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# Identification of Saccades from Event Related Spectral Dynamics during Reading

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**Abstract**
Abstract: In this study, we have used EEG data obtained during a reading activity. During the reading process, eye saccade and fixation activity are captured using dedicated hardware. We have used the data to show how the onset and progress of eye saccades can be tracked by the presence of high frequency gamma bands in the EEG time-frequency spectra. We also show that this tracking of eye saccades using the gamma bands can be captured by specific independent components of the EEG data. This relationship between saccades and gamma bands suggests caution in correlating gamma bands to cognitive or other neural activity.

***Keywords:** EEG, Fixation, Gamma Band, Reading, Saccade*

## I. INTRODUCTION

The presence of gamma bands in EEG spectra has been the subject of several research discussions[1],[2]. In this study, we have used EEG data obtained during a reading words displayed in sequence. The aim of the study is to identify EEG eye saccades through gamma bands. The frequency-domain spectra of EEG potentials are usually studied as frequency bands. During reading our eyes fixates on a word for around 250 ms and then rapidly moves or saccades to the next word. During a saccade which lasts about 25 ms, our eyes to jump from word to word and during each jump the retinal image moves[3]. Normally, however, we are unaware of such motion. In this study, eye saccade and fixation activity are captured during a reading activity, using dedicated eye-tracking hardware. We have used the data to show how the onset and progress of eye saccades can be tracked by the presence of high frequency gamma bands in the EEG time-frequency spectra. We also show how saccades can be tracked using the gamma bands obtained from independent components of the EEG data. This relationship between saccades and gamma bands in EEG time-frequency plots, shows that caution in needed in interpreting gamma bands as cognitive activity[3] or other neural activity.

## II. METHODOLOGY

In this paper we have used sample EEG data in which saccade and fixations have been recorded using

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eye-tracking hardware[5],[6]. The data was cleaned to remove EEG artifacts. Time-frequency based analysis using EEGLAB running in Matlab was used to identify gamma bands in the time-frequency plots[7],[8]. Using these plots and the time-domain EEG electrode potential and component potential plots, saccade onset and progression was identified to match the statistical average timing of saccades.

### A. EEG Data Capture and Cleaning

The sample dataset was obtained from the EYE-EEG toolbox website [5], [6]. The data is obtained for a natural reading experiment. In the experiment, a participant read lists of five words from left to right. Parafoveal words were masked using the Moving Window Paradigm. Note that there are 320 epochs where each epoch represents a single word that is read. Each epoch has a period of silence of 1 second (from -1000 to 0 ms) and a reading stimulus lasting for 2 seconds (from 0 to 2000 ms). Binocular eye movements were recorded with an Eyelink 1000 tracker at 1000 Hz. A 72 channel EEG data was recorded with Biosemi Active amplifiers at a rate of 512 Hz. The EEG data was band-pass filtered from 0.1 to 100 Hz and converted to average reference. Figure 1, shows the position of the electrodes. Online detection of saccades, fixations and blinks was switched on. Eye movement events can be directly imported using EYE-EEG. EEGLAB running in Matlab was used together with the EYE-EEG toolbox to identify saccades and fixations. Figure 2 the time-domain representation of the EEG potentials at each electrode.

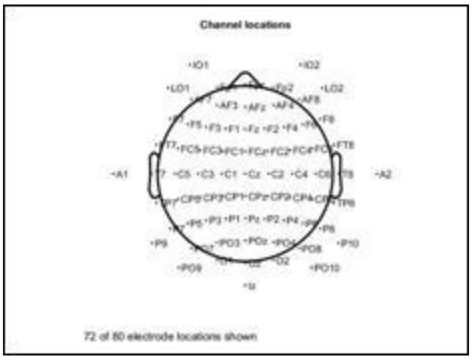


**Figure 1:** Electrode locations on scalp

### DATA ANALYSIS

The data was cleaned using EYE-EEG toolbox. Continuous data intervals with out-of-range eye tracking data are discarded. Whole epochs are discarded that contain any out-of-range eye tracking data. The time-frequency toolbox in EEGLAB was used to obtain event-related spectral perturbation (ERSP) plots. The ERSP plots, show EEG frequencies versus time with colors used to identify intensity. Figure 2 shows the time-domain original EEG data which has markers to indicate the time of onset and progression of saccades and fixations. In this figure, a saccade event (marked in a oval window) is seen at around 270 ms at epoch 65 i.e. the EEG potentials resulting from the reading of the 65th word sample.

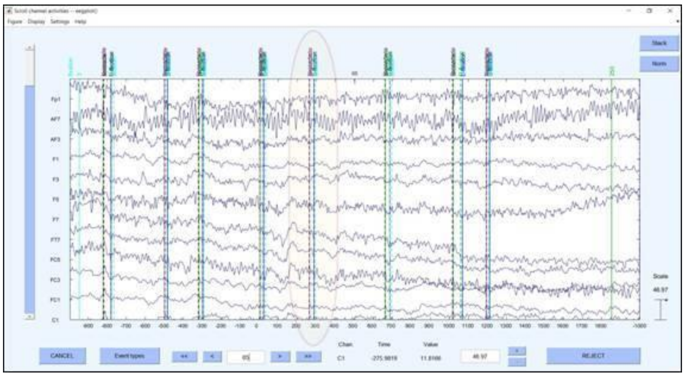

**Figure 2:** EEG voltage (mV) vs Time (ms). Time domain representations of EEG data at epoch 65. EEG saccade-related spike potential at 300 ms shown highlighted.

### B. Gamma Bands from Electrode Potentials

In EEG spectra, gamma bands are assumed to be above 30 Hz. As shown in Figure 2, single trial analysis of EEG potentials and eye tracking, shows that spike potentials[9]-[11] are tightly time locked to the onset of saccades[1]. Since a total of 320 words have been read, the statistically significant timing of the saccade onset and progression is shown as a gamma band. During saccades it is believed that neural signals are suppressed and as such, noise dominates. The rapid oscillations of noise gives rise to high frequency components in EEG spectra. Figure 3 shows the time of onset and progression of statistically significant ($p<0.05$) gamma bands at

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various scalp locations after stimulus 270ms (AF7), 350ms (AF8), 400ms (C5), 350ms (C4), 350ms (O1) and 350ms (O2) based on the 320 individual reading data epochs. A statistical threshold at $p<0.05$, by definition means that about 5% of the inferred significant values will be false positives. The gamma bands are significant from 50 Hz to more than 90 Hz. We cannot identify higher frequencies, since the data available has already been band-pass filtered from 0.1 to 100 Hz. Note that at each scalp electrode, the will be contamination of the electrode potential from all sources of EEG potential within the brain, i.e. sources close to the electrode as well sources further away. This will lead to uncertainties in the accurate identification of the time of onset and progression of a saccade. In order to further enhance the accuracy of saccade timing, we will study the EEG component spectra. These components have been obtained by independent component analysis (ICA) of the EEG data using EEGLAB[7],[8].

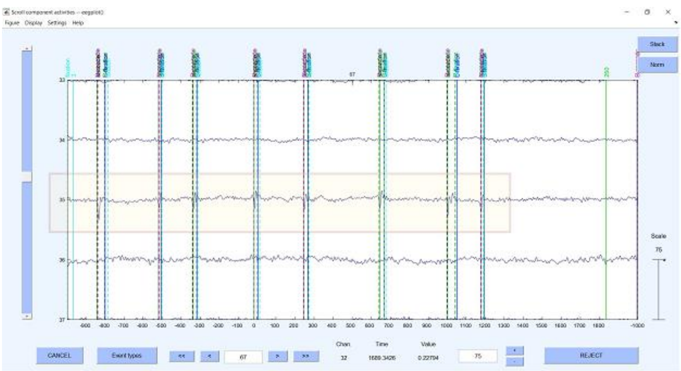

**Figure 4:** Component voltage (millivolts) vs Time (ms).

Biphasic signal spikes during saccades are shown in highlighted epoch 67 of IC35.

### C. Gamma Bands from Independent Components

The EEG data has also been analyzed by studying ERSP plots for independent components obtained by ICA. Figure 4 shows EEG potentials of various components in time. On examination of the complete data, we have identified that component 35 has captured the saccade as seen in Figure 4 in which component 35 has been highlighted.

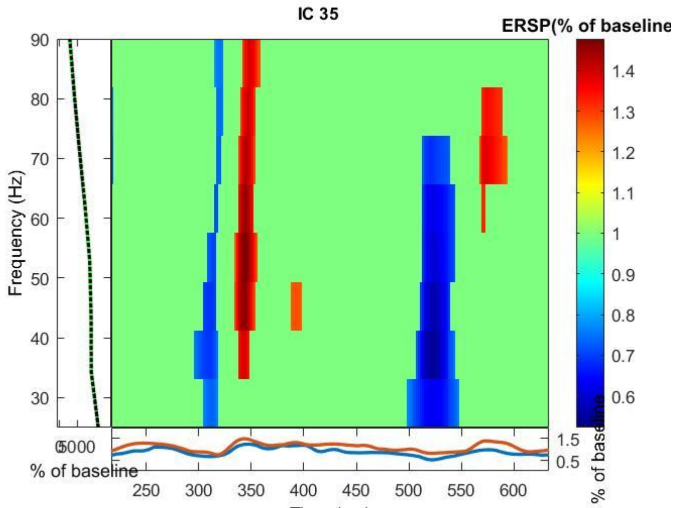


**Figure 5:** Gamma band shown as a vertical strip (in red) at around 350 ms.

Time-frequency analysis of component 35 shows a sharp gamma band at 350 ms as shown in Figure 5. Note that this gamma band matches the timing of eye saccades.

## III. Results and Discussion

We have shown how the time of onset and progression of eye saccades can be recognised by the presence of a vertical EEG gamma band in the ERSP spectra of the EEG data. Two methods were shown. The first method used individual EEG electrode potentials and the ERSP spectra to identify the timming information i.e. the onset and progression of saccades. In the second method, EEG components obtained from ICA analysis were used to obtain the saccade timing. By studying Figures 4 and 5, we can see that ICA 35 appears to contain most of the information of saccades. Figure 5 shows the timing of a saccade at around 350 ms with statistical significance at $p<0.05$ considering all the 320 epoch data obtained during reading. Single trial EEG response that is reflected in the increased gamma power is indeed of a transient nature rather than a sustained oscillation. It coincides and is time locked to the onset of saccades. However the importance of gamma-band activity in neural function, as found especially by intracranial recordings cannot be ignored[12]-[14].

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## IV. Conclusion

In this paper we have shown that the onset of eye saccades and its progression can be identified using gamma bands in ERSP plots of EEG potentials and also by the independent components. From this we have seen that the onset of a saccade based on the gamma band varies with electrode position. We have also shown that using ICA components can predict saccades with greater precision. We note that cleaning the data has not removed saccade related information. The identification of saccades using gamma bands will be useful for EEG datasets that have not simultaneously captured eye saccade and fixation related information which may be useful in some studies such as dyslexic reading. In future work it may be useful to further analyse the data to identify all saccades present with good precision for any given dataset. Further, differences in gamma activity in various scalp areas may possibly provide better understanding of the saccade differences between various scalp areas.

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