EFFECTS OF INTERACTION BETWEEN PHYSICAL AND MENTAL WORKLOAD ON HUMAN PERFORMANCE

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Workload is an important factor that affects human performance in an operating system. This research study investigates the interaction of physical workload, mental workload and arousal level on performance and working memory. Fifteen participants (ages 25-35) performed a physical task (pedalling on a bicycle-ergometer) under three different levels of resistance load (low, mid and high) concurrently with a mental task (arithmetic) at three levels of demand (simple, intermediate and difficult). Participants also completed two subjective assessments following the task, Borg-CR10 and NASA-TLX to evaluate the perceived physical and mental workload respectively. The hypothesis of the study is that optimum performance occurs at intermediate levels of workload, whereas poor performance is observed at the low and high levels of physical and mental demand due to underload and overload.

Introduction

For decades, scientists have been studying the impact of task workload on operator performance. Moreover, workload is a significant factor which impacts human performance in an operating system, especially in complex systems and demanding tasks (Hwang *et al*, 2007; Sluiter, 2006). Balancing task demands and attentional resources is essential in order to achieve acceptable performance (DiDomenico and Nussbaum, 2005).

Workload may be divided into two types: mental demands and physical demands (Hwang *et al*, 2008). Physical workload may be defined as tasks which require that the operators' muscles work, with the participation of the musculoskeletal, cardiorespiratory and nervous systems (Sluiter, 2006). In contrast, mental workload is a multidimensional concept and it can be identified by operator characteristics (e.g., experiences, attention and skills) and task features such as task load and procedures (Young and Stanton, 2004). Many tasks in the workplace impose a physical workload (PWL), which in turn places loads on mental tasks and cognitive resources (Perry *et al*, 2008). The human response to both mental and physical workload, as well as their interactions, leads to an increase in arousal level, which can be measured by a rise in both heart rate (HR) , blood pressure (BP) and rate pressure product (RPP) (Fredericks *et al*, 2005).

This study will investigate the impact of combinations of physical and mental workload on individuals' performance. The purpose of this experimental study is to identify the optimum level of human performance in a multi-task demand (physical and mental) scenario. Moreover, there may also be an interaction between these factors such that higher levels of physical workload could compensate for mental underload effects, and vice versa.

Methods

The current experiment was designed to investigate the interaction effects of physical workload (PWL) and mental workload (MWL) under different conditions and arousal levels on working memory performance tasks as illustrated in Table 1. Participants were asked to conduct a mental arithmetic task concurrently with a physical task, with the dependent variable being performance on the arithmetic task. The study also sought to examine whether an interaction with high levels of physical workload can compensate for the performance shrinkage caused by mental underload.

Table 1. Nine conditions of PWL and MWL interaction in this experiment and their associated hypotheses.

		Mental Workload (MWL)		
		Simple arithmetic task	Medium arithmetic load	Complex arithmetic task
Physical Workload (PWL)	Low PWL (20% VO_2 max)	Performance will decrease under this condition (underload).	×	Performance may be acceptable in this condition
	Medium load (50% VO_2 max)	×	Acceptable performance	×
	High load (80% VO_2 max)	High PWL may compensate for mental underload for acceptable performance	×	Performance will decrease under this conditions (overload).

The experimental hypotheses predict that performance will decrease under conditions of both high level of physical demand (i.e. cycling at 80% of VO2 max) and the complex mental arithmetic task, due to overload and high arousal levels. In addition, performance deteriorations will also occur under conditions of low physical workload (i.e. cycling at 20% of VO2 max) and low mental task demands (simple arithmetic task) due to underload and low arousal levels. Conversely, acceptable performance on the arithmetic task is expected at the intermediate level of physical and mental workload. Moreover, the study also seeks to determine if high/low combinations of physical and mental workload interact, such that (for instance) higher levels of physical workload can compensate for decrements in performance due to mental underload.

Materials and Participants

Fifteen healthy participants aged 25-35cycled on a bicycle ergometer to create the three different conditions of physical workload, while Mental-Math Software was used to perform the arithmetic problems at three levels of difficulty. Blood pressure(BP) , heart rate (HR) and heart rate variability (HRV) were measured electronically before and during the tests. Additionally, this experiment recorded the rate pressure product (RPP) and brain blood flow in order to identify the physiological arousal level of the participants due to the workload interaction. Also, the NASA-TLX (Hart and Staveland, 1988) and Borg-CR10 (DiDomenico and Nussbaum, 2008) were completed after each condition to evaluate subjective mental and physical workload respectively.

Future Work and Conclusion

A similar study is planned to investigate the effects of the interaction between physical and mental workload using a spatial figures task instead of mental arithmetic, to investigate the potential interactions with different attentional resource pools (Wickens, 2002). Furthermore, whereas the current study aimed to separate pure physical and mental workload in a laboratory setting, future work is planned to investigate the overlaps between physical and mental workload in a real domain. In conclusion, task workload measurement is a necessary tool in the process of operating system design and diagnosis. This research study examined the effects of the combination of physical and mental demands on human performance in dual occupations. Although the results were not available at the time of writing, it is anticipated that the findings may be used to influence the design of work systems in applied domains such as factory production lines.

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