

Brain Waves Measurement Based Evaluation of Mental Workload Related to Visual Information While Driving

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ABSTRACT

In order to build a useful and comfortable in-car human machine interface systems, the information presentation method should be easy to understand (low mental workload) and one should be able to respond with ease to the information presented (low response workload). We are making efforts to establish an evaluation method that would differentiate between mental workload and response workload. Here, we present the results of our trial using brain waves measurements (Eye Fixation Related Potentials). We focus on the relation between P3 latencies and drivers response workload compared to mental workload in a task involving eye movements. Previous experiments showed that P3 latency correlates strongly with the amount of information presented. The current experiment shows that P3 latencies seem to be independent to the type of response the subject is requested to perform. When asked to push a button with their right hand after detecting a Landolt ring pointing right, subjects react faster than when pressing the button with their right hand in response to a ring pointing left. The same situation is replicated whether the subjects is presented the visual stimulus in the center of their visual field, or a driving scene video is played in the center and the target stimulus is presented in a lower left position similar to in car navigation systems display position. In both situations P3 component latencies are similar. While needing to expand the experiment to a larger number of subjects, and to improve the measurements method for higher stability, this experiment combined with our previous findings show that P3 latencies seem to be a good independent measure for cognitive workload.

INTRODUCTION

Due to the continuous development of IT/ITS, a large variety of information is available in the car, and drivers can use a larger and larger amount of information. Yet, the amount of mental resources that the driver can allocate for information cognition and information systems usage is limited., mainly because the main task remains the driving task. So it becomes more and more important that in car information systems, like navigation systems and such, are both easy to understand and also easy to operate.

We believe that in order to develop easy to understand (low mental workload) and easy to operate (low response workload) Human Machine Interfaces (HMI), it is important to differentiate between the mental workload related to in car information systems and the workload generated by the driving task, and also it is important to be able to evaluate separately the mental workload and the response workload of the HMI system.

In this research we evaluate the possibility of using the latency of the P3 component of Event Related Potentials obtained from brain waves as a independent measure for in car information systems related mental workload. Since, when performing brain waves measurements related to visual information processing, the eye movements generate large artifacts, in most cases, the addressed visual stimuli are presented in the center of the subjects visual field. In this research we aim to develop a measurement method that could be also used in real environments so we present the visual stimuli on a screen placed in a lower left position similar to in car navigation systems display position and allow the subjects free eye movements.

RESEARCH BACKGROUND

Brain waves (Electroencephalogram: EEG) measurement stands for measuring the electrical activity that is generated by the firing of the neurons within the human brain using electrodes placed on the scalp's skin. A largely deployed analysis method of the recorded brain waves signals is frequency analysis. Another method is observation of Event Related Potentials (ERP) obtained by averaging together the signals from several trials where the subject is presented the same stimuli. ERP's are temporary brain activities generated potentials that are elicited by a certain internal (thought, body movement) or external stimuli (light, sounds). Since each response amplitude is small and is recorded with thousands of simultaneously ongoing brain processes, in order to observe ERP's one needs average the signals from several recordings so the activity regarding the stimuli presented is amplified and all other activities are leveled out[1]. Depending on the brain area where it can be observed, on the latencies and also on the type of stimuli, there are several ERP components defined. The third positive peak which can be observed at about 300~600 ms after the stimuli is called P3 or P300[2]. There are several research reporting the correlation between P3 and cognitive activities [3] and in this research we also focus on P3 component.

Furthermore, in the category of ERP related to visual stimuli in a free eye movements experimental setting, Eye Fixation Related Potential (EFRP) [4] is obtained by using the moment the eyes have stopped on the stimuli as the trigger for averaging. For evaluating the cognitive process of a driver while using an in-car information system, we focused on the P3 components of EFRP, especially on the P3 latencies. We looked into the correlation between P3 and mental workload in an attempt to gain more deeper information, like mental workload evaluation independent to response workload, than what one would obtain from simply measuring response times.

VISUAL INFORMATION RELATED MENTAL WORKLOAD

Response time to a certain stimulus is often used as a measure of the driver's mental workload related to that specific stimulus. But, as it is widely known, when presented a stimulus the driver detects it, interprets (cognition) it and in the end moves his body (response) and some of this detection, cognition, response processes take part in parallel. So the response time is a good evaluator for this processes together, as a whole, but gives us no hints whether the information presented as stimulus is easy to detect (detection workload), or easy to understand (cognitive workload), or even whether it is easy to respond (response workload) or not. In the development process for visual information systems, being able to individually evaluate the detection workload, the cognitive workload and the response workload

would let us know which one of these three features could be further developed and which one is achieving high performances. Such knowledge would highly accelerate the developing process.

This research is an attempt to deploy P3 component's latency as an individual measure for cognitive workload. In previous reports, the P3 latency is increasing when the amount of information presented as stimuli increases, hinting that P3 might be a good measure for cognitive workload. The same increase was observed when the information type and complexity increases (Landolt Ring, Letters, Numbers, Shapes) [5]. Also, in an experiment where the amount of information was constant and only the response workload changed, P3 component was observed in a setting in which subjects' eyes do not move and the stimulus is presented in the center of the visual field (ERP setting). In this case P3 component latencies are fairly constant suggesting independence to response workload. [6]

In this report we try to get closer to real in car measurement environment, by allowing the subject free eye movements and using eye fixation timing as triggers for measuring P3 component of EFRP. We report the results of measuring EFRP's P3 component latencies in different response workload tasks.

EXPERIMENTAL METHODS

An simple driving simulator was used in a setting as presented in [Figure 1](#). A 100" screen was used to present the subject the driving scene using an LCD projector. Furthermore, a 7" LCD screen was placed in a position similar to the one of the in car navigation system position.

We used two tasks with different response workload, similar to the ones used in our previous report[6] On the LCD screen a Landolt ring with an opening pointing left, right, up or down ([Figure 2](#)) was presented. The rings with an opening to the left or right are to be targets (the subject needs to respond) and the ones pointing up or down are non-targets (the subjects will ignore them)

In a task that we call "Straight Task" the subjects were asked to respond with the hand on the same side to the direction of the stimuli. That is, to respond with their right hand when the stimuli points right and to respond with their left hand when the stimuli points left. In the other task, which we call "Cross Task" the response should be performed with the hand on the opposite side to the direction the stimuli points to. This combination of tasks makes up for a "Simon Effect" setting. The Simon Effect is observed when one aspect of the stimulus (in this case the correlation between the direction of the ring opening and the hand to respond with) interferes with the aspect of the stimulus (in this case, the shape of the ring) that is to be taken in consideration for performing the task.

Due to this interference response times in the Cross Task are expected be longer than for the Straight Task [7].

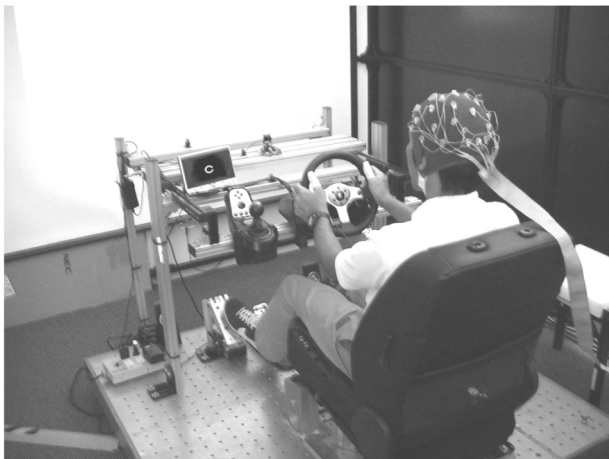


Figure 1. Experimental setting

For each task the stimuli in Figure 2 have been presented, in total, for 100 times. In order to make an Oddball paradigm, we used non-targets for 70 times and targets for 30 times. Oddball paradigm is known to help increasing the P3 amplitude correlated to target stimuli, when the subjects is presented with a low appearance frequency target stimuli and a high appearance frequency of non-target stimuli, being asked to count or respond by pressing a button for target stimuli. [1,4]



Figure 2. Example of presented visual stimuli

Each subject performed each task 2 times, in total 4 measurement sessions. Also, the order of performing the tasks has been changed between subjects to avoid order effects. Stimuli were presented for 1 second followed by a 2.0±0.5sec. random interval.

On the wide screen a video presenting the front view of computer-simulated driving scene was projected and the subjects were instructed to survey the video. Only when a stimuli would be presented on the small LCD screen the subjects would move their eyes on this small screen and, if a target would be detected, they were instructed to push the buttons placed on their thumbs (Figure 3) according to the task performed. The view angle of the Landolt ring was adjusted to a narrow enough value so that one could not make out where it points at only with peripheral vision and would have look at the LCD screen in order to make a decision.



Figure 3. Response Switches

An AD-box and an USB2-Receiver produced by Biosemi were used to record the timing of the stimuli and the subjects' response signals from the switches. Brainwaves were measured using a Biosemi 32 active electrodes and a 10/20 configuration cap. Also in order to record EOG signals electrodes were placed above and below the right eye and on the 2 temples of the subjects. As a reference we used a left ear lobe placed electrodes. All signals were synchronously recorded at 200 Hz sampling rate.

EXPERIMENTAL RESULTS

5 informed consent subjects participated in this experiment. They all reported that they have normal visual acuity and are right handed.

Measurements were performed for both right hand and left hand responses, but since there were no major differences in response times, number of mistakes or EFRP, here we present only the result for right hand responses.

RESPONSE TIME, EYE FIXATION TIME AND RESPONSE ACCURACY

In Table 1 the number of wrong responses (number of mistakes) for the 5 subjects is presented.

Table 1. Number of mistakes.

Task	Straight	Cross
A	1	2
B	0	0
C	0	3
D	1	3
E	0	2

Since the task was fairly easy there were only 2 subjects making one mistake each for the Straight Task. Even for the Cross Task there were only a few mistakes but 4 out of the 5