Improving P300 Speller Performance by Time-Variant Linear Discriminant Analysis

J. Gruenwald[1,2]*, M. Walchshofer[1], Ngadhnjim Sutaj[1,3], C. Kapeller[1], and C. Guger[1]
[1]g.tec medical engineering GmbH, Schiedlberg, Austria; [2]Johannes Kepler University Linz, Linz, Austria; [3]Technical University Vienna, Vienna, Austria

*g.tec medical engineering GmbH, Sierningstrasse 14, 4521 Schiedlberg, Austria. E-mail: gruenwald@gtec.at

Introduction: A popular brain-computer interface (BCI) application is the P300 speller [1], which relies on the well-known P300 brain wave in the electroencephalogram (EEG). We here present evaluation results from a P300 speller that employs the recently published time-variant linear discriminant analysis (TVLDA) as a classifier [3]. We compare our results to the ones obtained from standard linear discriminant analysis (LDA).

Material, Methods and Results: Five subjects participated in this study. We used the *Unicorn Brain Interface* (g.tec neurotechnology GmbH, Schiedlberg, Austria), providing wirelessly acquired EEG for 8 channels at 250 Hz, and the *Unicorn Speller* for stimulus presentation and data recording. The Unicorn Brain Interface features hybrid electrodes, so we conducted the spelling experiment with dry and wet electrodes. A training run consisted of five characters with 30 row/column flashes each. The training set consisted of 150 targets and 1050 non-targets. We performed power-based artifact rejection and extracted the P300 waves via bandpass filtering from 0.5 Hz to 30 Hz and decimation by a factor of 12. Trial windows were set to 0.1 s pre- and 0.7 s post-trigger, yielding 15 samples per trial and channel. No trigger feedback was used. We compared standard LDA with vectorized features (120-dimensional, see also [2]), and TVLDA as described in [3]. We also added a whitening stage before classification, which further improved performance. We evaluated the performance with respect to the number of training trials and test trial averages. To this end, we performed 200 repetitions of a randomized cross-validation for each scenario and determined the spelling accuracy. As shown in Figure 1, TVLDA at the same time dramatically decreases the training effort while outperforming standard LDA. Furthermore, no substantial difference between dry and wet electrodes were observed.

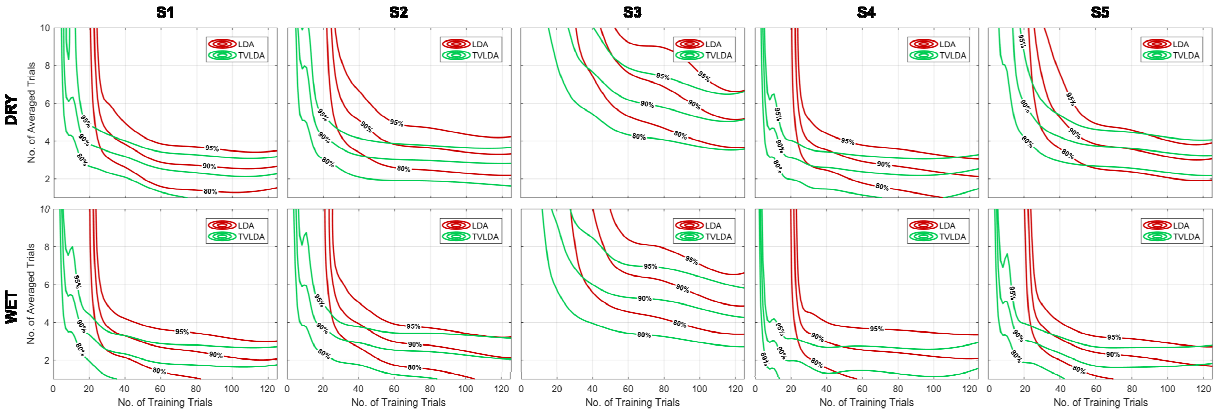

Figure 1. *Cross-validated spelling accuracy ISO lines (80%, 90%, 95%) with respect to training effort and number of averaged trials.*

Discussion: Our preliminary results have shown that TVLDA may be a powerful alternative for standard LDA for P300 spellers. For "good" subjects (S1, S2, S4, S5), as few as 20 training trials and three averages during test can be enough to reach accuracies around 90% and beyond. This dramatically reduces training and spelling time. There is no indication that wet electrodes should be preferred over dry electrodes.

Significance: Our results indicate that there is substantial room for improvement for P300 classifiers. With TVLDA, a simple extension of LDA is available that might become a standard classifier for future P300 spellers.

References

[1] L. A. Farwell and E. Donchin, "Talking off the top of your head: toward a mental prosthesis utilizing event-related brain potentials," *Electroencephalography and clinical Neurophysiology*, vol. 70, no. 6, pp. 510–523, 1988.

[2] D. J. Krusienski *et al.*, "A comparison of classification techniques for the P300 Speller," *Journal of Neural Engineering*, vol. 3, no. 4, pp. 299–305, Dec. 2006, doi: 10.1088/1741-2560/3/4/007.

[3] J. Gruenwald, A. Znobishchev, C. Kapeller, K. Kamada, J. Scharinger, and C. Guger, "Time-Variant Linear Discriminant Analysis Improves Hand Gesture and Finger Movement Decoding for Invasive Brain-Computer Interfaces," *Front. Neurosci.*, vol. 13, p. 901, Sep. 2019, doi: 10.3389/fnins.2019.00901.