Towards Affective Hybrid BCI based on fNIRS, EEG and Peripheral Physiological Signals

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Introduction

Today, there is a growing need to create affective, sensitive, and interactive *human-machine interfaces* in order to reduce the gap between man and machine. Within this light, **affective brain-computer interfaces** (BCIs), also known as passive BCIs [2], have emerged. Affective BCIs monitor the user's affective and mental states and adapt themselves in order to improve user experience. Typically, a single modality is used, such as electroencephalography (EEG) or peripheral physiological signals (PHY), such as the galvanic skin response. Recently, ***near-infrared spectroscopy*** (NIRS) has also emerged as a useful tool to characterize mental states, particularly cognitive load. *In the present work*, we propose a ***multimodal approach*** to emotion characterization based on a combination of NIRS, EEG, and PHY.

eNTERFACE Database

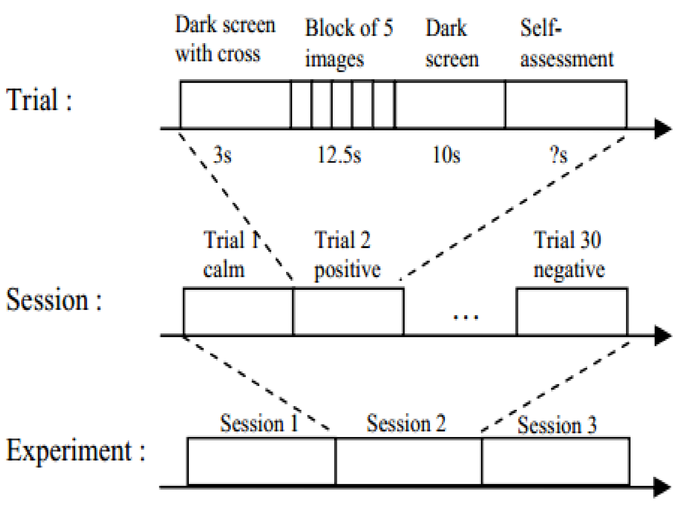

Fig. 1 Protocol Description [1]

5 subjects
150 Images from the *International Affective Picture System* (IAPS)
3 classes: calm, positive and negative
Subjective rating of valence and arousal

EEG - fNIRS – Physiological Signals (Respiration, Blood Volume Pulse and GSR)

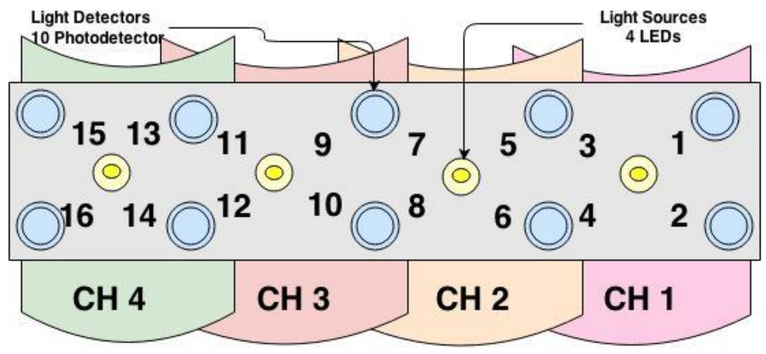

Fig. 2 NIRS Source-Detector Geometry applied to the prefrontal cortex

Methods

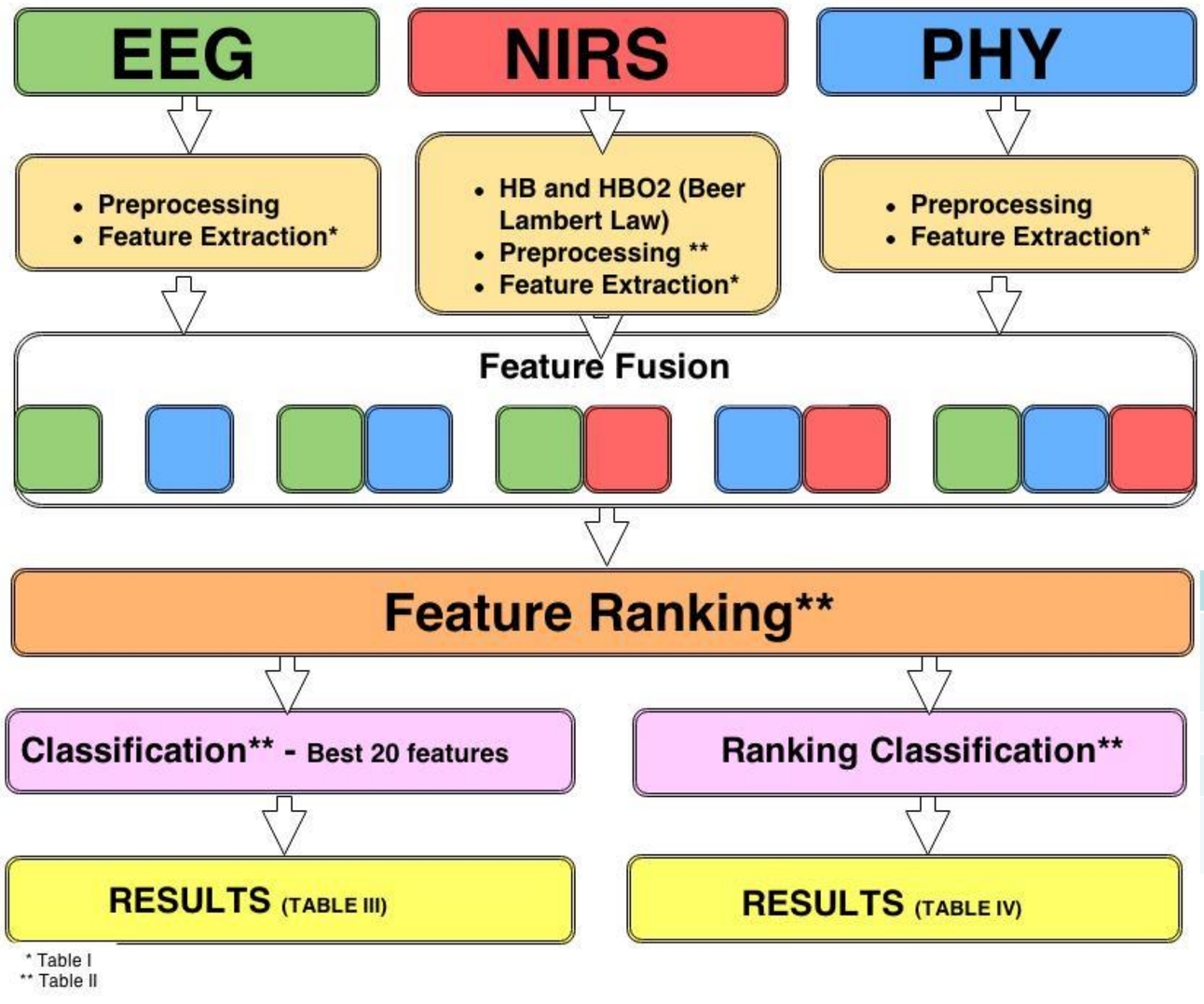

TABLE I: Feature Extraction

	Extracted Features	Total Number of Features
EEG	Magnitude Coherence and Spectral Power	3021
NIRS	Peaks, Area Under Curve, Latency and Slope (HB and HBO2)	304
PHY	Temporal, Power Spectral and Statistical Parameters	102

TABLE II: Specification

	Specification
Feature Ranking	Minimum Redundancy Maximum Relevance (mRMR)
Classifier	Relevance Vector Machine (RVM)
NIRS pre processing	Low pass filter (0.05 Hz) High pass filter (0.001) Wavelet denoising

Results

TABLE III: Accuracy and F1 score with the first 20 ranked features

	Valence		Arousal	
	Accuracy	*F1 Score*	*Accuracy*	*F1 Score*
EEG	0.53	0.53	0.44	0.43
EEG + NIRS ***	0.56	0.56	0.48	0.47
PHY	0.45	0.45	0.44	0.43
PHY + NIRS ***	0.51	0.51	0.47	0.46
EEG + PHY ***	0.53	0.53	0.44	0.43
EEG + PHY + NIRS ***	0.57	0.56	0.49	0.47

*** Decision Fusion

TABLE IV: Performance comparison between top-20 features feature fusion

	Valence			Arousal		
	N of features – Best performance	*Increase in Accuracy*	*Increase in F1 Score*	*N of features – Best performance*	*Increase in Accuracy*	*Increase in F1 Score*
EEG + NIRS	67	3 %	3 %	63	6 %	6 %
PHY + NIRS	9	2 %	2 %	13	7 %	6 %
EEG + PHY + NIRS	82	0 %	0 %	39	6 %	6 %

Conclusions

- Pre-frontal NIRS adds important affective information
- Multimodality increases performance [3]
- Arousal prediction more sensitive to number of features
- When combined with EEG, NIRS contributes 20% of the top features.
- When combined with PHY, NIRS contributes 80% of the top features.
- The most relevant features from NIRS are:

	CH 1	CH 2	CH 3	CH 4
HB		-Spec Range (0.3-0.4 Hz) -Std first derivative	- Median second derivative	
HBO2	- Mean	- Sum Slope - Ratio of local maxima of the derivative	-- Mean -- Median first derivative -- Max	- Spec Range (0.1-0.2 Hz) - Max - Ratio of local maxima of the derivative

1. Savran, A., Ciftci, K., Chanel, G., Mota, J. C., Viet, L. H., Sankur, B., ... & Rombaut, M. (2006). Emotion Detection in the Loop from Brain Signals and Facial Images.
2. Zander, T. O., & Kothe, C. (2011). Towards passive brain–computer interfaces: applying brain–computer interface technology to human–machine systems in general. *Journal of Neural Engineering*, *8*(2), 025005.
3. Merzagora, A. C., Izzetoglu, M., Polikar, R., Weisser, V., Onaral, B., & Schultheis, M. T. (2009). Functional near-infrared spectroscopy and electroencephalography: a multimodal imaging approach. In *Foundations of Augmented Cognition. Neuroergonomics and Operational Neuroscience* (pp. 417-426). Springer Berlin.