Influence of Mental Load on Driver's Attention

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ABSTRACT: This paper deals with influence of mental load on drivers' attention. EEG (electroencephalography) and ERP (event related potentials) techniques are used for investigation of the level of the drivers' attention. A short overview of experiments dealing with drivers' attention is given and the ERP technique and the P3 component are described. General assumptions related to P3 amplitude and P3 latency are introduced. Then the experimental design and the course of the experiment are described. The resulting EEG/ERP data are analyzed and their interpretation is provided.

KEY WORDS: event related potentials (ERP), driver, mental load, attention, P3 component.

1 INTRODUCTION

Our research group at the Department of Computer Science and Engineering, University of West Bohemia, in cooperation with other partner institutions (Czech Technical University in Prague, University Hospital in Pilsen, Škoda Auto Inc., amongst others), specializes in the research of attention, especially the attention of drivers and seriously injured people. We widely use the methods of electroencephalography (EEG) and event related potentials (ERP). Within our partner network we are responsible for technical and scientific issues, e.g., EEG/ERP laboratory operation, the development of advanced software tools for EEG/ERP research, or the analysis and proposal of signal processing methods.

In this paper we focus on the influence of the mental load on the drivers' attention. The ERP technique and the P3 component are used for developing an experimental design related to this issue. A set of testing subjects (university students) was selected to undergo an EPR experiment and their results were analyzed and interpreted.

The remainder of the paper is organized as follows: Section 2 gives a short overview of experiments dealing with drivers' attention and summarizes the basic principles of ERP technique and the assumptions related to P3 amplitude and P3 latency. A description of the experimental design is given in Section 3. Experimental results and their interpretations are provided in Section 4; they are followed by introducing the necessary modifications of the scenario used. Section 5 comprises of concluding remarks.

2 STATE OF THE ART

This section provides a short overview of the published EEG/ERP experiments, which deal with the attention of drivers. Basic principles and advantages of the ERP technique and the P3 component are then introduced. The relation of P3 amplitude and P3 latency to attention is described.

2.1 Previous Research Dealing with the Attention of Drivers

Several methods exist in order to examine the attention of drivers. A lot of experiments use so-called behavioral methods (meaning that the behavior of the driver under certain conditions is investigated – e.g., how often he/she leaves his/her lane), while some experiments use EEG and ERP techniques.

The paper "Changes in EEG alpha power during simulated driving" (Schier, 2000) deals with the suitability of EEG-based techniques for recording drivers' activity during a driving simulation task. As the result, an increase in alpha activity was interpreted as less attentional activity and a decrease as more attentional activity. Significant differences between drivers were also observed.

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, the performance of the driving task and this secondary task are both unaffected. However, analysis of brain activity showed reduced cortical processing of irrelevant, and potentially distracting, stimuli from the secondary task during driving.

2.2 Event Related Potentials

ERPs were first used as an alternative to measurements of the speed and accuracy of motor responses in paradigms with discrete stimuli and responses. ERPs 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; for a detailed set of examples see (Luck, Woodman & Vogel, 2000). The second advantage of ERPs is that they can provide an online measure of the processing of stimuli even when there is no behavioral response (Luck, 2005).

2.3 P3 component

The P3 component (which is an endogenous component) depends entirely on the task performed by the subject and is not directly influenced by the physical properties of the stimulus. The P3 component is sensitive to a variety of global factors, such as time since last meal, weather, body temperature, and even time of day or the time of year (Luck, 2005).

Thousands of experiments related to the P3 component have been published; however, we still do not know exactly what the P3 component really means. In general, the proposal that the P3 component is related to a process called "context updating" seems to be approximately correct (Luck, 2005).

However, the factors which influence the amplitude and the latency of the P3 component are known. First of all, the P3 component is sensitive to the probability of the target stimulus. P3 amplitude increases when the probability of the target stimulus class (not the probability of the target physical stimulus) decreases. The amplitude of the P3 component also becomes larger when it is preceded by a greater number of non-target stimuli. P3 amplitude is also larger when the subject pays more attention to a task. On the other hand, P3 amplitude is smaller if the subject does not know whether a given stimulus is / is not a target. This means that more difficult tasks can increase P3 amplitude, because the subject pays more attention to these tasks and simultaneously decreases P3 amplitude as the subject is not certain of the stimulus category (Luck, 2005).

Ideas and assumptions related to the latency of the P3 component are again associated with stimulus categorization. If stimulus categorization is postponed (this also includes increasing the time required for low-level sensory processing), P3 latency is increased. While P3 latency depends on the time required for 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 the processes related to a response. P3 latency is also postponed if the perception of stimuli is impaired (Luck, 2005).

3 EXPERIMENT DESCRIPTION

This section provides information about the objectives of the experiment and experimental design in detail.

3.1 Objectives of Experiment

The general assumptions described in Section 2 are taken into account in our study. The objectives of the experiment are to:

- Examine if a more difficult track with sharp turns and collisions with an oncoming car can be used as target stimuli for the P3 component elicitation (P3 amplitude is especially examined).
- Compare the latency of the averaged P3 component for two groups of drivers; one group of drivers is unaffected by alcohol, while the level of alcohol in blood reaches 0.5 mills in the second group of drivers.

3.2 Data Acquisition Conditions

The following experimental conditions were met (and devices were used) for data acquisition:

- All experiments were performed in the neuroinformatics laboratory (the quiet room) equipped with an experimental car-simulator (the front part of a real car; wheel, accelerator, and brake were connected to the computer).
- Drive's view was powered by Virtual Battlespace software (VBS) projected on the projection screen.
- EEG cap with the 10/20 system was used; Fz, Cz, and Pz electrodes were selected for data acquisition; a reference electrode was located near the Fz electrode; A1 and A2 electrodes (ground) were placed on ears.
- Brain Amp recording device synchronized with VBS was used (sampling frequency was set to 1 kHz).

3.3 Experimental Design

The experimental design has to take into account constraints resulting from the ERP technique and the P3 component described in Section 2. Moreover, occurrence of artifacts (which are common in EEG/ERP experiments) is more intensive than in the case of common experiments, due to the natural movements of the testing subject during driving simulation.

Two different stimuli evoking the P3 component were defined:

- Sharp turns. The driver is asked to negotiate these turns in his/her direction without leaving the track.

- Passing an oncoming vehicle. The oncoming vehicle does not keep precisely to its direction. The driver is asked to try and avoid a collision without leaving the track.

The next step included construction of a test track (Figure 1) according to the stimuli presented above. There are eleven sharp turns and four places where oncoming vehicles appear on the test track.

Figure 1: Test track (highlighted in red color), turns (highlighted in yellow color) and passing of oncoming vehicle (highlighted in blue color).

The set of testing subjects comprised of seven males and two females between 23 and 30 years of age. All of them were right handed and had no visual or auditory defects. Only one of them did not have a driver license (however, the subjects had enough time to learn to control the car simulator).

Each testing subject was informed about the experiment's scenario in detail (they knew that sharp turns and oncoming vehicles were the target stimuli in the simulation). They had enough time to get familiar with the test track and the car simulator. After this preliminary phase the main experiment started. The subject completed the test track and simultaneously the EEG/ERP signal was recorded. The same experiment was repeated the next day (to eliminate fatigue), but the subject was affected by alcohol. The level of alcohol in the blood reached approximately 0.5 mills (a certified alcohol tester was used). The testing subject had enough time to become familiar with the test track and the car simulator again. The main experiment was then performed with the same parameters.

4 RESULTS

It is to be supposed that the drivers' attention reaches maximum values at the beginning of the drive, and then decreases during driving. For this reason the first collision with the oncoming vehicle and the fourth sharp left turn were selected for a detailed analysis. The first collision is supposed to invoke the largest P3 amplitude, as the testing subject is not yet accustomed to the collisions.

The collected data were divided into epochs (each epoch starts 200 ms before stimulus onset and ends 1000 ms after stimulus onset). Epochs were preprocessed; the methods of artifacts rejection, baseline correction and filtering (IIR low pass filter with high cutoff set to 40 Hz) were used. The grand average of both groups of testing subjects (affected/

unaffected by alcohol) was computed separately for the first collision and the fourth sharp left turn.

Due to the montage used (the reference electrode is located near the Fz electrode) and the supposed occurrence of the P3 component on the scalp, the Cz and Pz electrodes were selected for the analysis of the P3 component occurrence. The Pz electrode was selected for the presentation of the results. Figure 2 provides the grand average waveform for the Pz electrode and the fourth sharp left turn.

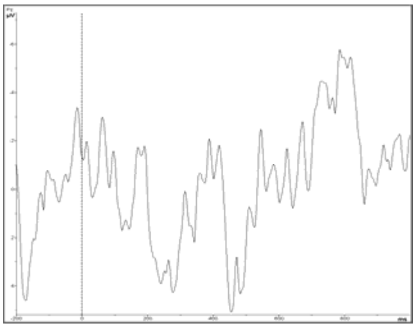

Figure 2: The grand average waveform - the fourth sharp left turn (the Pz electrode, testing subjects are not affected by alcohol).

According to our assumptions the P3 component should be visible in the time range between 300 and 400 ms. However, looking at Figure 2 there is no positive wave similar to a P3 component within the defined time range. Moreover, the averaged signal in the depicted time range (Figure 2) contains several waveforms with a higher frequency. This leads to an idea that the experimental design is too difficult for the use of the ERP technique. The first collision and the fourth sharp left turn were probably not well categorized as target stimuli by the test subjects. This also means that the mental load placed on the test subjects cannot probably be supposed as the same one (or similar) and therefore cannot be easily recognized and interpreted.

Since the P3 component was not recognized in the averaged waveforms, we cannot say anything about the differences in the latency of the P3 component looking at grand average waveforms for the two groups of test subjects (affected/ unaffected by alcohol). However, comparing the grand average waveforms for these two groups, the same trend in the ERP waveforms can be seen. Figures 3 and 4 show this trend for the Pz electrode in the case of the first collision and the fourth sharp left turn consequently.

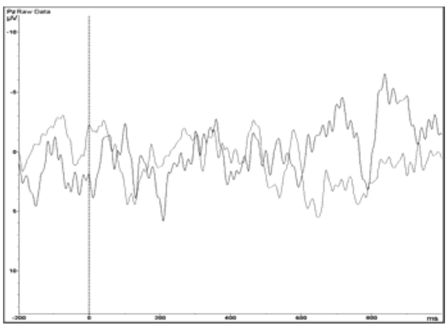

Figure 3: Two grand average waveforms - the first collision with an oncoming vehicle (the Pz electrode; the black line waveform - testing subjects are not affected by alcohol, the red line waveform - testing subjects are affected by alcohol).

The similar results (the P3 component was not detected) were also observed for other collisions and sharp turns. As a consequence, we have proposed a simpler experimental scenario. The target stimuli are no longer a part of virtual world, but are evoked by external hardware devices (blinking diodes or sound generators). The preliminary results of the experiments that we performed using the new experimental design showed that the P3 component was easily observable in the averaged waveforms.

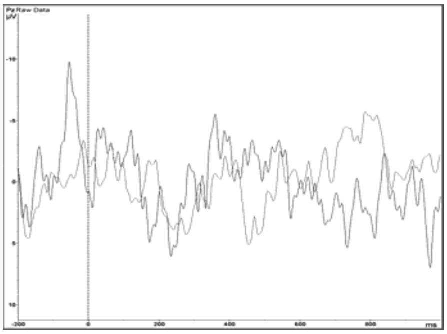

Figure 4: Two grand average waveforms - the fourth sharp left turn (the Pz electrode; the black line waveform - testing subjects are not affected by alcohol, the red line waveform- testing subjects are affected by alcohol).

5 CONCLUSION

In this study we proposed an experimental design for investigating the influence of mental load on drivers' attention. The ERP technique was used to perform experiments on a set of test subjects. The results did not prove the occurrence of the P3 component in the grand average waveforms. We observed a similar trend of the grand average waveforms for two groups of test subjects (affected/ unaffected by alcohol). Since the proposed experiment was most probably too complex, we proposed a new experimental scenario and performed the preliminary experiments, which provided more successful results.

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