Assessment of Electrode-Based Spontaneous Eye Blink Analysis

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Abstract: In this paper, we assess the use of electrode based spontaneous eye blink recording technique (which is considered to be a suitable indicator for fatigue diagnostics) through experiments, and conclude that the electrode based measurement of eye blink parameters has some drawbacks as compared to optical methods.

Key-Words: - Eye blink, electrodes, digital filters, prevention of occupational accidents

1 Introduction

Many serious occupational accidents occur every day, because of drowsy and sleepy people.

Various methods can be implemented in prevention of such accidents caused by fatigue, drowsiness and reduced alertness. The spontaneous eye blink (SEB) is considered to be a suitable indicator for fatigue diagnostics [1]. Eye blinking is the contraction of sets of muscles around the eye and produces a myographic electrical signal. The eye blinking can be due to a reflex blink, voluntary blink (as a result of a decision to blink) or an involuntary (spontaneous) blink. The SEB is a readily observable phenomenon. Blink duration and reopening time vary proportionally with increasing drowsiness. Furthermore, the proportion of long closure duration blinks proves to be an informative parameter.

To evaluate eye blink parameters as a drowsiness indicator, various methods are proposed in technical literature. The simplest method of eye blink detection is the direct observation of a person. The object's eyelids closed/open position can be determined via optical means as either the infrared light reflection from the eye fundus or eyelid is analyzed, or the movements of object's eyelashes are detected. The use of infrared (IR) light is preferred, because infrared light generates least distraction to the object. However, to use eyelashes for analyzing the eye movements of the object has disadvantages. Eyelashes are too whimsical for an optical system, since they can be dark, blond, thick or thin.

An IR light beam is interrupted by the movements of the eyelid, instead for being interrupted by the movements of eyelashes. In this method, A tiny slide-adjustable light emitter carrier, sliding along the eyeglass temple, is used for positioning the light emitter on the eyeglass properly for each object. A narrow-band light beam from this emitter is aimed across the surface of the object's eye, just above the eyeball, between the eyelids, and it is sensed in the opposite corner of the eye by means of a light sensor, which has a narrow band optical filter mounted in front of it.

Another method is based on different reflection of the infrared or visible light from eyelid and cornea/iris using a video camera. However, the motion of eyelids is fast, and the method is usually disturbed by shadows and noise. If the point tracking fails, the whole eyelid tracking fails, and
the error is accumulated in the following video frames [2].

In some of these methods [3], a sensor clipped to an eyeglass frame records eyelid movements. Although the method uses a simple physical design, it is prone to technical difficulties and measurement ambiguity, since the eyeglass may move out of the beam path.

In this paper, we assess the use of electrode based spontaneous eye blink recording technique.

2 Experimental

Ten healthy volunteers (students of Biomedical Engineering Department, mean age of 20) participated in this study. The eye blinks were recorded in the morning. Subjective estimation of the personal state served to evaluate the individually perceived drowsiness, especially the effects of previous night sleep or sleep deprivation.

The participants were seated about 2 m in front of a wall. They were asked to read a book for 20 min. Neither actual details about the objective of the experiment nor further instructions about eye movements or blinks were given to the subjects.

Each of the three electrodes used are of latex free single use neonatal type Ag/AgCl, with cloth, adhesive hydrogel and lead attached safety socket connector, which is prewired and has relatively small (2.54cm) diameter. (Ludlow Co., Chicopee, MA, USA)

Electronic circuit that has been used in amplification and signal conditioning consists of a high pass filter with cut-off frequency at 0.16 Hz, an instrumentation amplifier, a non-inverting amplifier and a twin-T band reject filter with notch frequency of 50 Hz., theory of which is given elsewhere [4]. The block diagram of this analog part is shown in Fig.1. Electrodes positioning is displayed in Fig.2.

Although the analog signal amplification circuit contains a twin-T notch filter, power line interference remains still a significant source of disturbance. This problem is solved by implementing a digital filter, following the analog hardware amplifier. Filter design is realized in Matlab platform. As part of the procedure, blink signal output of the amplifier-filter circuit is digitized and transferred to Matlab, so that it is first analyzed for its Fourier power spectrum. It has been shown that the signal main power is concentrated at frequencies below 10 Hz. On the other hand, contamination at the power line frequency seems apparent for this signal spectrum. A digital low pass Finite Impulse Response (FIR) equiripple filter of order 85 (with Passband Frequency at 30 Hz, Stopband Frequency at 45 Hz, Passband Ripple 0.0575, Stopband Attenuation factor 0.0001) yields acceptable results (with minimal delay).

Fig.1. Block diagram of electronics used. 1-High Pass Filters, 2-Instrumentation Amplifier, 3-Non-inverting Amplifier, 4-Notch Filter, 5,6- Electrodes.

Fig.2. Positioning of the electrodes

Fig.3. A typical blink signal spectrum
Fig. 4 Magnitude transfer function for digital low pass Finite Impulse Response (FIR) equiripple filter of order 85 (with Passband Frequency at 30 Hz, Stopband Frequency at 45Hz, Passband Ripple 0.0575, Stopband Attenuation factor 0.0001)

Figs 3 and Fig.4 show typical signal spectrum and the filter magnitude transfer function, respectively.

3 Results and Discussion

SEB records are obtained at three different gaze angles.(Downward, forward and upwards). Fig 5 shows a typical filtered blink signal with some dc bias. Evaluated parameters of eye blinks are blink frequency [blinks/minute], amplitude and duration.

Fig 5. A typical filtered blink signal recorded in down gaze, using three electrodes method.

The orbicularis oculi (OO) muscle contraction and lid movement are two related but different aspects of blinking. The orbicularis oculi contraction does not fully account for the lid movement. Relaxation of the levator palpebrae is also a determinant of the speed and amplitude of the lid movement.

Fig. 6. Forward (rightmost pulse), down (mid pulse) and up (leftmost pulse) looking eye blinks. It is expected that up looking blink would yield the signal with the highest amplitude, while down looking blink would have the least amplitude. However, experiments may show surprisingly different results, as displayed here. (Horizontal axis: 10 ms sampled data, vertical axis in volts. No further DSP filtering ).

Associations between lid movements revealed that reflex blink in comparison to spontaneous blinks, were characterized by: (1) an OO-EMG onset before the downward movement of the lid; (2) shorter durations in both OO-EMG activity and downward and upward eyelid movement; and (3) larger peak amplitudes in OO-EMG activity. Spontaneous blinks were characterized by a lower maximum lid velocity than reflex blinks [5].

In spite of the fact that it produces relatively characteristic and easily generated signals, inconvenience of applying sticky electrodes on the skin is an obvious drawback of the electrode based spontaneous blink analysis method. The cause of such an inconvenience for the object is mainly due to the lengthy connecting electrode cables and not the irritation due to skin-electrode interface, which can be reduced further by the use of small diameter neonatal type surface electrodes.

Blink rate appears to be influenced by psychophysiological factors. A relaxed person blinks about 15-20 times per minute. When performing cognitive tasks the blink frequency drops. Detecting the eye blink rate can be helpful for
the prognosis of physiological or psychological human conditions. For example, if the eye-blink frequency is abnormal, this may be an alert to an abnormal pathological state such as schizophrenia or Parkinson’s disease [6]. In addition, it is well known that when a person tells a lie, the eye-blink speed is faster than that found during relaxed states, owing to anxiety [7]. Blinking rate also depends on gender, age, kind of activity, ambient characteristics, and time of day [8]-[12].

However, BR can be more voluntary than the blink duration. For this reason, present study concentrates more on the spontaneous eye blink duration (SEBD), and its rise time as well as fall time, which will be the subject of our future report.

4 Conclusion

A mobile spontaneous eye blink measurement unit can be useful in assessing drowsiness under real life conditions. Such a mobile device can be made to fit on the object, and continuously register and/or monitor objects alertness. We aim to design and realize such a mobile device. As part of this ongoing research program, an electrode-based system is evaluated for its merits. It is noted that electrode-based system creates some inconvenience to the object for the long run experiments, although it produces acceptable records.

References: