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Eye-blink related changes in EEG during an auditory working-memory task performance

Petar Horki[1] and Gernot R. Müller-Putz[1]
[1]Institute for Knowledge Discovery, BCI Lab, Graz University of Technology, Graz, Austria
petar.horki@tugraz.at, gernot.mueller@tugraz.at

Abstract

We investigated eye-blink related changes in EEG during an auditory working memory task. To that end, we used the onset of eye blinks following the presentation of the target letter as triggers for data analysis. No evidence for an active role of spontaneous eye-blinks in the working memory task could be found.

1 Introduction

In (Horki and Müller-Putz, 2013) we reported frontal EEG theta band oscillations for a mental task related to working memory, but found no such event-related changes for a control task. Based on the current literature, we assumed these EEG changes were not due to eye-movement artifact, such as eye-blinks. However, having performed a more detailed analysis, precluded by a rigorous artifact rejection and removal procedure, we were surprised to find these EEG changes absent in the cleaned data. Thus, it seems that some users exhibited spontaneous eye-blinks correlated to the presentation of the target stimuli, even after being instructed differently.

A closer visual inspection of the original EEG data revealed that, while performing the working memory tasks, eight out of eleven participants blinked with their eyes more often than every second time. Was this merely a coincidence, or where these eye-blinks somehow task-related? The latter case could lead to a classifier adapted to eye-movements, and thus to a biased evaluation.

Spontaneous eye-blinks have been observed at breakpoints of attention during reading, listening to speech, and while viewing videos (Nakano et al., 2013). In a recent work (Nakano et al. 2013), it was suggested that spontaneous eye-blinks play an active role in the release of attention from external stimuli while attentively engaging in a cognitive task. Based on these findings, we investigated whether the eye-blinks observed during our experiment are somehow related to the working memory task. To that end, we have redone the analysis from (Horki and Müller-Putz, 2013), this time using the onset of eye blinks following the presentation of the target letter as triggers.

2 Methods

2.1 Subjects

Eleven healthy subjects (5 male, 6 female; 22 to 29 year old, mean age 26) participated in this experiment. They were recruited through university publice notice boards (i.e. newsgroup, forum). Participants gave informed consent prior to the beginning of the experiments and received monetary compensation afterwards. Half of the participants had no previous exposure to EEG experiments. The experiment was undertaken in accordance with the Declaration of Helsinki.

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2.2 Recording

The EEG was recorded with 29 active electrodes (g.tec, Guger Technologies, Graz, Austria) overlying the frontal, central, and parietal scalp areas. In detail, the electrodes were placed at positions AFz, F3, F1, Fz, F2, F4, FC2, FC1, FCz, FC4, C5, C3, C1, Cz, C2, C4, C6, CP3, CP1, CPz, CP2, CP4, P3, P1, Pz, P2, P4 and POz according to the international 10 / 20 electrode system. The EEG electrodes were referenced to the left ear lobe with the ground electrode placed on the right ear lobe. The electrodes were integrated into a standard EEG cap (Easycap GmbH, Herrsching, Germany) with an inter-electrode distance of 2.5 cm and connected to EEG amplifiers (g.tec, Graz, Austria).

The electrooculogram (EOG) was recorded with three active electrodes (g.tec, Guget Technologies, Graz, Austria), positioned above the nasion, and below the outer canthi of the eyes. The electromyogram (EMG) was recorded with four electrodes from both legs (musculustibialis anterior). The EEG amplifiers were set up with a bandpass filter between 0.5 and 100 Hz, and a notch filter at 50 Hz. The EEG and EOG were sampled with 512 Hz, the EMG with 2000 Hz. Participants were seated in an electrically shielded room.

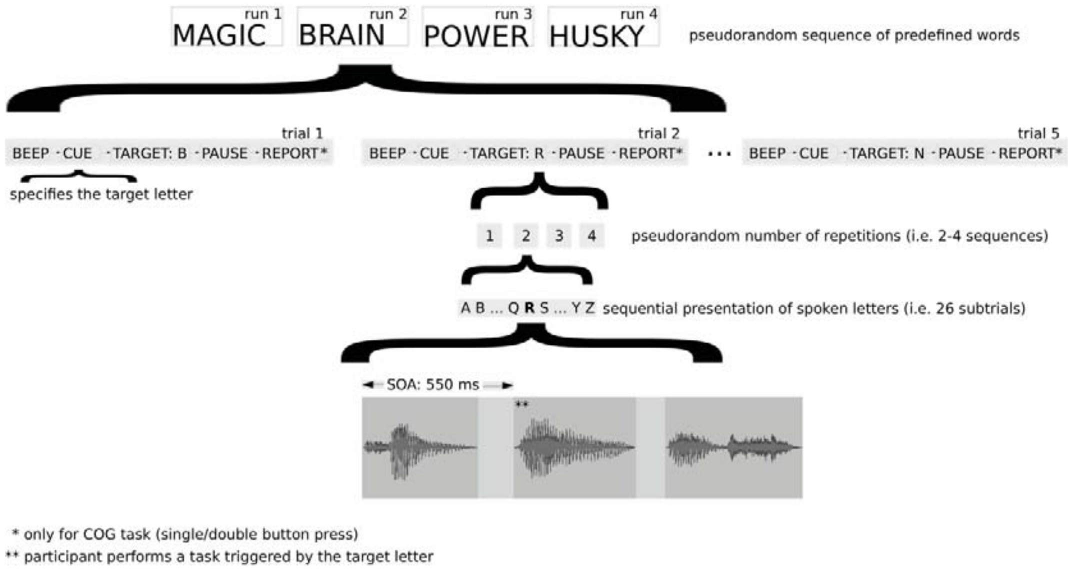
2.3 Stimuli

Spoken letters of the English alphabet, generated by a text-to-speech program (AT&T Natural Voices, AT&T, USA), were presented sequentially in alphabetical order through a right head phone for one of several predefined words. Presenting acoustic cues through one ear only, keeps the other ear free for incoming communication from surroundings. The task irrelevant acoustic cues were presented in either male or female voice, and were balanced across all the subjects. Stimulus onset asynchrony was set to 550 ms, including a 50 ms pause. Thus, it took 14.3 s for a single presentation of the whole alphabet. For each target letter, indicated through a verbal cue, the alphabet was repeated one to three times, for a total of two to four alphabet presentations, followed by a short break of random length (i.e. four to six seconds).

2.4 Experimental paradigm

The experimental paradigm is depicted in Figure 1. For the investigation the predefined words “brain”, ”power”, “husky” and “magic” – had to be spelled in copy spelling mode. They were chosen because their letters are distributed across the whole alphabet range. Each word was spelled letter by letter within a single run. Runs were separated by short break of 1-2 min to avoid fatigue.

The participants were instructed verbally to perform either a motor or an non-motor mental task whenever a target letter was presented. For the purpose of this abstract, we focus only on the following non-motor mental tasks: (i) discrimination of the target voice’s gender and comparison to the following repetition (i.e. whether the target voice’s gender has changed or it remained the same; reporting through single / double button press with index finger of the right hand in a dedicated time window) as a cognitive task (COG); and (ii) mental repetition of the target letter as a control condition (AEP). The COG and AEP conditions were pseudo randomized. We randomized the order of words, and balanced the voice of presentation (male / female). The participants were also verbally instructed to avoid any movements, and received no feedback.



2.5 Data analysis

EEG analysis was performed for the COG tasks using MATLAB 2009a (MathWorks, USA) and EEGLAB version 11.

The data was high-pass filtered (3rd order butterworth filter) with cut-off frequency at 1 Hz, and segmented into consecutive epochs of 0.5 s. Bad channels and prominent artifacts (i.e. swallowing, electrode cable movements, etc.) were identified by visual inspection and removed. The data was triggered by the onset of eye blinks. To that end, only the first eye blink during the 2s following the onset of the target letter presentation was used to determine the trigger. The eye-blinks before the target letter presentations were ignored. The same triggers were used to calculate grand average EEG event-related potentials (ERPs).

To analyze the percentage of power decrease (ERD) or power increase (ERS) relative to a reference interval (0.5 s preceding the stimulus onset), a time-frequency map for frequency bands between 4 and 40 Hz (35 overlapping bands using a band width of 2 Hz) was calculated on downsampled (128 Hz) data. Logarithmic band power features, calculated by band-pass filtering, squaring and subsequently averaging over the trials, were used to assess changes in the frequency domain. To determine the statistical significance of the ERD/ERS values a t-percentile bootstrap algorithm with a significance level of α=0.01 was applied. The ERDS analysis was conducted for the COG task on a single bipolar derivation AFz-Fz.

3 Results

In Table 1 the number of epochs containing eye-blinks during the 2 s following the target letter presentation, the most frequent eye-blink trigger latency relative to the target letter presentation onset, and the accuracy of reporting, for eight participants, are shown for the COG condition. The maximum number of epochs per participant possible was 60, and only the participants with 30 eye-blink epochs or more were included in the analysis. The distribution of the aforementioned eye-blink trigger latency could be approximated by a normal distribution peaking at around 0.8 s relative to the target letter presentation onset.

	S1	S2	S3	S4	S5	S6	S7	S8	μ±σ
#Eye-blink epochs	44	40	47	30	38	41	43	35	40±5
Trigger latency [s]	0.7	0.8	0.5	0.8	0.6	0.8	0.6	0.8	0.7±0.1
Reporting acc [%]	90	100	100	90	100	100	40	90	89±20

Table 1: Number of epochs containing eye-blinks during the 2s following the target letter presentation (COG condition), the most frequent eye-blink trigger latency relative to the target letter presentation onset, and the accuracy of reporting, for eight participants. The maximum number of epochs per participant possible

Reanalysis of eye-blink triggered data revealed no significant (p=0.01) frontal oscillatory EEG changes. The only time oscillatory EEG changes were observed, was when the original triggers (i.e. onset of the target letter presentation) were employed instead, indicating that these EEG changes were due to eye-blink artifacts. The grand average EEG event-related potentials were, as expected, dominated by the eye-blinks used to trigger the data.

4 Discussion and Conclusion

Using the methods from (Horki and Müller-Putz, 2013), no evidence for an active role of spontaneous eye-blinks in the working memory (COG) task could be found. However, methods for analysis of connectivity may provide further insight. Removing the EOG artifacts in COG condition revealed task-related modulation of several ERP components (Horki et al. 2014).

Notable is that in (Horki and Müller-Putz, 2013) a separate control condition (AEP) yielded different results in the presence of eye-blink artifacts. Also, for the AEP condition there were only two out of eight participants with 30 eye-blink epochs or more (μ±σ: 22±13, range: 8 to 38), with neither an apparent distribution nor mode of eye-blinks.

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References

P. Horki, and G. Müller-Putz. (2013) *A Novel Approach to Auditory EEG-Based Spelling.* Proceedings of the Fifth international BCI meeting, pp. 316 - 317.

P. Horki, D. S. Klobassa, C. Pokorny, and G. Müller-Putz. (2014) *Evaluation of Healthy EEG Responses for Spelling Through Listener-Assisted Scanning,* IEEE Journal of Biomedical and Health Informatics, in press.

T. Nakano, M. Kato, Y. Morito, S. Itoi, and S. Kitazawa. (2013) *Blink-related momentary activation of the default mode network while viewing videos.* PNAS 110 (2), pp. 702-706.