Impacts of Physical and Mental Workload Interaction on Human Attentional Resources Performance

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ABSTRACT

Motivation – Task workload is key determinant of human performance. It may include physical and/or cognitive components, and these can interact to influence operator performance. This research study investigates the interaction of physical workload, mental workload and arousal level on attentional resources in order to predict performance.

Research approach – This study was divided into two experiments. In both experiments, fifteen participants (aged 25-35) performed a physical task (pedalling on a bicycle-ergometer) concurrently with a mental task under nine levels of workload in a 3x3 design (low, medium and high levels for both physical and mental). In the first experiment, the mental task was designed to occupy verbal attentional resources through mental arithmetic, whereas a spatial figures task was used in the second experiment to evaluate spatial resources.

Findings/Design – The hypothesis of the study is that optimum performance occurs at intermediate levels of workload, whereas poor performance is observed at the extreme low and high levels of physical and mental demand due to underload and overload. It is also anticipated that physical and mental workload can interact to 'offset' underload or overload decrements.

Originality/Value – The present study will fill the gap in the ergonomics literature by explaining performance degradation due to mental underload and by clarifying the interaction with physical workload.

Take away message – It is possible that moderate levels of physical workload could compensate for attentional resource reduction with mental underload.

Keywords

Physical workload, mental workload, attentional resources, arousal, human performance

INTRODUCTION

For many years, researchers have been investigating the impact of task workload on individual performance. Task workload may include physical activity and/or mental (cognitive) activities, and the impact of the demand determines operator performance (DiDomenico and Nussbaum, 2008). Workload can be defined as how the operators can do the required work (their capacities) and how they can manage the task (task demands) to satisfy the operating system demand (Megaw, 2005). There are many definitions of mental workload; however, most agree that mental workload is "the amount of cognitive or attentional resources being expended at a given point in time" (Charlton, 2002, p.98). The relation between mental demand and operator performance is generally accepted to describe an inverted U-shape, although this relationship had not been supported experimentally until recently (Charlton, 2002). Further, it is recognized that mental workload can affect the attentional capacity of operators through its impact on arousal (Young and Stanton, 2002).

In most occupations, physical demands are also required and are associated with mental demands in impacting on human performance and attentional resources (i.e., information processing) (Perry et al, 2006). Indeed, the influence of physical and mental workload on performance varies (Tomporowski, 2003). The present study will examine if physical workload at some level of interaction can make up for the decrease in attentional capacity of operators that occurs due to mental underload.

METHOD

Design

The current study involves two experiments to investigate the effect of the interaction of physical workload (PWL) and mental workload (MWL) on physiological arousal and operator attentional resources. Two types of cognitive task were used - in experiment 1, a verbal (arithmetic) task, while experiment 2 used a spatial (figures) task. These tasks were selected to represent the different attentional resource pools of operators (Wickens, 2002). Pedaling on a bicycle-ergometer was used in each experiment to emulate physical workload. The experiment was a full factorial repeated measures design. Each experiment was carried out under nine conditions in order to observe various levels of physical and mental workload interactions in a 3x3 design. Tables 1 and 2 illustrate the nine conditions of interactions between the physical and mental tasks for each experiment. The experiment aims to determine if levels of physical demand can compensate for a low mental load in terms of task performance.

Table 1 The various nine conditions of interaction physical load and mental arithmetic tasks.

		Mental Arithmetic Workload (MWL)		
		Low arithmetic task	Medium arithmetic load	High mental arithmetic task
Physical Workload (PWL)	Low PWL (20% workload max)	The performance will decrease under this condition (underload)	×	×
	Medium load (50% workload max)	×	Acceptable performance	×
	High load (80% workload max)	×	×	The performance will decrease under this conditions (overload)

Table 2: The different nine conditions of interaction physical workload and spatial figures task.

		Mental Spatial Figures Workload (MWL)		
		Low spatial task (three figures)	Medium spatial load (six figures)	High mental spatial task (nine figures)
Physical Workload (PWL)	Low PWL (20% workload max)	The performance will decrease under this condition (underload)	×	×
	Medium load (50% workload max)	×	Acceptable performance	×
	High load (80% workload max)	×	×	The performance will decrease under this conditions (overload)

The present study hypothesises that participant performance will decrease when under both high levels of physical demand and high levels of mental demand due to overload and arousal level. In addition, it is hypothesized that the underload will occur under low physical workload with low mental workload, causing similar performance decrements. In contrast, it is hypothesized that acceptable cognitive tasks performance will occur at the intermediate levels of physical and mental demand. Meanwhile, we anticipate that physical demands may compensate for the reduction in attentional limitation due to underload in low mental workload conditions; furthermore we anticipate a potential interaction between the types of attentional resource pool (verbal/spatial) and task performance with a concurrent physical demand. Three dependent variables were measured: performance (number of correct responses); physiological indices [obtained by measuring the heart rate (HR), heart rate variability (HRV), blood pressure (BP), and rate-pressure product (RPP) (Fredericks et al, 2005); and subjective assessments of mental workload (observed by using the NASA-TLX scores) (Hart and Staveland, 1988). Borg-CR10 was used to assess the physical workload and perceived exertion levels (Borg, 1998).

Participants

Thirty participants (15 male; ages 25–35) from Brunel University took part in the experiments

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-task 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.

REFERENCES

Borg, G. 1998, Administration of the Borg Scales. In Borg's perceived exertion and pain scales, (Human Kinetics: US),44-52

Charlton, S.G. 2002, Measurement of cognitive state in test and evaluation. In S.G. Charlton and T.G. O'Brien (Eds.), Handbook of human factors testing and evaluation, (Lawrence Erlbaum: Mahwah, NJ), 97-126

Didomenico A. and Nussbaum M. A. 2008, Interactive effects of physical and mental workload on subjective workload assessment. *International Journal of Industrial Ergonomics*,38, 977-983

Fredericks, T. K., Choi, S.D., Hart, J., Butt, S.E. and Mital A. 2005, An investigation of myocardial aerobic capacity as a measure of both physical and cognitive workloads, *International Journal of Industrial Ergonomics*, 35, 1097-1107

Hart, S. G. and Staveland, L. E. 1988, Development of NASA-TLX (Task Load Index): results of empirical and theoretical research. In P. A. Hancock and N. Meshkati (Eds.), Human Mental Workload, (North-Holland: Amsterdam), 138-183

Megaw, T. 2005, The definition and measurement of mental workload. In J. R. Wilson and N. Corlett (Eds.), Evaluation of Human Work, (Taylor & Francis Group: US), 525-551

Perry, C.M., Sheik-Nainar, M.A., Segall, N., Ma R. and Kaber, D.B. 2008, Effects of physical workload on cognitive task performance and situation awareness, *Theoretical Issues in Ergonomics Science*, 9, 95-113

Tomporowski, P.D. 2003, Effects of acute bouts of exercise on cognition. *Acta Psychological*, 112, 297-324

Wickens, C.D. (2002). Multiple resources and performance prediction. *Theoretical Issues in Ergonomics Science*, 3, 159-177.

Young, M.S. and Stanton, N.A. 2002, Malleable attentional resources theory: a new explanation for the effects of mental underload on performance. *Human Factors*,44, 365-375