 DOI: 10.3217/978-3-85125-467-9-11

Leveraging Temporal Confusion in P300 Spellers

M. Higger[1*], M. Moghadamfalahi[1], P. Gonzalez-Navarro[1], D. Erdogmus[1]
[1]Northeastern Univserity, Boston, MA
*409 Dana Research Center, 360 Huntington Ave, Boston, MA 02115. E-mail: higger@ece.neu.edu

Introduction: A P300 classifier's performance depends on the time bin of the target stimulus. For example, a user may generate a different response when presented with a target early or late in a sequence. Further, knowing the target to be unique, a user may relax after seeing it such that pre and post-target P300 absent trials are different from each other.
There is structure to the accuracies and errors of P300 classifier which depend on the time bin a target stimulus is presented in. We aim to encapsulate and leverage this structure to build a speller which offers a better speed-accuracy trade-off. In particular, we incorporate the temporal confusion associated with a particular user-classifier pair for quicker and/or more accurate letter inference [1].

Material: We use g.USBamp, MATLAB and Psychtoolbox to build and simulate our BCI.

Methods: We describe the temporal confusion of a user-classifier pair by $P(\hat{X}|X)$ where X is the index of the unique time bin where the P300 is generated and $\hat{x}$ is our estimate. We estimate this confusion matrix by normalizing a count of our classifier's cross validated performance on a labeled training set. See Fig 1 for example.
The user-classifier pair of Fig 1 shows strong accuracy when the target is in the 4th time bin. Given this fact, we ought to trust a classification in favor of the 4th time bin more as it offers stronger evidence. We offer a Bayesian update which leverages this temporal confusion of P300 classifications; it accounts for the varying accuracy of each time bin in updating letter probabilities.

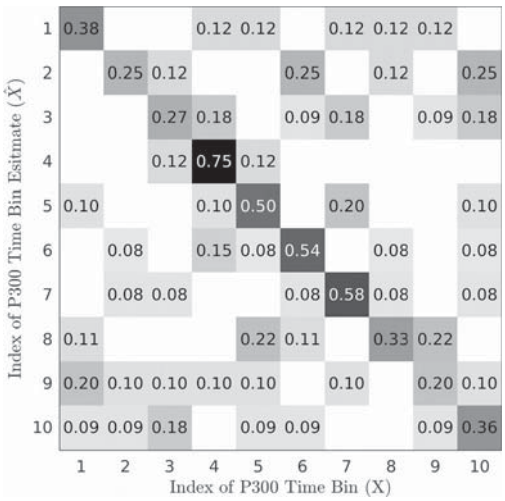

Figure 1. The temporal confusion matrix $P(\hat{X}|X)$ for a particular user-classifier pair. Note that this user-classifier shows stronger performance for targets which occur towards the middle of a sequence.

Results: As a preliminary work, we contrast the performance of an *Aware* decision scheme which uses the temporal confusion of Fig 1 against a *Naive* decision scheme which assumes accuracy is uniform across different target time bins. We simulate 100 recursive decisions (querying with a P300 sequence until a sufficient threshold is reached) under 4 different confidence thresholds. Fig 2 demonstrates that using this temporal structure can improve the speed-accuracy trade-off.

Discussion: While our simulation shows strong performance improvement, note that the *Aware* decision scheme has knowledge of the ground truth $P(\hat{X}|X)$ which the *Naive* doesn't. In practice we must estimate this distribution; we cannot provide a benefit without accurately doing so.

Some time bin classifications offer stronger evidence than others. In addition to performing letter inference, we seek to leverage the temporal confusion to construct stronger queries. Namely, we seek to arrange letters within the stimuli sequence such that we generate, on average, as strong evidence as possible.

Significance: For some user-classifier pairs, P300 classification accuracy strongly depends on the position of the target within the sequence. There may be a speed-accuracy benefit to leveraging this structure.

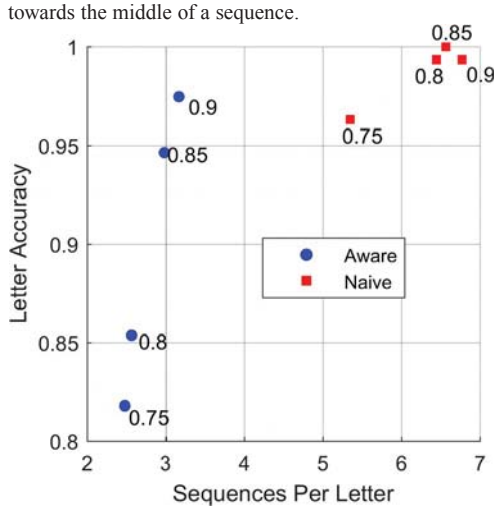

Figure 2: Each point represents the average of 100 decisions; probability thresholds are labeled next to their respective data points. In this simulation, the temporal confusion aware decision rule offers a better speed-accuracy tradeoff curve.

Acknowledgments: This work is supported by NIH R01DC009834, NIDRR H133E140026, NSF CNS1136027, IIS1149570, CNS1544895.

[1] Higger, M., Quivira, F., Akcakaya, M., Moghadamfalahi, M., Nezamfar, H., Cetin, M. & Erdogmus, E. (accepted 2015). Recursive Bayesian Coding for BCIs. Transactions on Neural Systems & Rehabilitation Engineering.