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ANALYSIS OF BLINK RATE VARIABILITY DURING READING AND MEMORY TESTING

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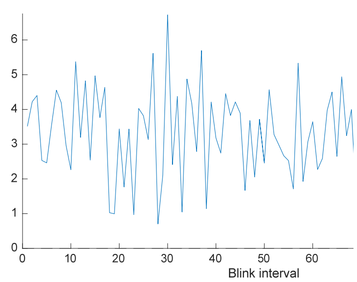
Graphical abstract



Abstract

In this paper we investigated how statistical properties of the blink rate variability changes during two mental tasks: reading a passage and memory testing. To construct time series of inter-blink intervals (blink rate variability) we detected exact blink time in EEG recordings using our blink detection algorithm. We found that among 13 subjects, all subjects blinked less during reading session. Moreover, standard deviation of the blink rate variability is higher during reading. Thus, we conclude that the variability of inter-blink intervals decreases during tasks that require concentration and intense mental activity.

Keywords: eye blink, blink rate variability

1.0 INTRODUCTION

Blinking is a semi-autonomic closing of the eyelids. Occurrence, reasons and characteristics of blink rate, varies between animals, and it is possible to trace the evolution of the blinking mechanisms through species. [1]. Every time we blink, our eyelids spread a cocktail of oils and mucous secretions across the surface of the eye to keep your globes from drying out. Each blink spreads the tears on the eye cornea to moisture and disinfects the eye. Reduced blink rate causes eye redness and dryness also known as Dry Eye, which belongs to the major symptoms of the Computer Vision Syndrome [2]. Besides blink keeps eyes protected against potentially damaging stimuli, such as bright lights and foreign bodies like dust.

However, people don't even notice the world going into darkness every few seconds. The sudden changes in an image due to saccades or blinks, do not interfere with our subjective experience of continuity 3, the very act of blinking suppresses an activity in several areas of the brain responsible for detecting environmental changes, so that you experience the world as continuous. Researchers have shown the synchronous behavior in blinking between listener and speaker in face-to-face conversation [3].

The blinks have been known to be linked to interior brain activities. Ponder and Kennedy 7 implicated that high processes are major determinants of Blink enhancements and inhibition [4].

Researchers have shown that blinks can play a significant role in detecting many different brain disorder and brain activities. Spontaneous Blink Rate (BR) has been studied in many neurological diseases like Parkinson's disease and Tourette syndrome [5-7]. Researchers have found that blink rates can be used as a source of data in detecting psychiatric disorders like schizophrenia and attention hyperactivity all this is because blinks are regarded as non-invasive peripheral markers of the central dopamine activity which makes their accurate detection more important.

World Health Organization (WHO) has announced that the ninth cause of death globally is car accidents. National Motor Vehicle Crash Causation Survey (NMVCCS) has found that 30% of car accidents are caused by the drowsiness of drivers [13]. It is known that workload increases heart rate and heart rate are known to decrease in monotonous and drowsy conditions. On the other hand BR is inversely correlated with the increase of workload, so blinks can be used to detect drowsiness before accident happens [14].

It is evident that eye blinks in general and the BR specifically is linked to brain activity. In this paper, we investigate the relationship between brain activities during reading and memory test, and the blink rate variability. To estimate blink rate variability, we utilize a blink detection algorithm that we proposed earlier [8] and briefly describe in section 3. The experimental setup is described in section 2. In the sections 4 we discuss on the relationship between the blink rate and the task, and in section 5 we elaborate on the statistical properties of blink rate variability and their relationship to the reading task and memory test.

2.0 EXPERIMENTAL SETUP

2.1 Data acquisition

The video stream while subjects were performing the test was captured with a Pointgrey Flea3 high frame rate USB camera. We stored the video for future work. Simultaneously, EEG signals were recorded using Mitsar-EEG 201 amplifier and accompanying WinEEG software. The electrodes were placed according to the international "10-20 system" standards of electrode placement [9]. Electro-gel was injected into electrodes hollow in order to decrease the electrode-skin resistance. Currently, we are more focused on the recording of the blinks than the brain data, but In the future we are planning to analyze EEG to detect different types of brain activities while performing these exams.

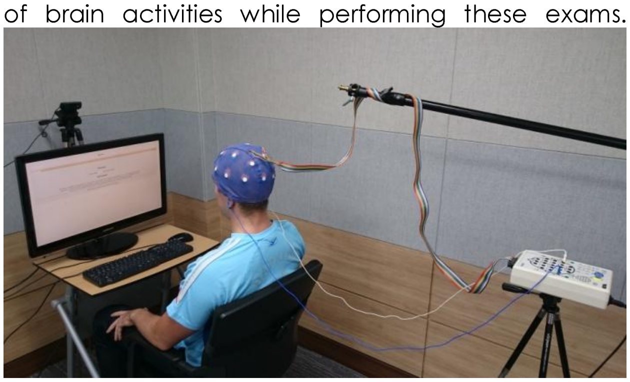


Fig. 1. Experimental setup

2.2 Testing procedure

Eighteen young subjects (15 men and 3 women) aged from 19-25 years, were recruited for the experiment. All provided their written consent. The subjects had no history of psychiatric illness, had normal physical, and they had not been affected by any significant medical, neurological or ophthalmological illness. To avoid substance abuse, we prepared a questionnaire testifying that they had none of these issues. Among them, five subjects were dropped due to heavy noise caused by the subjects falling asleep, adjusting the cap or constant head movements.

The Test for the data recording session consisted of two different stages: (A) Reading Passage, and (B) Comprehension Test. We developed the testing software is such a way that it does not require any interventions from either the Subjects or the experiment supervisor to conduct this experiment. The whole testing session took 10 minutes. The first 5 minutes is the passage reading session. The passage consists of basic facts about Ethiopia, and the target of this passage was to record data while subjects were trying to store memory. Lastly, subjects were given a 5 minutes comprehension test about the passage. The questions were derived from the information provided in the passage. It was designed to get subject to retrieve the memory they stored earlier making this session two different brain processes. Since EEG is prone to noise due to movement, we made sure that subjects answered the question by using the numbers from 1 to 6 on the keypad of a keyboard.

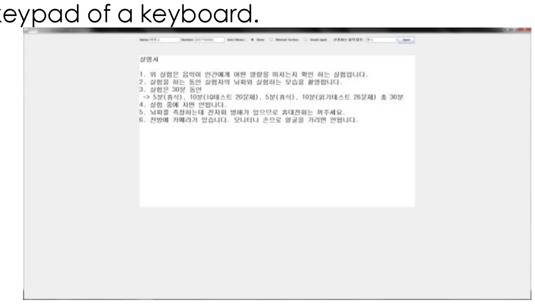


Fig. 2. Question delivery software

3.0 Estimation of the Blink Rate Variability

EEG signals were recorded while participants were taking the tests. We used bipolar montage while recording these signals, which means we determine the potential between Fp1 and Fp3, also Fp2 and Fp4 for both pairs. The recordings were then imported in the form of CSV files to Matlab for further analysis. The process of blink detection is described in our previous work [8]. Here we briefly overview.

Generally, it can be divided into two stages: the preprocessing stage and the blink detection stage. The preprocessing stage consists of the following steps: (a) bandpass filtering, (b) thresholding extreme amplitudes using Cumulative Distribution Function, characterizing amplitude distribution, (c) independent component analysis and (d) selection of the independent component with eye blinks. The blink detection stage consists of (d) signal thresholding, (e) candidate extraction, (f) polynomial fitting with finding maximum in the polynomial function (Fig. 4), and (g) finally calculating blink rate variability (Fig. 5).

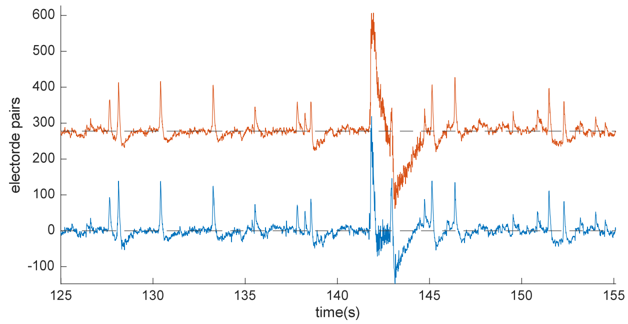


Fig. 3. Fp1-Fp3 and Fp2-Fp4 electrode pairs

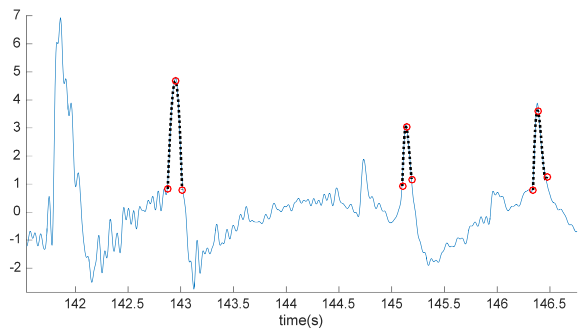


Fig. 4. 3rd degree polynomial function is fitted to every waveform blink candidate. The localized peak corresponds to the time of a blink.

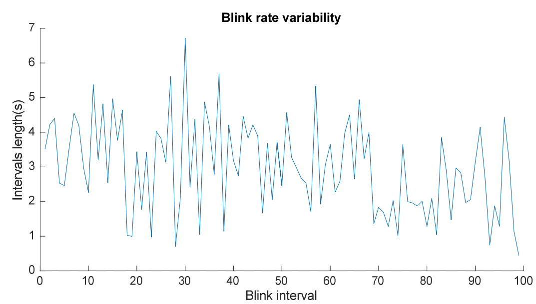


Fig. 5. Extracted blink rate variability

4.0 Blink rate and blink rate variability during reading and memory testing

Bentivoglio et al, studied blink rate during rest, reading and conversation. It was showed that blink rate patterns are influenced more by cognitive processes rather than by age, eye color or gender [10]. Hart H.W distinguishes three types of an eye blink: spontaneous, reflex and voluntary were identified [11]. He also estimated that blinks occur on average, about 12 -15 times/min [11]. In [12] it was noted that spontaneous BR increases at the evening time.

Here we investigate how the number of blinks changes depending on the task. We considered two tasks: reading a passage task and the memory test that is based on the same passage that subject was given. Among 13 subjects, all of them blinked less while reading. This result agrees with [15], where blinking has been related to certain cognitive processes. Blinking is a function of memory load, such that the more items in memory, the fewer the blinks. Reading is an intensive process in which eyes moves quickly to assimilate text. It is necessary to understand that reading is a searching process intern this requires a prolonged focus on reading material as we are relating each words with its predecessors to make sense out of the whole sentence.

Operational memory, which is used during solving mental tasks, and visual imagination, may share components with a visual perceptual system. To avoid interference of cognitive processes, blinking is slowed down [16]. Number of blinks per each of 13 subjects is presented in table 1 and Fig.6.

Subj.	Passage	Test
1	100	186
2	177	200
3	32	75
4	93	173
5	64	102
6	84	94
7	60	145
8	94	123
9	132	141
10	47	66
11	151	186
12	122	185
13	119	196

Table 1. Table comparison of manual blink counting vs. our proposed algorithm

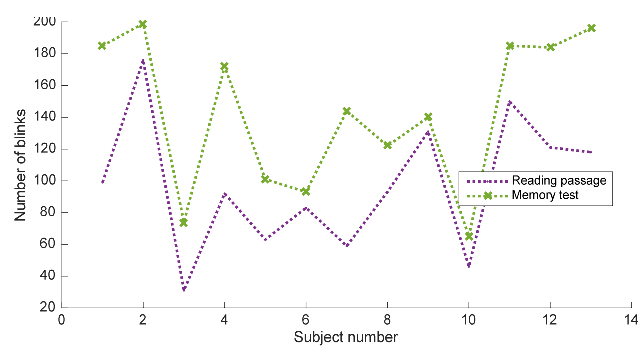


Fig. 6. Number of blinks depending on the task

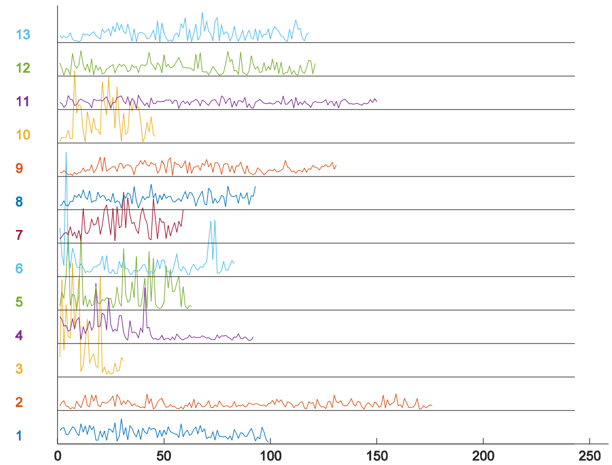


Fig. 7. Blink rate variability during passage reading

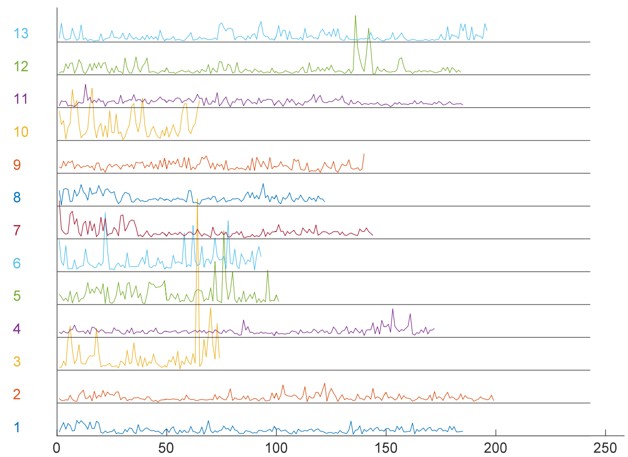


Fig. 8. Blink rate variability during memory testing

Fig. 7 and Fig. 8 compare BRV for all the subjects during the memory test. The X-axis is the blink interval where Y-axis presents interval lengths per each subject. Even though BRV visually looks different, the statistical properties are consistent. The mean and the standard deviations of BRV are lower during memory test than during reading session for all subjects. Passage test, as task involving memory, increases BR, while reading reduces it. Reading new information appears to be a heavier mental process than test, and operational memory is more in use. Moreover, in the text are longer, and ideas are more developed than in the test. Therefore, maybe we could find reflection in concept of blinking as an interlude between ideas or sentences[16].

Time between blinks changes, for reading it is shorter and elongates for the test. Fig. 9 presents average inter-blink per each subject in both stages, reading and memory test. Fig. 10 shows standard deviation of IBI dynamics. Longer inter-blink in reading is caused because of fixation points while reading. Humans read each word at a time this are called fixation. From one fixation to another there is a search for the next fixation so this requires less blinks and more focus. Also longer inter-Blinks are caused because reading is a cognitive process which increases brain activity [17].

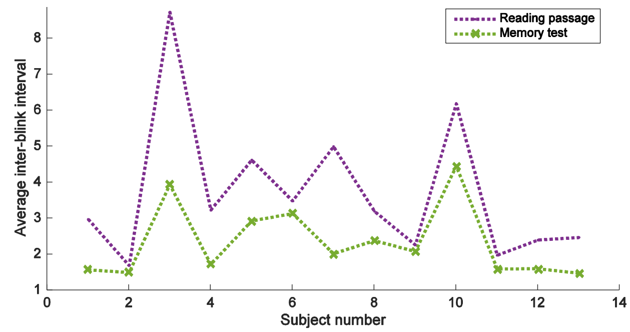


Fig. 9. Average inter-blink

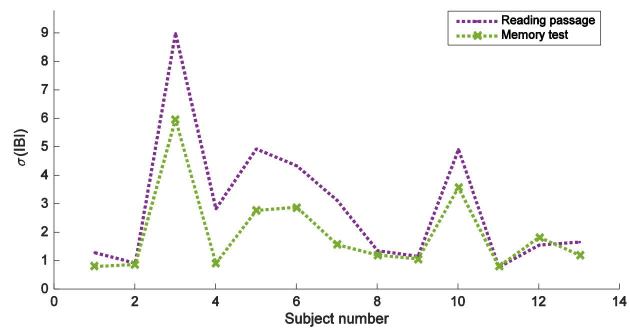


Fig. 10. Standard deviation of IBI dynamics

5.0 CONCLUSION

In 1927 Ponder and Kennedy Z's implication that high processes are major determinants of blink enhancements and inhibition. They also mentioned that blinks might serve as an index of attention, or as they termed it "mental tension". They inferred that person inhibits blinking while actively engaged in information abstraction, whether in response or to simple stimuli. In 1945, Hall wrote that blinks don't occur randomly during reading.

Our results have shown that there is lesser number of blinks in reading a passage than performing a memory test. Reading has lower blink rates because people read sentences by fixing on words so this search for the fixation will decrease there blinking rates. Also standard deviation of the blink rate variability is higher during reading. Studies suggested that blink behavior during reading is under perceptual and cognitive control [17]. Our results show higher blink rates while subjects performed the memory test. Subjects are aware that the memory test has a time limits and accessing memory needs faster brain activity. Therefore the conclusion is the inter-blink intervals' variability decreases during tasks with more intensive workloads. In other words it means that task requires concentration and intense mental activity, when we start blinking rarely.

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