EEG Index for Time-on-Task Mental Fatigue in Real Air Traffic Controllers Obtained via Independent Component Analysis

Deepika Dasari, Guofa Shou, *Member, IEEE*, and Lei Ding, *Member, IEEE*

Mental fatigue interferes with the cognitive functions of air traffic controllers (ATCers) on the job, causing lapses in attention which can lead to errors and even accidents [1]. Hence it is necessary to monitor and assess cognitive changes in ATCers operating critical tasks. Most of previous studies investigated EEG for indicators of mental fatigue by evaluating changes on channel locations and particularly using event related potentials (ERPs) [2-3]. In the present study, we used independent component analysis (ICA) technique to identify components related to specific brain functions and further evaluate dynamic changes related to time on task, known as the time-on-task mental fatigue [4].

Three certified professional controllers (Ages: 57.6± 2.5, all males) performed 2 hours of continuous ATC tasks in an en route environment on En route automation modernization (ERAM) interface. Informed consents were obtained before the experiment, according to the protocol approved by Federal Aviation Academy Institutional Review Board (FAA-IRB). EEG data were collected during the task using BrainVision actiCHamp amplifier (Brain Products Inc.) connected to a 64 channel sensor cap, which were sampled at 1000 Hz.

EEG data were first downsampled to 250 Hz to reduce computational loads. Then a band pass filter of 0.5-30 Hz was applied. Filtered data were segmented into epochs of 1 second and bad segments were identified and removed to obtain artifact free EEG data. On clean data, Infomax independent component analysis (ICA) algorithm was applied to obtain 64 independent components [4]. Independent components related to brain activity were identified based on their spatio-spectral pattern. Temporal time course of each identified IC was calculated, which was then transformed into spectral power by applying a Fast Fourier Transform (FFT) with 'Hanning' window of 1 second without overlapping. Spectral data were divided into multiple frequency bands i.e., theta (4-<8 Hz), alpha (8-<12Hz), and beta bands (12-<30Hz). Engagement index was calculated using the ratio of beta band spectral power to the sum of alpha band and theta band spectral powers [5]. These ICs were investigated for the time-on-task effect using linear regression on engagement index data at different frequency bands.

Three IC patterns related to brain activity were identified in all subjects. Distinct spatial and spectral patterns were identified for individual ICs, the frontal IC with a spectral peak in the theta band (5-<8Hz), and the central medial and occipital ICs having the spectral peaks in the alpha band (8-<13Hz). The linear regression analysis indicates a significant decreasing slope for the engagement index in all three ICs in all subjects. However, power spectra from individual frequency bands didn't show consistent patterns across subjects. Hence, the engagement index is a better indicator of the time-on-task effect. All identified ICs and their spatial and spectral characteristics indicate that they are related to specific neurophysiological functions, and each can play a vital role in monitoring the performance of subjects. Prominent theta band activity in the frontal IC is related to cognitive attention [6], while the alpha band activity in the central medial IC is associated with motor planning and execution and in the occipital IC to visual processing [6].

In conclusion, we have identified useful brain patterns from continuous EEG data obtained from professional controllers performing en route ATC tasks. We have been able to identify significant changes in IC spectral power index with the time on task, an indicator of the development of mental fatigue. Such technology can enable automatic measurement and monitoring of mental fatigue, and can help in preventing mental fatigue related errors.

References

[1] M.M. Lorist, E. Bezdan, M. ten Caat, M. M. Span, J.B.T.M. Roerdink, &N.M. Maurits. "The influence of mental fatigue and motivation on neural dyanamics; an EEG coherence study." *Brian Research* 1270, 95-106, 209.

[2] Boksem, M.A., Meijman, T.F., Lorist, M.M., "Effects of mental fatigue on attention: an ERP study." *Brain Res Cogn Brain Res* 25, 107-116, 2005.

[3] Craig, A., Tran, Y., Wijesuriya, N., & Boord, P., "A controlled investigation into the psychological determinants of fatigue." *Biological Psychology*, *72*, 78–87, 2006

[4] T.W. Lee, M. Girolami, & T.J. Sejnowski, "Independent component analysis using an extended infomax algorithm for mixed subgaussian and supergaussian sources". *Neural Computation 11*, 417-441, 1999.

[5] F.G. Freeman, P.J. Mikulka, L.J. Prinzel, & Scerbo M.W., "Evaluation of an adaptive automation system using three EEG indices with a visual tracking task," in *Biological Psychology*, 50, pp. 61–76, 1999.

[6] Klimesch, W., "EEG alpha and theta oscillations reflect cognitive and memory performance: a review and analysis." *Brain Res Brain Res Rev* 29, 169-195, 1999.

Research supported by NSF CAREER ECCS-0955260, DOT-FAA 10-G-008, and OCAST HR09-125S.Deepika Dasari, Guofa Shou, and Lei Ding are with the School of Electrical and Computer Engineering, University of Oklahoma, Norman, OK 73019 USA. Lei Ding is also with Center of Biomedical Engineering, University of Oklahoma, Norman, OK 73019 USA. (e-mails: deepika@ou.edu, gshou@ou.edu, leiding@ou.edu).