Do Automatic Artifact Removal Algorithms Reduce Accuracy By Removing Dependence on Post-Stimulus Blinks

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Introduction: Noninvasive Brain-Computer Interfaces (BCIs) are highly susceptible to noise artifacts. There exist many automated methods for removing these artifacts based on blind source separation. In prior work [1] we discussed how these Automated Artifact Rejection (AAR) algorithms significantly reduced the accuracy of P3 spellers. We proposed several mechanisms for why this could occur. One mechanism is that a participant could be inadvertently timing their blinks after target stimuli in a way the classifier might use. Here we investigate if the post-target stimulus blink behavior occurs, and if the classifier is using this behavior to detect target stimuli.

Materials, Methods, and Results: Data were collected from 39 participants. Each participant typed 1 training sentence and 1 to 9 test sentences resulting in 39 sets of training data and 313 sets of test data. We manually labeled the time of each blink using the EEG data and checked to see if a blink occurred 300-600ms post stimulus for each stimulus. We found a mean of .41 and .74 blinks post-non target and post-target stimulus respectively for training data and a mean of .21 and .32 blinks post-non target and post-target stimulus respectively for the test data.

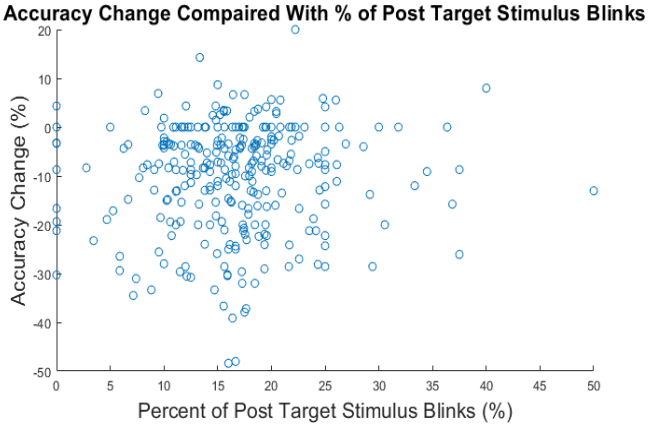

Figure 1 Percentage of stimuli that occur 300-600ms before a blink that are target stimuli compared with the reduction in detection accuracy caused by cleaning the data with the JADAR AAR algorithm.

We then looked at what percentage of all stimuli followed by a blink were target stimuli and compared this per test to the reduction in accuracy caused by JADER [2], one of the AAR algorithms. We can see in figure 1 there is no apparent correlation ($r = 0.054$, $p = 0.348$) between the percentage of target stimuli followed by a blink and reduction in accuracy.

Finally, we created a new data set by removing data for stimuli with a blink occurring within its analysis window (-100-900ms) and created another data set by removing the same amount of random data. We found a -3.44% mean drop in accuracy for removing the blinks and a -2.99% mean drop in accuracy for removing random data. This is much lower than the drop in accuracy from using the JADER AAR which caused a -10.9% mean drop in accuracy. Using a two-sample t-test on the two new data sets, we found a p value of 0.78, far from the threshold of statistical significance.

Discussion: We found that the behavior to preferentially blink 300-600ms after a target stimulus is present in many individuals. There seems to be little to no correlation between this preferential blinking and a drop in detection accuracy from AAR algorithms. Removing the blinks from the data entirely had no significant difference from removing random data. This indicates that the reduction in accuracy caused by AAR algorithms is not primarily due to this mechanism.

Significance: This result removes one of the possible mechanisms through which AAR algorithms might be reducing P3 Speller accuracy. Further, it provides evidence that blinks are not being inadvertently used for classification.

References:

[1] David E. Thompson, Md. Rakibul Mowla, Katie J. Dhuyvetter, Joseph W. Tillman & Jane E. Huggins (2019) Automated artifact rejection algorithms harm P3 Speller brain-computer interface performance, Brain-Computer Interfaces, 6:4, 141-148, DOI: 10.1080/2326263X.2020.1734401

[2] Cardoso JF, Souloumiac A Blind beamforming for non-Gaussian signals. IEE proceedings F (radar and signal processing); Vol. 140. IET; 1993. p. 362–370. Available from https://digital-library.theiet.org/con tent/journals/ip-f-1