Towards Mental Workload Measurement Using Multimodal EEG-fNIRS Monitoring

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Introduction

A promising approach to developing high-performance and robust cognitive monitoring systems is to **combine neurophysiological modalities**. For example, electroencephalography (EEG) and functional near-infrared spectroscopy (fNIRS) can both offer complementary information on brain activity [1,2,3].

This work describes innovative **temporal dynamics-related** EEG and fNIRS features, to enable the development of highly effective **multimodal mental workload** measures.

Methods

Participants:
- 9 (5 females, mean 24.6 years old)

Paradigm:
- Perform 7 mental tasks eliciting various levels of mental workload (see **Fig. 1**).
- Complete **NASA-TLX** questionnaire:
  Mental demand, Temporal demand, Performance, Effort, Frustration & Task ranking.

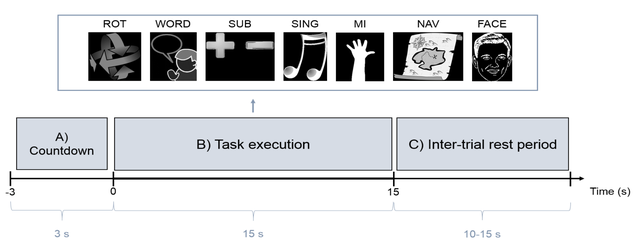

Figure 1. Diagram of a trial in the experimental paradigm.

Neurophysiological signals (see **Fig. 2**):
- 62 EEG electrodes
- 16 NIRS sources, 24 detectors following a 10-10 montage

Methods

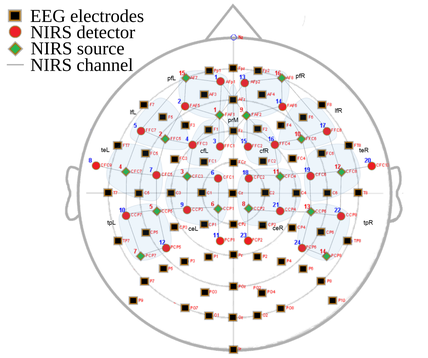

Figure 2. EEG and NIRS topology used in this study.

Feature extraction:

1. ***Benchmark 'static' features***
   a) EEG frequency band powers and ratios (**pwr**)
   b) Coherence (**coh** & **pha**)
   c) Global phase synchrony (**gfs**)
   d) Average fNIRS amplitude and latency (**mean**, **peak** & **valley**)
2. ***EEG frequency modulation features*** [4] (<band1>_**m-**<band2>, see **Fig. 3**)
3. ***NIRS temporal dynamic features***
   a) Amplitude difference (**diff**)
   b) Polynomial fit coefficients (**fit**)

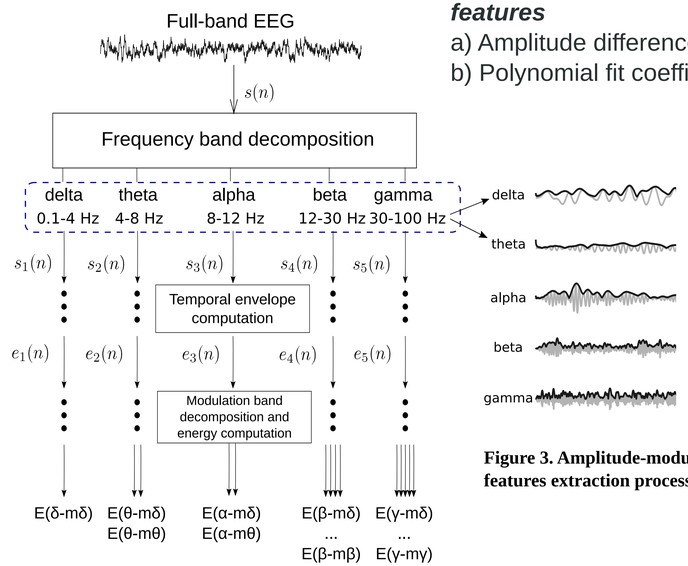

Figure 3. Amplitude-modulation EEG features extraction process. From [4].

Statistical analysis:
- Spearman's rank correlation (ρ_{spear}) for each feature - NASA-TLX rating pair.
- Absolute correlations thresholded at 0.4.
- p-values (alpha=0.05), Bonferroni-corrected.

Results

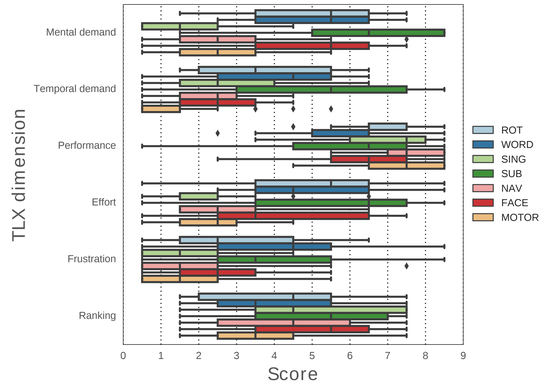

Figure 4. NASA TLX ratings and mental task ranking.

- Benchmark features exhibited little to no relationship.
- Many suggested dynamic features were significantly correlated, particularly with the temporal demand and performance dimensions.

Table 1. Features positively or negatively correlated with the NASA TLX ratings.

Correlated with **temporal demand** rating	Correlated with **performance** rating
alpha_m-delta_P7	pwr_high_gamma/beta_Cz
alpha_m-delta_P9	alpha_m-theta_T7
delta_m-delta_PO7	alpha_m-theta_CP3
alpha_m-delta_PO7	beta_m-delta_CP3
diff_S1-D4_HbO	beta_m-theta_CP3
diff_S1-D13_HbO	beta_m-delta_CP1
diff_S16-D13_HbO	beta_m-theta_CP1
diff_S1-D4_HbT	beta_m-beta_CP1
diff_pfR_HbO	beta_m-delta_CPz
diff_frM_HbO	alpha_m-theta_C4
peak_S1-D4_HbO	alpha_m-theta_C6
peak_S1-D4_HbT	alpha_m-theta_CP4
fit1a_S8-D18_HbO	alpha_m-theta_CP2
fit1a_S9-D3_HbO	beta_m-delta_CP2
fit1a_S10-D14_HbO	beta_m-theta_CP2
fit3a_S3-D7_HbO	
fit3a_S4-D8_HbO	
fit3c_cfL_HbR	

Conclusion

This work paves the way to cognitive monitoring systems based on multimodal neurophysiological techniques, and shows that innovative features such as **amplitude-modulation features** can outperform conventional ones. Further investigations on the complementarity of such multimodal features will reveal if higher performance can be attained when used in combination.

References

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