use of different measures of mental fatigue may identify the causes of mental fatigue or explain why mental fatigue impairs performance.

Despite these recommendations, few existing procedures allow experts to assess mental load and fatigue, making them difficult to control [3]. On the one hand, different instruments have been used for this purpose indirectly, subjectively, and behaviorally. For mental load, (i) NASA Task Load Index [10], (ii) the Subjective Mental Workload Scale (SCAM) developed by Ceballos-Vásquez et al. [11], or (iii) the “StuMMBE-Q” [12], among others. For mental fatigue, the subjectively reported Visual Analogue Scale (VAS) has been the most used instrument. Despite the high reliability and validity of these instruments, information about brain processes is lacking. On the other hand, objective instruments have also been used for this purpose. Pupil dilation [13], eye tracking [10], and different electrophysiological indicators such as

electroencephalography (EEG; [14]) or brain functional connectivity patterns [15] have been recommended by authors to quantify mental load and fatigue.

2. Mental Load and Fatigue Assessment Instruments

2.1. Mental Load and Mental Fatigue Assessment Instruments for Subjective Derivations

75% of the instruments included in the present study focused on the subjective derivations of mental load and fatigue. These results indicated a tendency to use self-reported questionnaires or scales in the analysis of mental load and fatigue. The extended use of these types of instruments may be explained by the high validity and usefulness of their measurements [16]. However, experts should take into account the context involved to choose the most valid instrument, according to the data to be extracted. Previously, Russell et al. [8] defined the complex nature of human factors, which could explain why, when analyzing mental fatigue, experts also analyzed other psychological factors. Indeed, work settings and hospitals were the main contexts where these instruments have been used, whereas in other contexts, such as schools or sports, where mental fatigue is present [17][18], few papers have analyzed the validity and reliability of these instruments [7].

These types of instruments are useful in the research of students and athletes because these populations usually have little time to answer our research questions [1]. The main interest of these instruments is the individualization of the feelings of mental fatigue [8]. Such individualization of the context is important from a clinical and practical viewpoint. For example, in a sports context, one task may significantly increase the mental fatigue of a certain athlete, while this same task will not change the mental fatigue of another athlete. This may be extended to hospital patients, students, or workers because mental fatigue has a subjective derivation, among others. Indeed, this situation justifies the use of these scales. However, although these types of instruments have highlighted the role of mental fatigue and promoted the study of this variable, a great number of experts have declared that further analysis of the physiological mechanisms is needed to explain mental load and fatigue [1].

2.2. Mental Load and Fatigue Assessment Instruments for Behavioral Derivations

12.5% of the instruments included in the present study focused on the behavioral derivations of mental load and fatigue. These variables allow experts to determine how mental fatigue may influence performance indicators in each context. Russell et al. [19] asked an athletic population about their symptoms in the presence of mental fatigue. These athletes felt slower, with poor reaction times and decreased accuracy. Moreover, a great number of papers have demonstrated the relationship between an increase in the feelings of mental fatigue and a decrease in the specific behavioral performance in different areas [20][21][22].

Few instruments have been validated for this purpose from a behavioral perspective. From a clinical and practical point of view, this implies a limitation in the analysis of the negative effects of mental fatigue. Mental fatigue is important because of its negative consequences in surgeons, athletes, or performance and health drivers. More studies designing instruments for behavioral derivations or examining the effects of mental fatigue in human behavior are necessary to further analyze the importance of mental fatigue.

2.3. Mental Load and Fatigue Assessment Instruments for Physiological Derivations

The influence of the brain in mental fatigue has been demonstrated; indeed, this influence has allowed researchers to differentiate the mental and physical nature of fatigue [2]. Whereas physical fatigue is normally caused by an impairment in the traditional physiological systems, such as heartrate or blood lactate, impairments in these systems have not been observed in the performance-related decreases in mental fatigue [2]. This shows that less is known about the psychobiological processes involved in mental fatigue. Although the complexity of these instruments (price, complexity, time…) could explain the few papers published about these instruments, this information would allow researchers to understand the mechanisms that underly the presence of mental fatigue and its consequences [7]. This information is interesting from a clinical and practical viewpoint. For example, it would be useful to know how mental fatigue can be manipulated, how recovery strategies can be used, or how to maintain performance in presence of mental fatigue.

References

1. Ishii, A.; Tanaka, M.; Watanabe, Y. Neural mechanisms of mental fatigue. Rev. Neurosci. 2014, 25, 469–479.

2. Van Cutsem, J.; Roelands, B.; Pluym, B.; Tassignon, B.; Verschueren, J.O.; De Pauw, K.; Meeusen, R. Can creatine combat the mental fatigue-associated decrease in visuomotor skills? Med. Sci. Sports Exerc. 2020, 52, 120–130.
3. Pageaux, B.; Lepers, R. The effects of mental fatigue on sport-related performance. Prog. Brain Res. 2018, 240, 291–315.
4. Hopstaken, J.F.; van der Linden, D.; Bakker, A.B.; Kompier, M.A. A multifaceted investigation of the link between mental fatigue and task disengagement. Psychophysiology 2015, 52, 305–315.
5. Tran, Y.; Craig, A.; Craig, R.; Chai, R.; Nguyen, H. The influence of mental fatigue on brain activity: Evidence from a systematic review with meta-analyses. Psychophysiology 2020, 57, e13554.
6. Van Cutsem, J.; Marcora, S.; De Pauw, K.; Bailey, S.; Meeusen, R.; Roelands, B. The effects of mental fatigue on physical performance: A systematic review. Sport Med. 2017, 47, 1569–1588.
7. Van Cutsem, J.; Marcora, S. The effects of mental fatigue on sport performance. In Motivation and Self-Regulation in Sport and Exercise; Routledge: London, UK, 2021; pp. 134–148.
8. Russell, S.; Kelly, V.G.; Halson, S.L.; Jenkins, D.G. Cognitive load in sport. Human Factors and Ergonomics in Sport: Applications and Future Directions; CRC Press: London, UK, 2020; pp. 181–200.
9. McMorris, T. Cognitive fatigue effects on physical performance: The role of interoception. Sport Med. 2020, 50, 1703–1708.
10. Li, J.; Li, H.; Wang, H.; Umer, W.; Fu, H.; Xing, X. Evaluating the impact of mental fatigue on construction equipment operators' ability to detect hazards using wearable eye-tracking technology. Autom. Constr. 2019, 105, 102835.
11. Ceballos-Vásquez, P.; Rolo-González, G.; Hernández-Fernaud, E.; Díaz-Cabrera, D.; Paravic-Klijn, T.; Burgos-Moreno, M.; Barriga, O. Validation of the Subjective Scale of Mental Workload (ESCAM) in health professionals in Chile. Univ. Psychol. 2016, 15, 261–270.
12. Krell, M. Evaluating an instrument to measure mental load and mental effort considering different sources of validity evidence. Cogent Educ. 2017, 4, 1280256.
13. Sampei, K.; Ogawa, M.; Torres, C.; Sato, M.; Miki, N. Mental fatigue monitoring using a wearable transparent eye detection system. Micromachines 2016, 7, 20.
14. Käthner, I.; Wriessnegger, S.C.; Müller-Putz, G.R.; Kübler, A.; Halder, S. Effects of mental workload and fatigue on the P300, alpha and theta band power during operation of an ERP (P300) brain-computer interface. Biol. Psychol. 2014, 102, 118–129.
15. Sun, Y.; Lim, J.; Meng, J.; Kwok, K.; Thakor, N.; Bezerianos, A. Discriminative analysis of brain functional connectivity patterns for mental fatigue classification. Ann. Biomed. Eng. 2014, 42, 2084–2094.
16. Barte, J.C.M.; Nieuwenhuys, A.; Geurts, S.A.E.; Kompier, M.A.J. Motivation counteracts fatigue-induced performance decrements in soccer passing performance. J. Sports Sci. 2019, 37, 1189–1196.
17. Key, A.P.; Gustafson, S.J.; Rentmeester, L.; Hornsby, B.W.Y.; Bess, F.H. Speech-processing fatigue in children: Auditory event-related potential and behavioral measures. J. Speech Lang. Hear. Res. 2017, 60, 2090–2104.
18. Thompson, C.J.; Noon, M.; Towlson, C.; Perry, J.; Coutts, A.J.; Harper, L.D.; Skorski, S.; Smith, M.R.; Barrett, S.; Meyer, T. Understanding the presence of mental fatigue in English academy soccer players. J. Sports Sci. 2020, 38, 1524–1530.
19. Russell, S.; Jenkins, D.; Rynne, S.; Halson, S.L.; Kelly, V. What is mental fatigue in elite sport? Perceptions from athletes and staff. Eur. J. Sport Sci. 2019, 19, 1367–1376.
20. Knobel, H.; Loge, J.H.; Brenne, E.; Fayers, P.; Hjermstad, M.J.; Kaasa, S. The validity of EORTC QLQ-C30 fatigue scale in advanced cancer patients and cancer survivors. Palliat. Med. 2003, 17, 664–672.
21. Shuman-Paretsky, M.; Zemon, V.; Foley, F.W.; Holtzer, R. Development and validation of the State-Trait Inventory of Cognitive Fatigue in community-dwelling older adults. Arch. Phys. Med. Rehabil. 2017, 98, 766–773.
22. Van Cutsem, J.; De Pauw, K.; Buyse, L.; Marcora, S.; Meeusen, R.; Roelands, B. Effects of mental fatigue on endurance performance in the heat. Med. Sci. Sports Exerc. 2017, 49, 294–306.