Assessing a new form of BCI user learning

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Introduction: Optimizing BCI user training requires to understand it and thus to discover various possible user learning forms. The *classDis* metric [1], which aims at quantifying class seperablity, may not capture potential user adaptation to the BCI classifier. Indeed, we suspect that, with BCI training, some users may learn to produce EEG patterns that are not more discriminant, but that become increasingly more similar to what the classifier expect, i.e., training EEG data, thus increasing classification accuracy. Thus, here we aim at studying and quantifying whether users' online (test) EEG data becomes increasingly more similar to the training EEG data with training.
Material, Methods and Results: To do so, we choose some robust landmarks from both the training and test sets and propose a Test-Train Adaptation (TTA) metric. TTA computes the average Riemannian distance, d_R, between these landmarks in the training and test sets: $TTA = (\sum_{ci} d_R\left(\bar{C}_{train}{}^{(ci)}, \bar{C}_{test}{}^{(ci)}\right)/\sigma_{train}{}^{(ci)} + d_R(\bar{C}_{train}, \bar{C}_{test})/\sigma_{train}))/(N_c + 1)$, with $\bar{C}_{train}{}^{(ci)}$ the mean and $\sigma_{train}{}^{(ci)}$ the standard deviation of class ci training Spatial Covariance Matrices (SCMs) and N_c the class number [2]. Decreasing TTA values may suggest increasing adaptation of user's test EEG signals to the classifier training set. We assessed user learning on a CYBATHLON dataset [3] (1 user for 10 sessions) and a Mental Tasks (MT) dataset [4] (16 users for 6 sessions each). For both, we reduced between-session non-stationarity using SCMs recentering to the mean of either the baseline or each session first run as in [3,4]. We evaluated BCI users learning using Pearson correlation between run index and Classification Accuracy (CA), *classDis*, or TTA. For the CYBATHLON dataset (Fig. 1.(a)), results revealed significant learning effects using TTA in 8-24 Hz ($\rho = -0.56$, $p = 0.05$) and CA ($\rho = 0.68$, $p = 0.01$) while *classDis* did not show significant learning. On the MT dataset (Fig 1. (b)), 4 users showed significant learning with TTA (mean $\rho = -0.47$, $p = 0.03$), 4 with *classDi*s (mean $\rho = 0.56, p = 0.04$) and 2 with CA (mean $\rho = 0.51$, $p = 0.03$) in 8-30 Hz. These frequency sub-bands were used in the online experiments. Only one user showed significant learning with all three metrics.

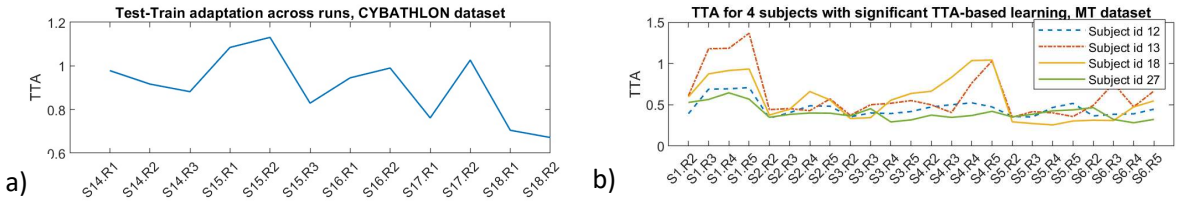

Figure 1. *(a) TTA on test ssessions (CYBATHLON dataset) (b) TTA for subjects with significant learning effects (MT data set).*

Discussion: The observed inconsistencies between learning metrics suggest that there is not a single type of BCI user learning, and that users' adaptation to the classifier is one of them.
Significance: TTA can quantify this new type of learning, and thus may be used in the future to better understand and refine BCI user training to each user learning progress.
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