Inter-individual differences in executive control activity during simulated process control: comparison of performance and physiological patterns

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Abstract

Task duration and environmental stressors have the potential to threaten maintenance of sustained attention, especially for tasks in process control environments that impose high demands on working memory and executive control processes. Experimental sessions of three hours were conducted to investigate effects of noise and prolonged work on operator performance. Ten highly trained operators performed monitoring and control tasks, including fault management, under different environmental conditions. Although integrity of central aspects of task performance was maintained at a high level, inter-individual differences in primary task performance were identified and could be attributed to differences in control and information sampling behaviour. Further comparisons of relatively high and low level performers showed differential effects for effort investment as indicated by heart rate variability analysis. They also revealed differences in frontal midline theta activity consistent with the view that high performers were better able to maintain or adjust level of executive control activities, such as applying different monitoring and control strategies over the session. These findings suggest that individual differences in monitoring and control strategies may be masked by overt system performance, but have a significant impact on detection and selection of appropriate support for operators in adaptive automation scenarios.

Introduction

In automation-enhanced human-machine systems the operator is required to continually adapt to new and unforeseen changes in the dynamic process under control, and to determine whether and what actions are required to prevent or correct for drifts or faults of the technical subsystem (Meshkati, 2003). In continuous process control, monitoring and control operations not only impose high demands on working memory and executive control processes but also require the operator to maintain sustained attention over prolonged work periods and under variations of environmental stressors that add to the threats to system safety and performance. Consequently, the human operator is exposed to dynamic task demands, with executive control functions becoming a major determinant in operator's attempts to control the task (Royall et al., 2002; Shallice, 2005).

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