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Editors' note: Suitable measurements of mental workload depending on its dimensions

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Abstract ■ This Editors's note introduces the special issue on the suitable measurement of mental workload.

Keywords ■ mental workload, cognitive load, measurement, intrinsic, extraneous and germane load.

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Introduction

For the past fifty years, the concept of mental workload has been frequently studied and used in research carried out in cognitive psychology and ergonomics, both theoretically and empirically, in areas such as driving, aeronautics, learning and multimedia learning, memory, etc. (see for instance, Chanquoy, Tricot, & Sweller, 2007). This concept refers to a feeling that everybody can regularly experience: while certain activities seem to be very easy, others require more effort and some others can still remain very difficult, or even impossible.

Nowadays, mental workload remains a central concern, as it impacts everyday activities that are in constant evolution, due to technological progress. Mental workload is the result of a balance between the limited individual resources to be mobilised and the task demands (Leplat, 1977). A high level of mental workload can have negative consequences, by provoking an overload and a decreasing in performance. This can range from a failure to realize certain actions on a website to serious accidents in critical areas (e.g., driving, air traffic). Several theoretical models have been developed by researchers depending on the context of their study, in order to explain mental workload variations. It has been shown that different elements of the situation (e.g., learning environment, situation complexity, etc.) and cognitive processes implied to perform the task (e.g., controlled vs. automatic processing) contribute to the variation of mental workload dimensions (e.g., mental effort, visual processing, temporal demands, etc.). These variations can be measured in a variety of ways and each measurement has advantages and disadvantages.

Mental workload can be subjectively measured by questionnaires (e.g., SWAT; see Reid & Nygren, 1988; or NASA-TLX; see Hart & Staveland, 1988), or objectively measured through physiological – such as mean heart rate (e.g., Luque Casado, Perales, Cardenas, & Sanabria, 2016) or event-related potentials (see Solís-Marcos & Kircher, 2019) – and/or behavioural data (e.g., reaction time: Makishita & Matsunaga, 2008). Subjective measurements directly question the individual's feeling and are relatively easily set up. Multidimensional scales have a good diagnosticity by identifying the changes in workload variations and the cause of these changes. However, intra-individual differences can appear for example as a function of the motivational fluctuation during the tests. Physiological indicators can quickly identify mental workload variations in real time but are also sensitive to other factors as physical exertion and emotional states (Kramer, 1991). Behavioural measurements are objective and can be obtained in real time. Nevertheless, a slight increase in mental workload cannot be identified through the performance degradation, which is only provoked by a high level of mental workload. The examples of the limits described above highlight the issue of mental workload measurement. Which measurements are the most suitable to assess the level of certain mental workload dimensions?

The concept of mental workload is relatively similar to cognitive load – or cognitive overload –, which was first developed by John Sweller who published two papers about "Cognitive Load Theory", the first one in 1988 in the journal *Cognitive Science* and the second one in 2011 in the *Journal Psychology of Learning and Motivation*. Cognitive load can be defined as the amount of information that working memory, whose capacity is limited, can maintain at one time. To avoid overload due to working memory characteristics and specificities of human cognitive architecture, instructional methods have been elaborated and are known as "Cognitive Load Theory" (see Sweller, Ayres, & Kalyuga, 2011).

In the field of instructional design, Sweller, 2011's (1988, 2011) *Cognitive Load Theory* (CLT) is still a standard from which many studies were based on. This theory claims that learning is hampered when working memory capacity is exceeded during a task, which is when there is a cognitive overload (de Jong, 2010). CLT distinguishes three different types of load that contribute to the total amount of cognitive load: (1) Intrinsic cognitive load relates to inherent characteristics of the content to be learned or the topic to be processed; (2) extraneous cognitive load is caused by information and instructions used to specify the task; (3) germane cognitive load refers to the load imposed by learning processes to create knowledge.

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Relatively recently, these three dimensions (extraneous load, intrinsic load and germane load) have been debated, due to the similarity between germane and intrinsic load, and germane load has been suppressed (Kalyuga, 2011; Choi, van Merrienboer, & Paas, 2014). The two first papers are based on this new theoretical framework.

In Jiang and Kalyuga's (2020) paper, following Kalyuga who argued, in 2011, that germane cognitive load was not supported by theories and findings and was redundant considering the two other types of load, the authors hypothesized that rating scales based on intrinsic-extraneous model of cognitive load should valid tools for assessing levels of cognitive load. To test this assumption, they led a confirmatory factor analysis that constitutes a psychometric empirical support to the new two-factor model. The authors modified the questionnaire from Leppink, Paas, van der Vleuten, van Gog, and van Merriënboer (2013) in order to only have the two required dimensions. The results of the confirmatory factor analysis supported the hypothesized two-factor (intrinsic and extraneous) model and this dual model of cognitive load is discussed.

Debue, Oufi, and van de Leemput (2020) are also in the line with the two-factor (intrinsic and extraneous) model, in which the two types of load have been measured by subjective ratings and eye-tracking data during information search tasks on the web. The authors compared laptop and tablet performance in two lab-based experiments about wiki-based search. As tablets have smaller screens than laptops and require specific actions, the authors hypothesized that they should require more mental resources and this demand should impact performance. As predicted, laptop users performed better than tablet users during both experiments, due to an increase in extraneous load.

The last paper from Galy (2020) concerns the elaboration and validation of a questionnaire designed from the theoretical model Individual-Workload-Activity (IWA; Galy, 2017). This questionnaire assesses mental workload in the context of work situations through five dimensions: 1) available resources, 2) intrinsic load, 3) external load: organization and social ambiance, 4) external load: temporal aspects of work and 5) germane load. Among these dimensions, there are the same three dimensions as in CLT (Sweller, 1988), including germane load that seems to be relevant in this work situations context, contrary to the Human-Machine Interface context. Indeed, intrinsic load and germane load have not the same effects on job satisfaction. This questionnaire allows identifying the impact of mental workload on job satisfaction and self-reported performance.

This special issue provides new suitable measurements of mental workload depending on its dimensions and on the underlying models. It also shows the complementary of subjective and objective measurements. The present issue presents a good vision of the suitable measurements for specific mental workload dimensions, in order to better target the appropriate indicators in future studies. We want to warmly thank all the authors who have contributed to the broad field of mental workload by adding some new stones to the edifice. We also thank the reviewers without whom this work would not have been possible. As in many fields of psychology or ergonomics, research about cognitive load or mental workload is moving and progressing due to advances in neuroscience, brain imaging, etc. Undoubtfully, there will be an interesting and bright future for this concept!

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