Attention of Driver during Simulated Drive

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Abstract: Attention of drivers is a key factor of road safety. Since inattentive drivers cause a considerable number of accidents, it is worth to examine the causes and course of driver's attention even in laboratory conditions during a simulated drive. This paper deals with the experiment in which the methods of electroencephalography and event related potentials are used under various conditions to investigate driver's attention. Eleven participants, university students, were stimulated with audio signals during monotonous drive in four experimental sessions. The hypothesis is that the peak latency of the P3 component increases in time as the driver is more tired from monotonous drive, daytime and sleep deprivation. The background of the used methods, experimental design, participants, data processing, results and final discussion are presented in this paper.

1 INTRODUCTION

Attention of drivers is a key factor of road safety. Inattentive drivers are dangerous to their surroundings and cause a considerable number of accidents. However, decline of attention, especially during long rides, is natural.

In this paper we focus on influence of monotonous drive on driver's attention during simulated drive. Moreover, attention of driver can be also influenced by daytime and sleep deprivation. This is not investigated by using common behavioral techniques; the methods of electroencephalography (EEG) and event related potentials (ERP) are used. An ERP auditory experiment is performed during a drive (a car simulator is used) and the subsequent analysis of the changes in the peak latency of the P3 component is investigated. The hypothesis is that the peak latency of the P3 component (peak latency represents the level of driver's attention) increases in time as the driver is more tired from monotonous drive, daytime and/or sleep deprivation. University students as tested subjects participated in the EPR experiment; their results were analyzed and partially interpreted. However, a deep analysis that includes e.g. statistical evaluation of the results is still in progress and thus it is not described in this paper. The paper builds on the already published experiments and results (Moucek and Rondik, 2012) and (Moucek and Rericha, 2012) provided by the authors research group. These experiments are based on the same hypothesis but their design differs and evolves in time according to previous experience and knowledge.

The paper is organized as follows. Section 2 gives a short overview of basic principles of the ERP technique and assumptions related to P3 amplitude and P3 latency. It provides readers with essential ideas that are important for the design of experiments described further. Then the experiments dealing with attention of drivers are summarized and extended with respect to the papers (Moucek and Rondik, 2012) and (Moucek and Rericha, 2012). The objectives of the designed experiment are given in Section 3. The description of experimental design, hardware equipment, software tools, participants, course of experiment, environment and obtained data and metadata is given in Section 4. Data preprocessing is presented in Section 5; experimental results extended by the final discussion are provided in Section 6.

2 STATE OF THE ART

This section provides a short description of the ERP technique, the P3 component and especially the relation of P3 amplitude and P3 latency to attention. Then a short overview of EEG/ERP experiments deal-

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ing with driver's attention is presented.

2.1 Event Related Potentials and P3 Component

ERPs were first used as an alternative to measurements of the speed and accuracy of motor responses in paradigms with discrete stimuli and responses. They have two advantages compared to behavioral methods: they are useful for determining which stage or stages of processing are influenced by a given experimental manipulation (a detailed set of examples is in (Luck et al., 2000)) and they provide an online measure of the processing of stimuli even when there is no behavioral response (Luck, 2005).

The P3 component depends entirely on the task performed by the subject and is not directly influenced by the physical properties of the stimulus. It is sensitive to a variety of global factors, such as time since the last meal, weather, body temperature, and even day time or the time of year (Luck, 2005). Although thousands of experiments related to the P3 component have been published, we still do not know exactly what the P3 component really means. The proposal that the P3 component is related to a process called context updating seems to be approximately correct (Luck, 2005).

On the other hand, there are known the factors which influence the amplitude and the latency of the P3 component that is sensitive to the probability of the target stimulus. Ideas and assumptions related to the latency of the P3 component are associated with stimulus categorization. If stimulus categorization is postponed (it also includes increasing the time required for low-level sensory processing), P3 latency is increased. While P3 latency depends on the time required to stimulus categorization, it does not depend on consequent processes (e.g. response selection). Thus P3 latency can be used to determine if a performed experiment influences the processes of stimulus categorization or processes related to a response (Luck, 2005).

In our case we suppose that stimulus categorization is influenced by driver fatigue and the time required for low-level sensory processing of incoming stimuli increases with the level of fatigue.

2.2 Experiments on Driver's Attention

Omitting behavioral studies not many experiments dealing with driver's attention during simulated drive were performed using the techniques of electroencephalography and event related potentials.

Suitability of EEG-based techniques is described in (Schier, 2000); drivers' activity during a driving simulation task was recorded. As the result, an increase in alpha activity was interpreted as less attentional activity and a decrease as more attentional activity.

EEG data as an effective indicator to evaluate driver fatigue are presented in (Li et al., 2012). The evaluation model for driver fatigue was established with the regression equation based on the EEG data from two significant electrodes Fp1 and O1. The accuracy of the model was about 92.3%.

The impact of a surrogate Forward Collision Warning System and its reliability according to the driver's attentional state by recording both behavioral and electrophysiological data was presented in (Bueno et al., 2012). These results showed that electrophysiological data could be a valuable tool to complement behavioral data and to have a better understanding of how these systems impact the driver.

The effect of a normal night's sleep vs. prior sleep restricted to five hours, in a counterbalanced design, on prolonged (two hours) afternoon simulated driving in 20 younger and 19 older healthy men was studied in (Filtness et al., 2012). After sleep restriction younger drivers showed significantly more sleepiness-related deviations and greater 4 to 11 Hz EEG power, indicative of sleepiness.

The ERP technique was used in (Wester et al., 2008) where the impact of secondary task performance (an auditory oddball task) on a primary driving task (lane keeping) was investigated. The study showed that when performing a simple secondary task during driving, performance of the driving task and this secondary task are both unaffected (Wester et al., 2008).

3 OBJECTIVES OF EXPERIMENT

The assumptions described in Section 2 have been taken into account during designing the experiment. Then the objectives of the experiment are:

- To construct a monotonous track where a substantial decrease of attention is supposed.
- To design and implement a simple auditory ERP experiment.
- To perform the auditory ERP experiment on the group of participants in the following way: each participant undergoes four drives in a car simulator, these drives are held in two days, one drive in the morning (between 9 and 12 AM) and one

drive in the afternoon (between 1 and 4 PM). The participant completes first two drives after a usual night's sleep, while the other two drives are completed after a sleep restricted to a maximum of four hours.

- To divide each drive into time intervals of the same length.
- To compare the latency of the averaged P3 components depending on daytime and sleep deprivation and to evaluate results to confirm/reject the hypothesis given in Section 1.

4 DESIGN OF EXPERIMENT

A simple auditory ERP protocol was designed. All participants were elicited by the following three auditory stimuli:

- non-target stimulus S1 is a harmonious tone at a frequency of 560 Hz, duration time 500 ms with probability of occurrence p = 0.86,
- target stimulus S2 is a harmonious tone at a frequency of 880 Hz, duration time 500 ms with probability of occurrence p = 0.11,
- rare stimulus S3 is a continuous change of a harmonious tone at a frequency of 200 Hz to a harmonious tone at a frequency of 1000 Hz and back, duration time 1000 ms, probability of occurrence p = 0.03.

The stimulus onset asynchrony (SOA) was set to 1500 ms. Two target stimuli cannot be sequential. The stimuli were played from the speakers inside the car simulator.

Each drive was 20 minutes long and consisted of four sub-sessions. Each sub-session was five minutes long, participants were stimulated in the second and fourth sub-session. The first and third sub-sessions served both for relaxation of the participant and for preventing the participant from familiarity with the presented stimuli. During all stimulation sessions the participants drove the car simulator on a monotonous track. The participant responded to the target stimulus by changing lanes.

4.1 Hardware Equipment

All experiments were performed in the neuroinformatics laboratory at Department of Computer Science and Engineering, University of West Bohemia, equipped with all necessary hardware devices for EEG/ERPs recording. The experimental car simulator was equipped with the Logitech G27 wheel, accelerator, and brake. Four computers were used: the first one for presentation of stimuli, the second one for storing recorded data, the third one for the presentation of the track, and the fourth one for storing video recordings of drivers from the cab of the car simulator. The track was projected on the wall in front of the car simulator. V-Amp was used as an EEG amplifier.

4.2 Software Tools

The stimulation protocol was implemented in the Presentation software tool produced by Neurobehavioral Systems, Inc (Neuro Behavioral Systems, 2013). The protocol itself was five minute long. The sequence of stimuli was generated randomly, but it always contained the same number of target, non-target, and rare stimuli. The harmonious tones were generated in the Audacity software tool. The track was prepared using the World Racing 2 game produced by the Synetic Company (SYNETIC GmbH, 2013). There was used the same track as in (Moucek and Rericha, 2012). The BrainVision Recorder (Brain Products, 2013b) was used for recording and storing EEG/ERP data and the BrainVision Analyzer (Brain Products, 2013a) was used for processing raw EEG/ERP data.

4.3 Recording System

Common EEG caps (the 10-20 system defining the location of scalp electrodes) were used depending on the size of the participants' heads. The reference electrode was placed above the nose and the ground electrodes were placed on ears.

4.4 Participants

A group of 11 volunteers, university students (eight men, three women), aged 19-23, participated in the experiment. Table 1 summarizes detailed information about the participants obtained from completed questionnaires.

4.5 Course of Experiment

All participants got all necessary information about the experiment in a written form in advance. Then informed consent was obtained from all participants. Before starting each experiment the participant was familiarized with basic behavioral rules during an EEG/ERP experiment. Then the participant was familiarized with the car simulator controls and with the track, subsequently they were allowed to drive around.

During the experiment the examiner controlled data recording, video recording and activated/deacti-

Table 1: Data about participants (Vision - number of diopters, Hours of sleep - usual sleep/sleep before experiment/sleep deprivation before experiment).

Participant	Gender	Laterality	Vision	Hearing	Driving license	Active driver	Hours of Sleep
1	M	R	-	-	Y	Y	7 / 6 / 4
2	M	R	1.75	-	Y	Y	7 / 8 / 0
3	W	R	-	-	Y	Y	7 / 7 / 0
4	M	R	5	-	Y	Y	8 / 5 / 2
5	W	R	-	-	N	N	8 / 8 / 2
6	M	R	-	-	Y	Y	7 / 7 / 0
7	M	R	-	-	Y	Y	7 / 7 / 4
8	M	L	-	-	Y	Y	7 / 10 / 4
9	M	L	-	-	Y	Y	8 / 8 / 3
10	W	R	-	-	Y	N	6 / 10 / 2
11	M	R	2	-	Y	Y	7 / 7 / 4

vated the stimulation program. The experiment was ended after 20 minutes. The participant left the car stimulator and the examiner asked him/her to fill in the questionnaire containing the questions related to his/her feeling of fatigue during/after the ride.

4.6 Environment

All experiments were performed during February 14 and April 12, 2013 (late winter and spring in the Czech Republic).

4.7 Data and Metadata

EEG/ERP data were recorded with the sampling frequency 1 kHz; no filters were used during data recording. The resulting signal was stored into three files: .eeg file containing raw data; .vhdr file containing metadata that describe raw data in .eeg file, and .avg file containing the averaged signal around the used stimuli. All recorded data, collected metadata, and questionnaires were stored in the EEG/ERP portal (EEG/ERP Portal, 2013). The data are publicly available for registered users.

5 DATA PROCESSING

The recorded EEG/ERP data were further processed using the following workflow:

- Data Filtering: IIR filter was applied to data from the Fz, Cz and Pz electrodes. These three electrodes were also selected for further processing.
- Data Segmentation: The epochs were extracted from datasets, data corresponding to each target stimulus were selected in the time interval (-100ms, 900ms) in the area of occurrence of the target stimulus.
- Rejection of Corrupted Data: The segmented data containing artifacts were manually rejected.
- Baseline Correction: The baseline was corrected using the interval (-100ms, 0ms) before occurrence of each target stimulus.
- Data Averaging: The epochs selected from each twenty minutes long experiment of each participant were averaged and stored Then the grand averages for each of four experimental sessions (morning + usual sleep, afternoon + usual sleep, morning + sleep deprivation, afternoon + sleep deprivation) and for some of their combinations were computed.

The latency of the P3 component was determined using the following techniques:

- Peak Latency: The simplest way to determine the latency of the P3 component is to find its maximum amplitude in the time interval of possible occurrence of the P3 component. This maximum value is referred to as peak latency. However, this measure of peak latency has several shortcomings and is more suitable for the components with a clearly identifiable maximum value. Therefore, two other techniques of latency determination were used in this study (Luck, 2005), (Kiesel et al., 2008).
- Fractional 50% Peak Latency: This technique simply marks the time point, when 50% percentage of the maximum amplitude (this maximum amplitude is not necessarily the true peak amplitude) was reached in the backward direction.
- Fractional 50% Area Latency: This technique works by computing the area under the component over a given latency range and finding the time point that divides that area into halves.

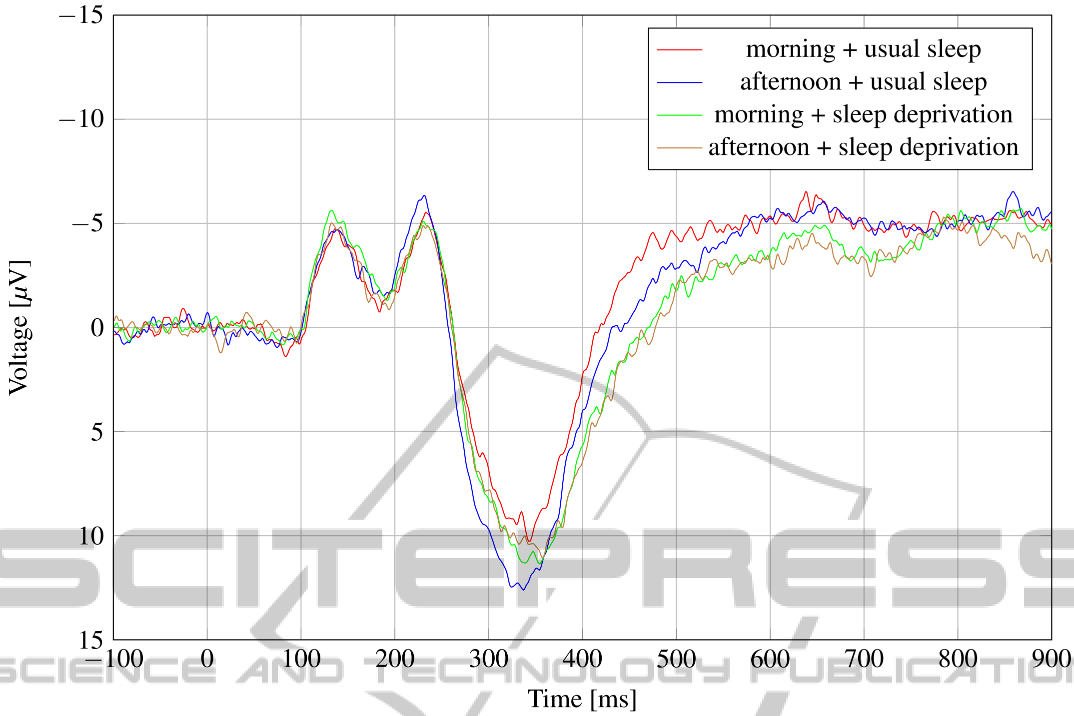

Figure 1: Grand average on the electrode Fz - experimental sessions differ in the daytime and duration of sleep.

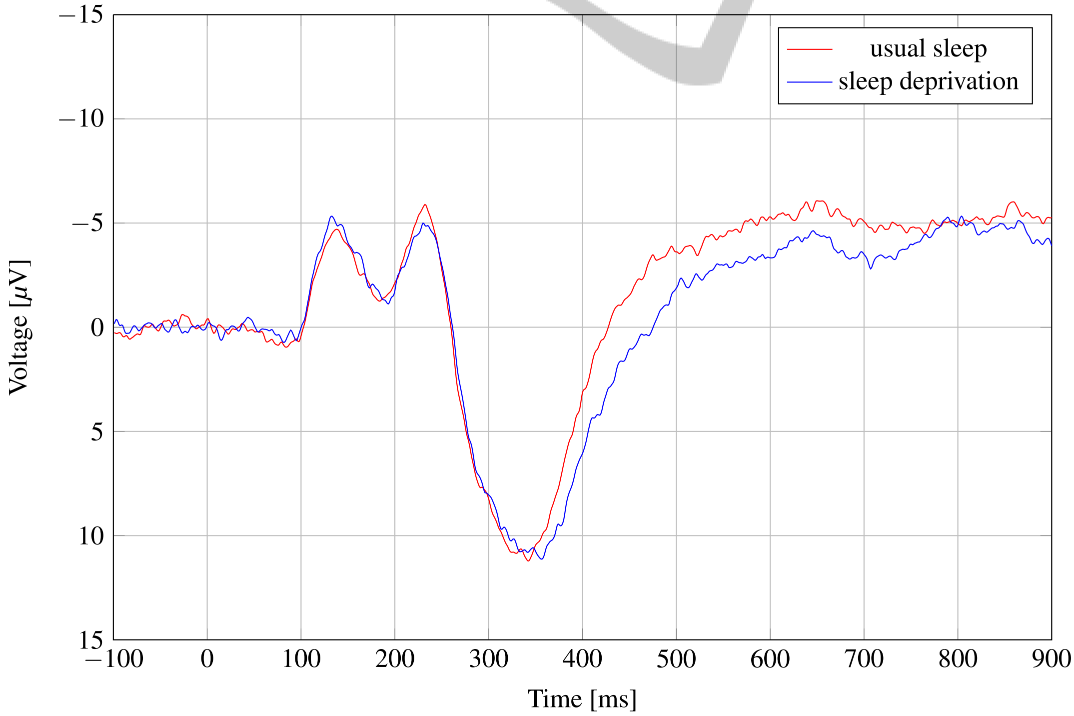

Figure 2: Grand average on the electrode Fz after usual sleep and sleep deprivation.

6 RESULTS AND DISCUSSION

The results from performed experiments are summarized in the figures and tables presented further. The following description is then valid for each figure and table:

Table 2: Latency of the P3 component on the electrode Fz; the peak latency technique applied.

Participant	**Experimental session 1 [ms]**	**Experimental session 2 [ms]**	**Experimental session 3 [ms]**	**Experimental session 4 [ms]**
1	299	271	276	291
2	300	319	316	320
3	296	298	296	289
4	288	278	280	281
5	286	292	290	284
6	294	301	303	303
7	291	284	300	301
8	284	294	304	298
9	291	299	323	315
10	280	281	279	273
11	291	288	289	296
Grand average	*GA1*	*GA2*	*GA3*	*GA4*
	293	295	304	299
Grand average	*GA12*	*GA34*	*GA13*	*GA24*
	293	298	293	298

Table 3: Latency of the P3 component on the electrode Fz; the fractional 50% peak latency technique applied.

Participant	**Experimental session 1 [ms]**	**Experimental session 2 [ms]**	**Experimental session 3 [ms]**	**Experimental session 4 [ms]**
1	333	270	310	323
2	290	283	312	314
3	278	278	272	280
4	270	271	278	263
5	325	291	268	323
6	291	284	289	284
7	269	266	273	269
8	283	265	280	283
9	300	337	320	332
10	269	271	277	268
11	312	314	316	309
Grand average	*GA1*	*GA2*	*GA3*	*GA4*
	286	277	284	282
Grand average	*GA12*	*GA34*	*GA13*	*GA24*
	281	283	284	279

Table 4: Latency of the P3 component on the electrode Fz; the fractional 50% area latency technique applied.

Participant	**Experimental session 1 [ms]**	**Experimental session 2 [ms]**	**Experimental session 3 [ms]**	**Experimental session 4 [ms]**
1	378	363	359	375
2	342	343	361	360
3	336	342	346	353
4	329	324	345	320
5	352	351	321	338
6	341	340	345	351
7	319	318	320	317
8	402	390	339	398
9	328	343	354	361
10	337	330	338	334
11	350	337	347	346
Grand average	*GA1*	*GA2*	*GA3*	*GA4*
	336	333	344	346
Grand average	*GA12*	*GA34*	*GA13*	*GA24*
	335	345	339	339

- Experimental Session 1 - a set of experiments performed in the morning after usual sleep
- Experimental Session 2 - a set of experiments performed in the afternoon after usual sleep
- Experimental Session 3 - a set of experiments performed in the morning after sleep deprivation
- Experimental Session 4 - a set of experiments performed in the afternoon after sleep deprivation
- GAX - the grand average computed by averaging together the averaged waveforms of the participants of the experimental session X
- GAXY - the grand average computed by averaging together the averaged waveforms of the participants of the experimental sessions X and Y

Figure 1 shows the grand averages on the electrode Fz for all experimental sessions and Figure 2 shows the grand averages on the electrode Fz for sessions after usual sleep and sleep deprivation.

Table 2 presents the latency of the P3 component on the electrode Fz using the technique of peak latency. The resulting data were determined manually using Brain Vision Analyzer software. Table 3 and Table 4 show the latency of the P3 component after application of the fractional 50% peak latency and fractional 50% area latency. These latencies were determined by using a custom software application.

It is not possible to mutually compare the latencies obtained by using different techniques. The importance of latency is not in its absolute value but in the difference between the values measured for the experimental sessions described above.

The results did not demonstrate that the latency of the P3 component was influenced by daytime. The assumption that the latency of the P3 component increases with sleep deprivation can be shown on the results from Table 2 and Table 4. However, latencies of individual participants do not confirm this hypothesis when any technique described in this paper is used. One possible reason for this result is that the number of the target stimuli for each participant is too small to get rid of signal noise. This noise is more eliminated when grand averages are computed.

7 CONCLUSIONS

This paper shortly described the experiment that had investigated attention of drivers by using the methods of electroencephalography and event related potentials. Experimental results showed that the P3 component had been clearly identified during all experimental sessions. Despite expectations, prolongation of peak latency in time was not clearly observed when the grand average measure of each participant was investigated. On the other hand, this prolongation was observable when the techniques of peak latency and fractional 50% area latency were applied to compute the grand average for each experimental session. The results are currently not statistically evaluated to provide more detailed information.

In the future, it would be probably appropriate to increase the number of target stimuli (i.e. to prolong the drive) to get more evident results from individual participants.

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