Labeling mental fatigue for passive BCI applications: Accuracy vs applicability tradeoff

Marcel F. Hinss[12]*, Emilie S. Jahanpour[1], Anke M. Brock[2], Raphaëlle N. Roy[1]

ISAE-SUPAERO, Université de Toulouse, France | ENAC, Université de Toulouse, France

Corresponding Author*: marcel.hinss@isae-supaero.fr

Introduction: Within BCI research, particularly passive-BCI (pBCI) research, mental fatigue estimation is of great popularity, as mental fatigue can be attributed to catastrophic events in risky work settings (e.g. aviation and nuclear plant domains). Mental fatigue is often understood as a psychobiological mental state, caused by prolonged cognitive activity resulting in an increased probability of a performance decrement [1]. The most popular method to label brain activity data is time-on-task (TOT)**.** In practice, data are often labeled using the first and last blocks of an experimental procedure for binary classification between non-fatigued and fatigued states [2]. While these approaches often yield high classification accuracies, their usefulness in practical applications is debatable, as the classification is not directly linked to the behavior of the user. A more applicable approach may be to move towards performance estimation in the context of mentally fatiguing environments. Another aspect to consider is that using the entire frequency spectrum of the EEG signal may inflate classification accuracies, due for instance to different motor activity between conditions which generates different amounts of artifacts within epochs and trials. This study has been designed to directly assess the impact of the type of mental fatigue labeling on estimation accuracy using a surveillance task dataset. In addition, the impact of the range of frequencies used for estimation is also considered. We hypothesize that TOT labeling as well as using the entire EEG frequency spectrum will result in a more accurate classification as compared to using performance estimation and a restricted EEG frequency spectrum.

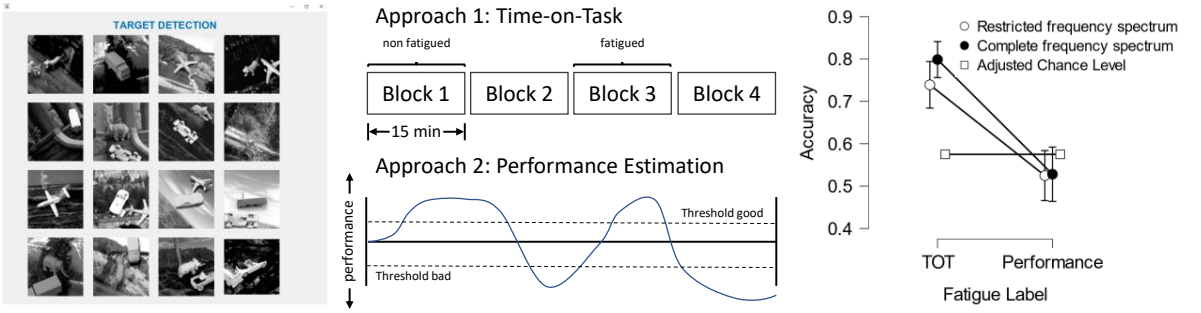

Figure 1 (from left to right) Screenshot of the visual search task in which participants had to detect humans to launch a rescue. | Comparison of the two labeling approaches | Results of the analysis, showing the upper limit of the confidence interval for chance level (57.5%) according to [3].

Methods: Data from 13 participants performing a 60-minute visual search task was recorded using a 64-electrode EEG setup. The data was preprocessed, either filtering out any motor-related activity (>20 Hz) or keeping the entire spectrum (only a 50 Hz notch filter). The data was labeled using one of two approaches. The TOT approach used the first and third (out of 4) blocks. The second approach used behavioral performance to label the epochs. Data were then classified using a Riemannian minimum-distance-to-mean classifier. Accuracies were compared using a 2x2 ANOVA.

Results: Classification accuracies obtained using TOT labeling were significantly higher as compared to performance labeling ($F(2,48)=89.87$ $p<0.001$). While the difference between the two spectra used in this approach was not significant, using the entire frequency spectrum still resulted in an almost 6% increase (79.9% vs 73.9%) in accuracy.

Discussion: As shown by these results, performance estimation is significantly more challenging as compared to TOT estimation. However, for real-world applications, TOT labeling has no real added value compared to actually knowing how much time has been spent on a task, whereas performance labeling presents more use cases for instance in order to predict and mitigate degraded attentional states via adaptive interfaces based on a pBCI [1].

References:

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