Neuroimaging Biomarkers for Surgical Skill Level Prediction

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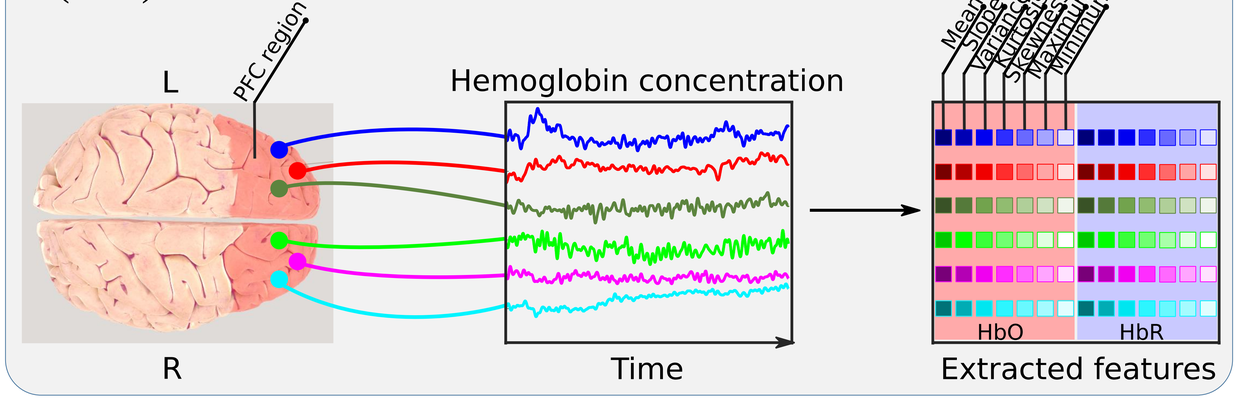
Background

- The surgical certification process is based, in parts, on quantitative metrics aggregated during the completion of surgical bimanual tasks.
- Obtaining such quantitative metrics, however, can be resource and time consuming;
- We have recently established that functional near-infrared spectroscopy (fNIRS) enables to retrospectively classify subject surgical skill levels, showing its potential utility of determining the surgical performance within the FLS program accredited framework [1] and clinically relevant environments [2].

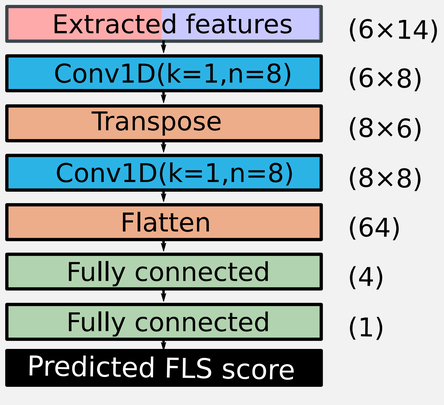
Data acquisition

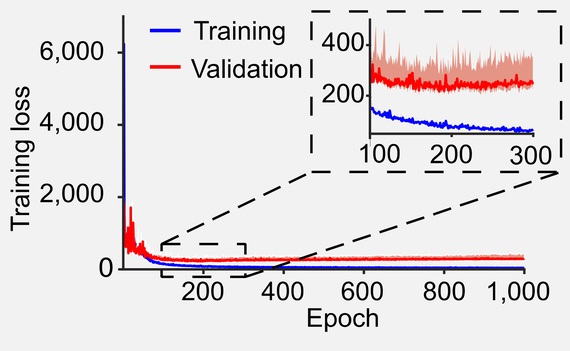
- fNIRS data was acquired from 13 medical students during the execution of a surgical task;
- Seven features (mean, variance, slope, skewness, kurtosis, minimum and maximum) were extracted for both oxy- (HbO) and deoxy-hemoglobin (HbR) concentration from the fNIRS data.



Brain-NET

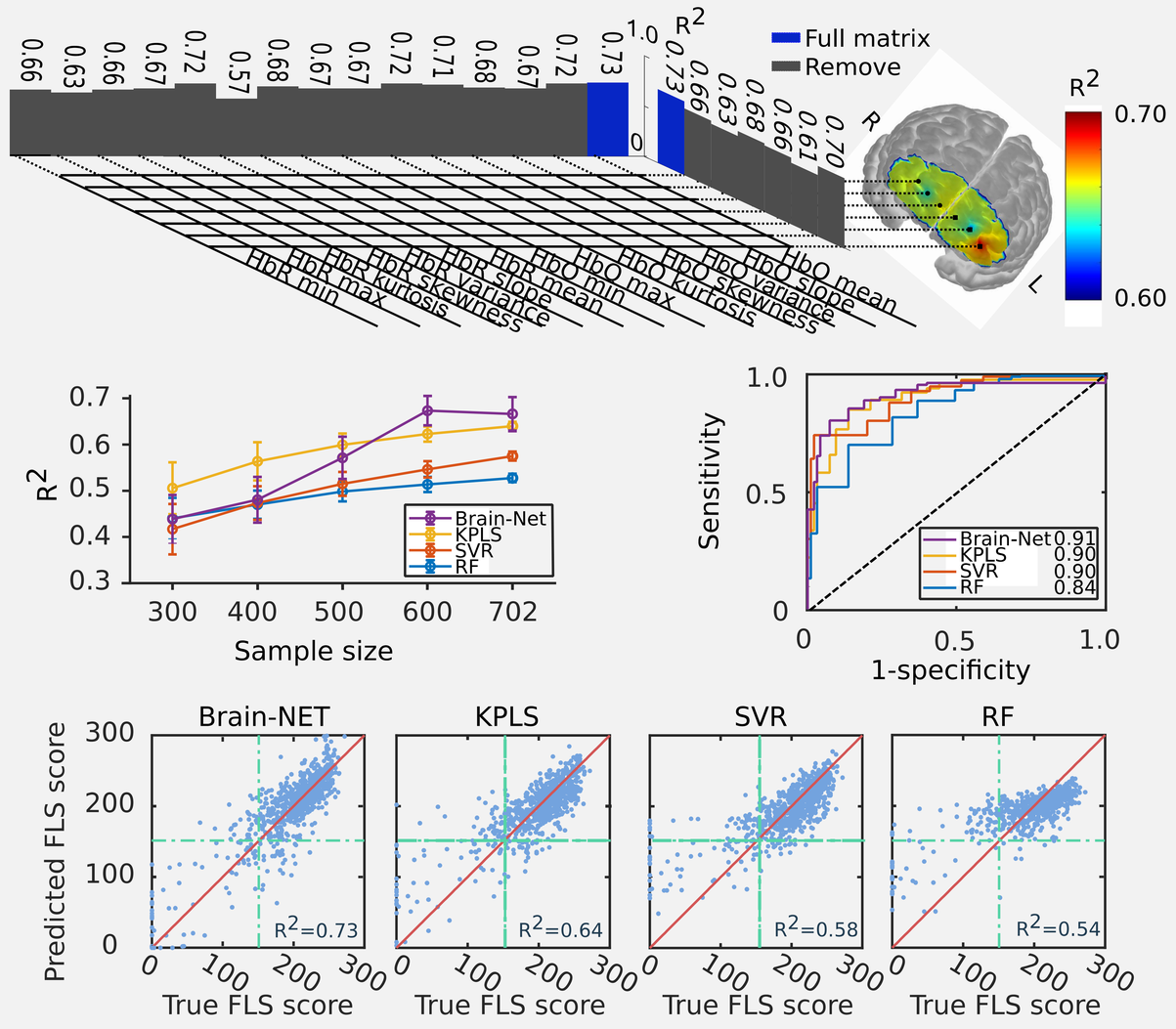
- 1D convolutional kernels are applied along the feature direction and along the PFC location direction hierarchically to learn the relationships which embedded within hemoglobin feature domain and interactions across the PFC locations;
- Then the output derived from the first two CNN layers is flattened into a vector and apply two fully connected layers;
- To test the robustness of the proposed methods, the model is evaluated with 30 rounds of ten-fold cross validation using randomly shuffled samples for each round.





Results

- Removing any of the features lead to a significant reduction of the network accuracy. Among all the features, removing the HbR slope produces the lowest R^2 value;
- Brain-NET is able to predict surgical performance based on neuroimaging data accurately;
- The classification ability of the Brain-NET model is also demonstrated for surgical certification based on receiver operating characteristic (ROC) curves and area under the curve (AUC) values of 0.91.



Discussion

- Hence, these results establish that fNIRS associated with deep learning methodologies is well suited for a bedside, real-time and cost-effective assessment of bimanual skill levels for surgical certification;
- Resulting from the high computational efficiency of the proposed method, this work presents a step forward to a real-time neurofeedback system.

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References

[1] Nemani, A. *et al.* Assessing bimanual motor skills with optical neuroimaging. *Sci. Adv.* 4, 1–10 (2018).

[2] Nemani, A. et al. Objective assessment of surgical skill transfer using non-invasive brain imaging. *Surg. Endosc.* (2018).