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A SYSTEMS APPROACH TO THE ASSESSMENT OF MENTAL WORKLOAD IN A SAFETY-CRITICAL ENVIRONMENT

by

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SUMMARY

TITLE: A systems approach to the assessment of mental workload in a safety-critical environment

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The objective of this study is to develop a quantified method for determining the mental workload imposed on train control officers (TCOs) and to express this mental workload by means of an index that is objective and can stand up to the tests of validity and reliability. The method addresses an existing operational shortcoming in Spoornet train control operations and could be used as a tool for predicting the mental workload imposed on operators at particular train control centres. The method could be applied to manage and improve operational safety in the rail transport environment. A participative systems approach was followed in the development of the measuring methodology. A work group comprising expert users of the specific train control system was involved in identifying task factors and assigning weights for task and moderating factors. The newly developed Mental Workload Index (MWLI) consists of three task factors and eleven moderating factors, each with a different weight in terms of its contribution to overall mental workload. The work group performed several iterations to reach final consensus on the following task factors and their respective contributions to the MWLI: the number of data transactions, the number of authorisations, and the number of communications via telephone and radio. The systems approach used in the development process is discussed, and the final index with the task and moderating factors is presented. In conclusion, the value and possible application of the MWLI are discussed. The MWLI is shown to provide an objective method for the assessment and prediction of mental workload in the train control environment.

Keywords: *Mental workload, Mental workload assessment, Mental workload prediction, Workload, Stress, Cognitive load.*

OPSOMMING

TITEL: A systems approach to the assessment of mental workload in a safety critical environment

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Die doel van die studie is die ontwikkeling van ’n gekwantifiseerde metode om die kognitiewe werkslas van treinbeheeramptenare (TBAs) te bepaal en om hierdie kognitiewe werkslas uit te druk as ’n indeks wat objektief en kwantifiseerbaar is en wat die toetse van geldigheid en betroubaarheid kan deurstaan. Hierdie metode spreek ’n bestaande operasionele tekortkoming aan en kan gebruik word as ’n instrument om die kognitiewe werkslas wat op ’n operateur geplaas word by ’n spesifieke treinbeheersentrum, te voorspel. Die metode kan gebruik word om operasionele veiligheid in die spoorverkeeromgewing te bestuur en verbeter. ’n Deelnemende sisteembenadering is gevolg in die ontwikkelingsproses. ’n Werkgroep, bestaande uit ekspert gebruikers van die spesifieke treinbeheerstelsel was betrokke by die identifisering van taak- en modererende faktore sowel as by die toekenning van gewigte aan hierdie faktore. Die nuut-ontwikkelde Mental Workload Index (MWLI) bestaan uit drie taakfaktore en elf modererende faktore, met verskillende gewigte na aanleiding van elkeen se bydrae tot die totale werkslas. Die werkgroep het verskillende iterasies uitgevoer ten einde konsensus te verkry oor die volgende taakfaktore en hul onderskeie bydrae tot MWLI: aantal datatransaksies, aantal magtigings en aantal kommunikasies oor die telefoon en radio. Die sisteembenadering wat gevolg is in die ontwikkelingsproses word bespreek en die finale indeks met die taak- en modererende faktore word aangebied. Ten slotte word die waarde en moontlike toepassing van die MWLI bespreek. Die MWLI word aangebied as ’n objektiewe metode vir die meting en voorspelling van kognitiewe werkslas in die treinbeheer omgewing.

Sleutelwoorde: *Mental workload, Mental workload assessment, Mental workload prediction, Workload, Stress; Cognitive load.*

Dedicated to my mother – a courageous woman

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LIST OF ABBREVIATIONS

AFFTC	Air Force Flight Test Centre
ATC	Air Traffic Control
BMI	Body Mass Index
CNS	Central Nervous System
CTC	Centralised Traffic Control
DBP	Diastolic Blood Pressure
ECG	Electrocardiogram
EEG	Electroencephalogram
ERP	Event-related Potentials
ETA	Estimated Time of Arrival
ETD	Estimated Time of Departure
FRA	Federal Railroad Administration
HPA	Hypothalamo-pituitary-adrenocortical
HRV	Heart Rate Variability
IWS	Integrated Workload Scale
MWLI	Mental Workload Index
NASA-TLX	National Aeronautical and Space Administration Task Load Index
ODEC	Operational Demand Checklist
PNS	Peripheral Nervous System
RTO	Radio Train Order
SA	Situation Awareness
SAM	Sympatho-adrenomedullary
SBP	Systolic Blood Pressure
SIMS	Spoornet Information Management System
STSS	Short-term Sensory Store
SWAT	Subjective Workload Assessment Technique
TCO	Train Control Officer
TLA	Timeline Analysis
TLI	Traffic Load Index
TRB	Transportation Research Board
TWS	Track Warrant System

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