Analysis on the electroretinography response for flickering and current stimulations

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Analysis on the Electroretinography Response for Flickering and Current Stimulations

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Abstract—**In this paper, an analysis of the Electroretinography response for both flickering and current stimulations is presented. To perform the analysis, data from 6 subjects was collected. The subjects underwent two types of stimulation: (1) flickering, and (2) current. Electrodes with two different inner diameters (0.4 cm) and (0.7 cm) were used to record retina responses. The configuration of electrode connection followed ISCEV standard protocol for ERG responses. The electrodes were placed on the forehead and inner and outer canthus of the eye. Data analysis using MATLAB produced a graphical illustration of flicker and current stimulation in both, time and frequency domain. Results show amplitudes at 12.56 Hz and 50.26 Hz. We conclude that these frequencies correlate with retinal functions and may serve as a physiological indicator. Future works may use these results to improve the evaluation of retina function.**

Keywords—**Current stimulation, electrodes, electroretinography, eyes, flickering stimulation, frequency domain, time domain, retina.**

I. Introduction

ELECTRORETINOGRAPHY (ERG) is procedure used to measure the electrical response of cell types in the retina, which are sensitive to light [1]. The retina is a light-sensitive layer of tissue, lining the inner surface of the eye and is the most metabolically active tissue in the body [2]. Retina cell types include photoreceptors (rods and cones), inner retinal cells (bipolar and amacrine cells), as well as ganglion cells [3]. ERG response measurements follow a standard, which is determined by the International Society for Clinical Electrophysiology of Vision (ISCEV). The electrode is the main component of this experiment and is usually placed at the earlobe in form of a ground electrode. Moreover an indifferent electrode is placed on the forehead [4]. These two electrodes get connected to a bio-signal amplifier.

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Further electrode configuration recommendations stated by ISCEV can be found. These configurations include contact lens electrodes, conductive fibers and coils, conjunctiva loop and corneal wick electrodes as well. Since ERG evaluates the function of retina, it is also known as a clinical test used to measure the functionality of the retina in form of electrical responses [5]. An ERG test helps to diagnose diseases related to the retina and further diseases affected by other organs rather than the eyes. The test uses light flashes stimulating the eye. The rods and the cones in the cells of retina enable a tiny amount of current flow in ganglion cells. The knowledge about the quantity of light perceived by the eye as well as the quantity of electricity as an output helps to understand the clinical condition of the cells. Basically, ERG measurements require a setup consisting of several electrodes [6]. Usually, one electrode is placed on the forehead and another one is placed on the ear as the ground electrode. These two electrodes act as amplifiers [7]. Eye electrodes are usually placed close to the inner and lateral canthus as shown in Fig. 1.

II. METHODOLOGY

This section shows the methods and materials used in this project. It encompasses the methodologies for data collection and data analysis. Specific of the articles and journals related to ERG, ERG response to local luminance modulation and carriers of X-Linked Retinitis Pigmentosa (XLRP) were searched and studied [7], [8]. All articles were found in "Web of Knowledge" and "Google Scholar" websites. The aim of this research is to find frequencies that correlate with retinal functions and serve as an physiological indicator. Signal processing techniques used are based on previous research [9], [10] and [11].

A. Data collection

The procedure of ERG requires two eye electrodes placed close to the inner and lateral canthus of the subject. In this experiment, two types of electrodes were used: (1) small electrodes and (2) large electrodes.

Fig. 1. Position of eye electrodes: red circle represents the lateral canthus, whereas, the green circle shows the positionn of the electrode on the inner canthus.

In order to measure the ERG response of the retina, flickering stimulation, current stimulation and flickering with current stimulation tests were carried out.

B. Data Analysis

All ERG data were saved in CNT, EVT and TRG formats, where the CNT format contains the data, the EVT format contains event files and the TRG format contains trigger files.

In this project, we loaded CNT and TRG format files into MATLAB. Data files contained 240 s of ERG information. Notch filters of 10 Hz, 30 Hz, 50 Hz and 80 Hz with bidirectional Butterworth band pass filters from 0.2 Hz to 90 Hz were applied for the analysis. Data files contained five blocks ERG's response, which represent first baseline, first stimulation, second baseline, second stimulation and third baseline with a duration from 0 s to 60 s, 60 s to 120 s, 120 s to 240 s, 240 s to 300 s and 300s to 360s, respectively.

Analysis was preceded by extracting and averaging the stimulation blocks along 5 ERG signal blocks. The running analysis only extracted a single stimulus with a duration of 80 ms. Artifact removal was applied Averaging the artifacts with free stimuli was done before the calculation of frequency spectra could be performed by using Fourier analysis.

III. RESULTS

This section provides results on the setup explained above. Amplitude to time responses for all tests are shown as well as power to frequency spectra.

A. Flickering Stimulation Experiment

The following figures show the result of the average chunks of flickering stimulation for large electrodes analyzing in type 1, type 2 and type 3 filter, which are 50 Hz notch filter and band pass of 2 Hz – 50 Hz, 50 Hz notch filter and band pass of 2 Hz – 90 Hz and 50 Hz and 80 Hz notch filter as well as band pass of 2 Hz – 90 Hz, respectively.

An analysis of average chunks of the flickering stimulation is divided into two types of electrodes used in recording data, which are large electrodes and small electrodes. 2 subjects were chosen randomly for the 50 Hz notch filter and band pass of 2 Hz – 50 Hz tests. It was observed that results for FS, Type 2 (Fig. 3) and Type 3, regarding time and frequency chunks with 50 Hz Notch filter with Band pass 2-50Hz and Notch filter with Band pass 2-90Hz are highly similar. Therefore, the results for Type 1 are shown only. Results displayed in Fig. 3 show sinus like waveform for the evoked potential with a higher frequency in time structure compared to Fig. 2 and Fig. 4 considering the same time frame. In Fig. 4 it can be seen that the voltage values do not drastically change in time as it is the case in Fig. 2 and Fig. 3. Moreover, from the power spectra in Fig. 2 and Fig. 3 a similarity can be observed expressed in form of two extreme points being at 15 Hz and 50 Hz respectively. This is not the case in Fig. 4, where only one peak frequency at 40 Hz can be observed.

Results for the average chunks of flickering stimulation for small electrodes analyzing in type 1, type 2 and type 3 filters (Fig. 4, Fig, 5 and Fig. 6), which are the same filters applied to the large electrodes are similar to the previously mentioned results. In this analysis, four subjects were chosen randomly. The analysis of average chunks was divided into two methods.

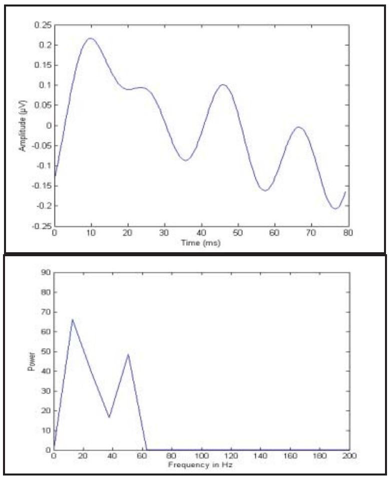

Fig. 2: Type 1, time and frequency chunks, 50hz Notch filter with Band pass 2-50Hz.

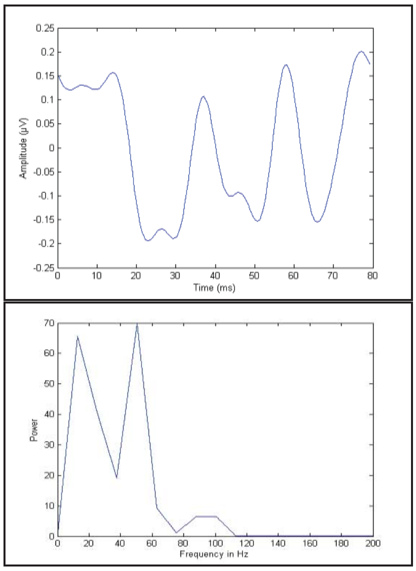

Fig. 3: Type 3, time and frequency chunks, 80 Hz Notch filter with Band pass 2-90Hz.

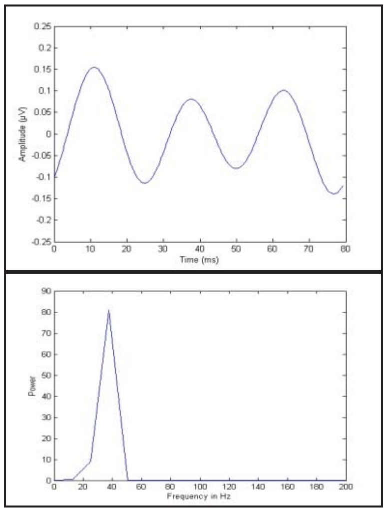

Fig. 4: Type 1, time and frequency chunks, 50 Hz Notch filter with Band pass 2-50 Hz.

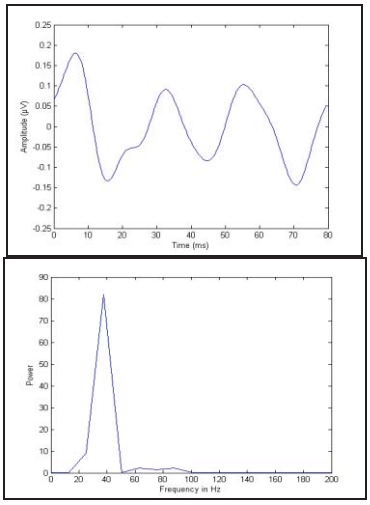

Fig. 5: Type 2, time and frequency chunks, 50 Hz Notch filter with Band pass 2-90 Hz.

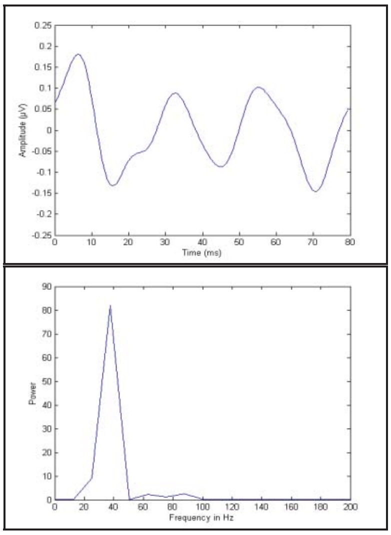

Fig. 6: Type 3, time and frequency chunks, 80 Hz Notch filter with Band pass 2-90 Hz.

The first method analyzed the signal in time domain and the other method analyzed the signal in frequency domain. Both analyses of small and large electrodes are based on the same method for data analysis purposes. For the time analysis of the signal, a graphical representation of the signal's amplitude (µV) over the time (ms) is shown. The duration of the response was about 80 ms while the amplitude showed variations over time. Frequency spectra of the time domain signal are representations of the same signal in the frequency domain. The frequency spectrum of the signal was generated via Fourier transformation.

B. Current Stimulation Experiment

Current stimulation is another experiment used for measuring the ERG response. Fig. 7 shows the example of average chunks of current stimulation analyzed in type 1 filter with 50 Hz notch filter and band pass of 2 Hz-50 Hz. The waveform of the signal is represented in the time domain. The signal shows an unstable form with a variation of amplitudes over the duration of 80 ms. For this experiment, several data of all subjects were subject to the graphical analysis. The graphical analysis was divided into two methods of analysis, which are (1) the time domain and (2) frequency domain analysis.

Fig. 7 shows the average chunks of current stimulation for type 1 filter and Fig. 8, respectively, the spectrum of the average chunks for current stimulation of 50 Hz Notch filter with band pass 2-50 Hz. This frequency spectrum output shows these characteristics because the signal source already includes varying amplitudes over time.

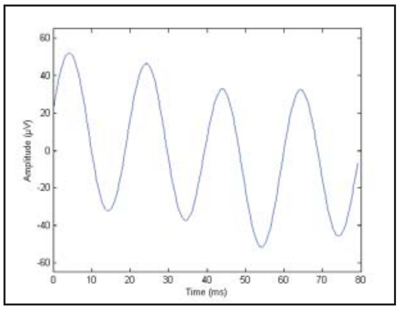

Fig. 7. Average chunks of current stimulation for type 1 filter of 50 Hz Notch filter and bandpass of 2-50 Hz in time domain.

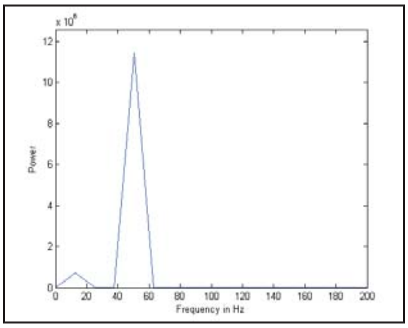

Fig. 8. Amplitude spectrum of avergae chunks of current stimulation for type 1 filter of 50 Hz Notch filter and band pass of 2-50 Hz.

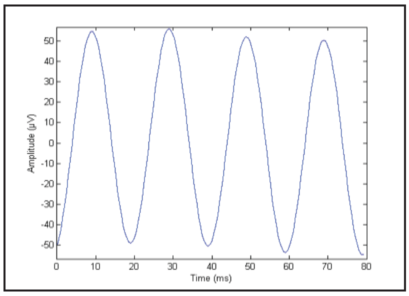

Fig. 9. Average chunks of current stimulation for type 2 filter of 50 Hz Notch filter and bandpass of 2-50 Hz

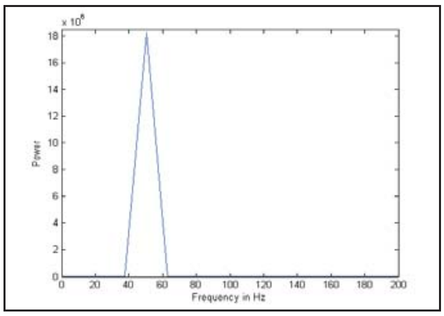

Fig. 10. Amplitude spectra of average chunks of current stimulation for type 2 filters of 10 Hz, 30 Hz and 50 Hz Notch filter and band pass of 2-50 Hz

Another type of filter was also subject to data analysis of current stimulation with 10 Hz, 30 Hz and 50 Hz Notch filter and band pass of 2-50 Hz. Its time domain response is shown in Fig. 9. This figure shows the result of average chunks of current stimulation of 50 Hz Notch filter and band pass of 2-50 Hz in time domain for the same subject but with a different filter type. The signal shows more stable sine waves. This is because various frequencies for the notch filter were applied. Fig. 10 shows amplitude spectra of Average chunks of current stimulation, which was filtered out by type 2 filters, which are 10 Hz, 30 Hz and 50 Hz Notch filters and band pass of 2-50 Hz. The spectrum of the amplitude over frequency above shows that there is no amplitude at 10 Hz and 30 Hz as the notch filters are applied in the same way to that frequency. The analysis of this current stimulation experiment was performed with another subject. Almost all subjects were producing the same results as this subject. Similar characteristics of signal waveform over time and frequency domain of type 1 and type 2 filters were observed for all subjects.

IV. DISCUSSION

Several filter types were applied for the purpose of signal analysis. However, some signals were processed with errors. Most of them are artifacts caused by the movements of the electrodes during the record of ERG responses. These data was filtered out due to interpretation deficiencies. Various filter types were used in order to reduce noise and remove artifacts of the signal. This is in accordance with [4]. For the flickering stimulation experiment, the type 1 filter produced a slightly stable signal waveform in time analysis compared to the type 2 and type 3. Signal data was filtered above of 50 Hz because most artifacts have high frequency characteristics. For the purpose of frequency analysis, two frequencies, 12.5 Hz and 37.6 Hz, were examined more precisely. It is assumed that flickering caused responses, which are visible in the amplitude spectrum at 12.5 Hz. For the current stimulation, two types of filters were used. After application of type 1 filter, the signal appears to be similar to sine waves. However, it could not produce a completely stable sinusoidal waveform. An amplitude at 12.56 Hz and 50.26 Hz was continuously observed. After application of type 2 filter, the signal produced characteristics with high similarity to the sine waves with spectrum signals at 50.26 Hz. The causality is still unclear and part of current research. These results can be used for future applications considering mobile follow up of results for medical doctors [12] and performance observation [13]. In order to avoid coarse signals in the power spectra of the ERG signal it is recommended to use spectral analysis for future works. This work is considered to be used in an online platform [14].

V. CONCLUSION

Electrodes represent the main components for ERG measurements. For comparisons, their configuration should follow standard protocols provided by ISCEV. Artifacts might occur due to human errors like movements. We could show that specific filters can be used to reduce those artifacts and noise. We could successfully identify different frequency components at 12.56 Hz and 50.26 Hz in ERG measurements in our analysis. Depending on the applied stimulations these frequencies can serve an indicator for retina function.

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