ANALYSIS OF MEMORY IMPAIRMENT IN ALCOHOLICS

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Abstract: A general problem with the analysis of visual evoked potentials (VEP) signals is the corruption from ongoing electroencephalography (EEG). The common method of reducing EEG from VEP is to use ensemble averaging from multi-trials. In this paper, we propose a single trial VEP extraction using two-levels of Principal Component Analysis (PCA). The novelty of the technique is the two-level application of PCA, which reduces background EEG thereby enabling single trial analysis. In the first level, PCA is applied to multi-channel VEP signals from one trial. The output VEP signals from the first level are used in the second level, where PCA is applied to multi-trial VEP signals from a single channel. These single trial VEP signals are studied at the low frequency domain using N4 parameter to investigate the differences in memory coding of alcoholics and non-alcoholics. N4 responses are the negative peak that occur after P3, P2 and N1 responses. Alternate hypothesis T-tests are conducted on 61 active channels to show lower N4 amplitude and higher N4 latency for alcoholics as compared to non-alcoholics. This indicates that slower and lower memory coding takes place for alcoholics as compared to non-alcoholics.

Introduction

A problem with the analysis of VEP signals is the corruption from the ongoing EEG and noise artifacts. VEP signals are relatively lower in signal strength as compared to EEG and therefore, the EEG distorts the VEP signal. The common method to solve this problem is to use signal averaging from a number of trials. This method is disadvantageous because VEP responses are not strictly time-locked to the stimulus. Therefore, the averaging process might tend to smooth out the inter-trial variation in latency and amplitude. In this paper, a single trial method of analyzing the VEP signals is proposed using two-levels of PCA, which preserves the single trial information. PCA is a common technique used to reduce the dimension of the feature set. It has also been used to reduce noise from VEP [3] and EEG signals [4]. But these methods work on a single level PCA, i.e PCA is applied only once. The novelty of the proposed method lies in the two-level application. The method proposed in this paper works by applying PCA twice; firstly with multi-channel VEP signals from one trial and secondly with multi-trial VEP signals from one channel.

The method does not assume any property of VEP signals but require that VEP signals be recorded from many channels and across many trials (sessions). This requirement of multi-channel and multi-trial recordings is not a drawback for VEP signals because most VEP recordings are obtained from many channels and across many trials. Although one-level PCA is sufficient to improve the SNR, the use of second-level PCA becomes important to further improve the SNR in cases involving VEP signals. This is because the EEG levels are comparable to the VEP signal levels.

The first-level PCA reduces EEG from multi-channel VEP signals obtained from a single trial. VEP signals are more correlated from one channel to another as compared to EEG during visual perception. As such, PCA which uses eigen analysis of data covariance matrix can be applied to reduce EEG in VEP signals. The output VEP signals from the first-level PCA are used by the second-level PCA, which is applied to multi-trial VEP signals from a single channel. The ability of the two-level PCA to reduce EEG from VEP signals is shown through a simulation study using VEP signals contaminated with EEG.

The extracted single trial VEP signals after applying two-level PCA are studied in the low frequency domain using N4 parameter to investigate the differences in memory coding of alcoholics and non-alcoholics. N4 responses which generally occur from 400-600 ms after stimulus onset, is used to measure the ability of memory encoding. Quite often, N4 responses are the negative peak that occurs after P3, P2 and N1 responses. N1 response generally denotes the stimulus perception, while P2 response denoted memory access and P3 response denotes memory recognition. The T-tests results show lower N4 amplitude and higher N4 latency of alcoholics as compared to non-alcoholics. This indicates that slower and lower memory coding taking place for alcoholics as compared to non-alcoholics.

Method

VEP Data Recording

The processing of N4 parameter starts by recording the VEP signals. The VEP data is recorded from subjects while being exposed to single picture stimulus, which

are chosen from Snodgrass and Vanderwart picture set [6]. Figure 1 shows an illustrative example of a single stimulus presentation. Measurements are taken from 64 electrodes (61 active electrodes and 3 reference electrodes) placed on the subject's scalp, which are sampled at 256 Hz as shown in Figure 2. This will evoke potential in the brain related to recognition and memory. Each subject completed 40 trials of one-second measurements. Actually, the number of trials is slightly higher because of the eye blink contamination. But after removing eye-blink contaminated artifacts, there are 40 trials. Also the mean from the data is removed by setting the pre-stimulus baseline to zero. The VEP is averaged across 40 trials to reduce background EEG. This is necessary so that we know the actual VEP for computing the SNR improvement of the proposed method.

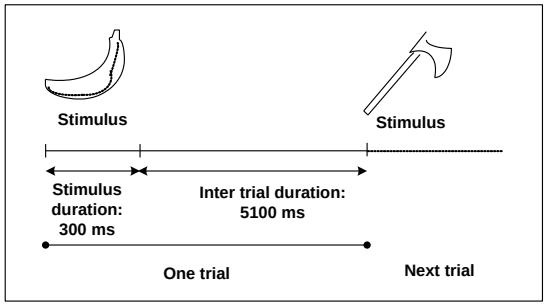

Figure 1: Example of Single Stimulus Presentation

EEG Reduction Using Two-level PCA

The recorded VEP signals consist of two parts: EEG and VEP. Therefore, using PCA, it is possible to separate EEG from VEP using the fact that the EEG subspace will constitute of principal components (PCs) with eigenvalues chosen below a certain threshold and eigenvalues with PCs above this threshold represent the VEP subspace. Assuming matrix $\mathbf{x}$ to represent the extracted EEG corrupted VEP signal, the covariance of matrix $\mathbf{x}$ is computed using

$$\mathbf{R} = E(\mathbf{x}\mathbf{x}^{\mathbf{T}}). \quad (1)$$

Next, matrices $\mathbf{E}$ and $\mathbf{D}$, are computed where $\mathbf{E}$ is the orthogonal matrix of eigenvectors of $\mathbf{R}$ and $\mathbf{D}$ is the diagonal matrix of its eigenvalues, $\mathbf{D} = diag(d_1,....,d_n)$. The PCs can now be computed using

$$\mathbf{y} = \mathbf{E}^{\mathbf{T}}\mathbf{x}^{\mathbf{T}} \quad (2)$$

In this work, percentage of total power (variance) [2] retained is used to give the number of required PCs. Using this method, PCs that account for 95% of the total power is assumed to consist of VEP in the first-level PCA, while PCs that account for 99.9% of the total power is assumed to consist of VEP in the second-level PCA. The PCs that account for the 5% and 0.1%, respectively account for the unwanted EEG. These values are chosen after some preliminary simulations. The higher value of power retained in the second-level PCA is to reflect the EEG, which decreases. The VEP can now be reconstructed from the selected PCs using

$$\tilde{\mathbf{x}} = \hat{\mathbf{E}}\hat{\mathbf{y}} \quad (3)$$

where $\hat{\mathbf{E}}$ and $\hat{\mathbf{y}}$ are the eigenvectors and PCs, respectively.

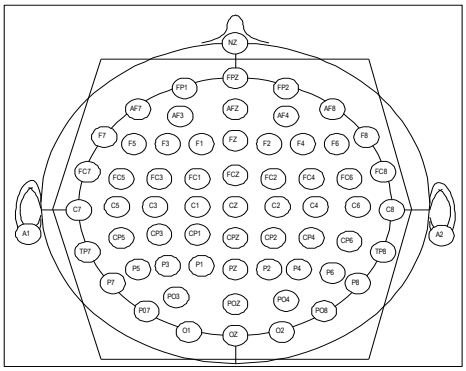

Figure 2: 64 Electrode System

Extraction of N4 Parameter

The extracted VEP signals are low pass filtered using a 9^{th} order Butterworth digital filter with a 3-dB cut-off frequency at 8 Hz. The main reason for cut-off frequency of 8 Hz is chosen based on the research by Begleiter et. al. [ ]. Order 9 is used since it gives a minimum attenuation of 30dB in the stop band with a transition band from 8 to 12 Hz. Forward and reverse filtering are performed to achieve zero phase response i.e. to avoid any phase distortion because Butterworth filter is a non-linear filter. First the filtering is done in the forward direction, then the filtered sequence is reversed and run back through the filter. The result has precisely zero phase distortion and magnitude modified by the square of the filter's magnitude response. Care is taken to minimize startup and ending transients by matching initial conditions. MATLAB's filtfilt function is used for this purpose.

The T-test is the most common valuable tool in statistical procedure and is normally used when there are two different groups. The alternative hypothesis is tested using T-test analysis for N4 amplitude and N4 latency with the values for $p<0.05$ using

$$t = \frac{\overline{X_1} - \overline{X_2}}{\sqrt{\left(S_1^2/n\right) + \left(S_2^2/n\right)}} \quad (4)$$

Figure 3 shows the block diagram of the various stages involved in the VEP feature extraction for analysis of N4 parameter and Figure 4 and 5 shows the

N4 response of a randomly selected alcoholic and non-alcoholic subject.

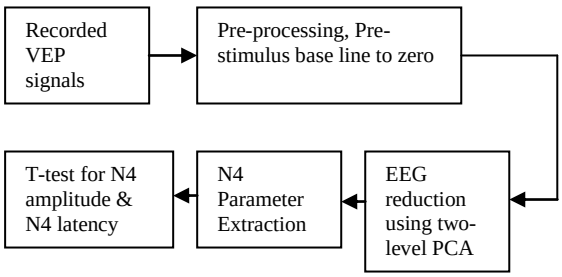

Figure 3: VEP Feature Extraction

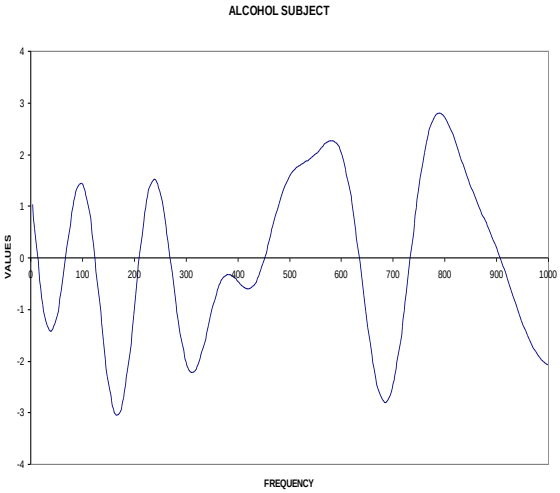

Figure 4: N4 Response of an Alcoholic Subject

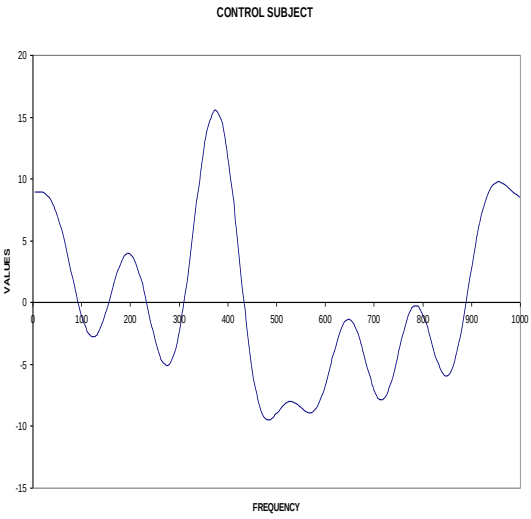

Figure 5: N4 Response of an Non-alcoholic Subject

Results

Table 1 shows the results for 5 randomly selected channels from a trial and also averaged results from all 40 trials. All channels showed improvement in SNR using the two-level PCA but to save space, only SNRs from 5 randomly selected channels are shown. The last row shows the averaged results from all 64 channels. SNR0 denotes the SNR of the actual VEP with EEG contamination, while SNR1 and SNR2 denotes the SNR of VEP signals after first-level PCA and second-level PCA, respectively.

Table 1: Two-level PCA results of VEP Signals

	One Random Trial			Average of 40 trials		
Channels	SNR0	SNR1	SNR2	SNR0	SNR1	SNR2
1	12.14	19.42	20.25	22.58	35.99	36.63
2	10.41	17.85	18.84	24.21	36.88	37.69
3	16.44	21.2	21.72	26.02	35.85	36.44
4	10.89	14.84	15.79	26.71	37.61	38.47
5	11.16	16.96	17.67	18.88	32.21	33.12
Average (64 channels)	9.77	16.31	16.96	19.78	31.53	32.3

Figure 5 shows the graphical representation of the comparison of SNR values for VEP signals with EEG, after first-level and second-level PCA.

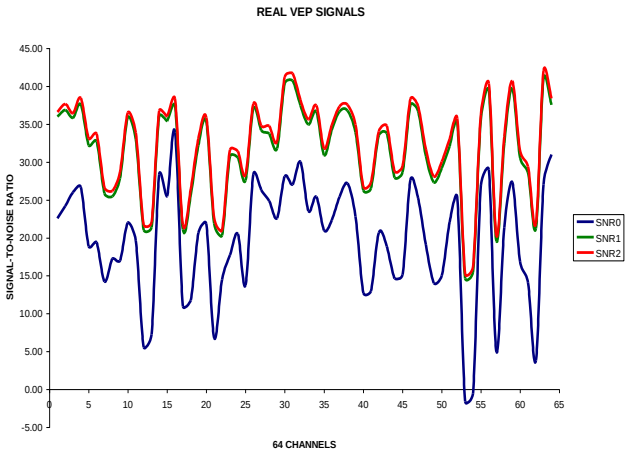

Figure 5: Comparison of SNR values

Due to space constraints the results of T-test for N4 amplitude and N4 latency are not shown. But the diagrammatic representation of N4 amplitude and N4 latency for all the active 61 channels are shown in Figure 6 and 7 respectively with the significance of $p<0.05$.

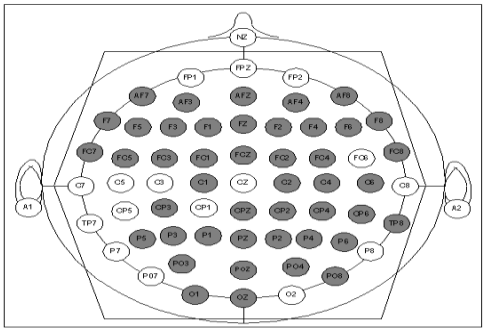

Figure 6: T-test results of N4 amplitude for 61 channels

Figure 6 shows almost all the channels are shaded except a few. The shaded channels indicated the lower amplitude values for alcoholics when compared to non-alcoholics. Therefore the alternative hypothesis tested in the T-test analysis shows that N4 responses for non-alcoholics are higher than alcoholics.

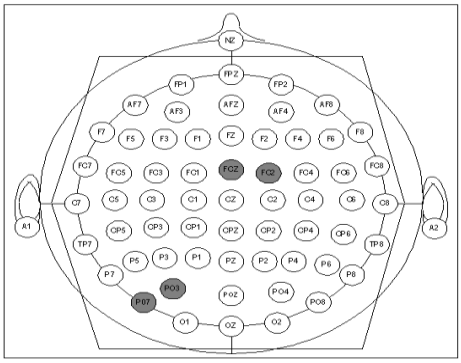

Figure 7: T-test results of N4 latency for 61 channels

Figure 7 shows the result for T-test analysis of the differences of N4 latencies between alcoholics and non-alcoholics of a single stimulus. The shaded channels shows a high N4 latency which means the alcoholics take more time in short-term memory encoding.

Conclusion

In this letter, two-levels of PCA has been proposed to extract single trials of VEP signals. In the simulation study, VEP signals are contaminated with EEG and the application of PCA improves the SNR of VEP signals, where the SNR improvements are obtained at both levels of PCA. The technique could be further extended to more levels, if necessary, where the odd-level PCA works on multi-channel single trial VEP signal, while the even-level PCA work on multi-trial single channel VEP signal. The percentage of power retained (to select the PCs) must be gradually increased to reflect the decreasing EEG power.

Next to conclude the results of T-tests, lower N4 amplitude value for alcoholics indicated that they have difficulty in short-term memory encoding and higher N4 latency shows that slower and lower memory encoding takes place for alcoholics as compared to non-alcoholics. Therefore it is proved that long term alcohol use causes persistent electrophysiological impairments though the alcoholics abstained from drinking for a month and this impairment lingers even after quitting.

In the method proposed in this letter, VEP signals were extracted from the background EEG using low pass filtering with the range of 0-8 Hz for the analysis of N4 parameter. In general EEG signals vary for same memory coding extracted during different periods of time of the continuous growth that takes place in the brain. Therefore it may preferable to use a different signal processing technique to extract the VEP signals from the background EEG.

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References