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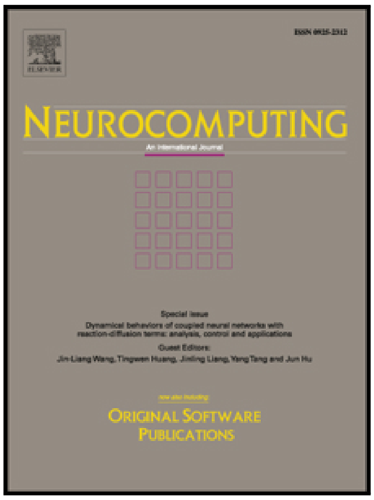

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TASK-RELATED EEG AND HRV ENTROPY FACTORS UNDER DIFFERENT REAL-WORLD FATIGUE SCENARIOS

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***Abstract*— We classified the alertness levels of 17 subjects in different experimental sessions in a six-month longitudinal study based on a daily sampling system and related alertness to performance on a psychomotor vigilance task (PVT). As to our best knowledge, this is the first EEG-based longitudinal study for real-world fatigue. Alertness and PVT performance showed a monotonically increasing relationship. Moreover, we identified two measures in the entropy domain from electroencephalography (EEG) and heart rate variability (HRV) signals that were able to identify the extreme classes of PVT performers. Wiener entropy on selected leads from the frontal-parietal axis was able to discriminate the group of best performers. Sample entropy from the HRV signal was able to identify the worst performers. This joint EEG-HRV quantification provides complementary indexes to indicate more reliable human performance.**

Keywords—human performance; entropy analysis; alertness prediction; EEG; HRV; psychomotor vigilance task

I. INTRODUCTION

Stress, fatigue, and sleep deprivation have each been demonstrated to affect human performance [1][2][3]. Being stressed or fatigued means that a person is over- or under-aroused and will not perform to the best of his/her ability. Early studies established the existence of an empirical relationship between performance and arousal. This relationship is usually referred to as the Yerkes–Dodson law [4]. This curvilinear performance-arousal relationship has been challenged by many other theories in the past. For some authors, performance on complex tasks degraded with increased arousal [5], while others suggested a linear relationship when task complexity was low [6].

Electroencephalography (EEG) provides a neurophysiological measure in situations where stress, mental fatigue and drowsiness are involved. In healthy people not experiencing stress, there is a balance between the sympathetic and parasympathetic arms of the autonomic nervous system. Stress causes activation of the emotional and vigilance systems, affecting the production of alpha waves [7] over frontal regions. When people become fatigued, they usually report difficulties concentrating and focusing on tasks that they are required to perform. EEG alpha and theta oscillations reflect cognitive and memory performance [8] and are possible markers of fatigue-induced changes. Drowsiness is easily detected through EEG by measuring the power spectrum in the alpha band at parieto-occipital sites [9].

By its nature, heart rate variability (HRV) provides an indicator of parasympathetic and sympathetic balance. HRV modifications in low-frequency (LF, 0.04 to 0.15 Hz) and high-frequency (HF, 0.15 to 0.4 Hz) domains are associated with stress exposure. A reduction in the high-frequency component of HRV and an increase in the low-to-high-frequency ratio were observed in the stress condition compared with those in the control condition [10] in a mental workload study. Modifications of the LF/HF ratio were also noted by another study [11] on mental stress. A test of mental fatigue after a long arithmetic task showed that total power, low-frequency power and the LF/HF ratio increased after the task [12]. Drowsiness was measured in car drivers by HRV in a recent study [13]. The authors reported increased HF and decreased LF and LF/HF ratio in comparison