Simulation Framework for ERP Experiments

Jiří Coufal and Martin Mojžíš

Abstract— **This paper addresses a problem of conducting experiments helping us to reveal connection between level of vigilance and individual's brain activity. In our experiments we measure the brain activity with use of encephalography, specifically analysis of event related potentials. It is a response of the brain on an external stimulus manifesting itself with alteration of EEG signals. Our laboratory for experimentation has been established and equipped with state-of-the-art EEG recorder. The actual experiments use number of supporting software. First of them – the most simple one is ERP Scenario. It provides stimuli for our test subjects allowing us to study their ERP response. For advanced experiments involving vehicle driving activities we use flexible and complex simulation software. It is able to simulate various real life traffic situations. We can create and modify scenarios fitting to needs of particular experiment. It is possible because of user friendly point and click scenario editor and powerful scripting language. One of them involves driving on a straightforward monotonous road. The ride is occasionally interrupted with sudden appearing of an obstacle in front of the driver. Simulator is easy to control and provides no distraction for the tested subject. The level of vigilance is determined by interval between moment, when obstacle shows up, and brain response. The interval provides feedback affecting the course of the experiment. Its effect on the experiment is also subject of research.**

I. Introduction

In this paper, we present simulation environment specialized for designing event related potentials (ERP) experiments. Framework can be used for designing simple scenarios specialized on ERP components extraction. Also it is suitable for experiments based on real life situation.

Some of them deal with the important problem of today – driving safety. States of reduced vigilance caused by long monotonous driving are often the main cause of traffic accidents [1]. The main purpose of our framework is to run the driving simulation and provide data for further analysis and evaluation of person's attention.

II. Simulation Framework

A. Simple experiments

First part of the framework is an application called ***ERP Scenario***. More information about the program itself can be found at [4]. It can be used for conducting simple experiments, i.e. presenting two letters (O, Q) to a subject and monitoring appearance of P3 (response to the unpredicted stimuli - positive deflection in voltage approximately 300 milliseconds after the stimulus is presented) component in the signal as the response to the stimuli – subject is instructed to count the occurrence of the target stimuli. All experiments are using averaging of several epochs to obtain data with reduced noise.

1) Experiment for reading the number from mind using P300

An experiment for trail run and illustration has been designed. Subject is asked to pick a number from zero to nine. Then each number of that range is displayed on the screen repeatedly in random order. Subject is instructed to count the occurrence of his/her number.

An experiment had been conducted with 20 testing subjects, so far. The correct number was revealed at 17 subjects.

P3 component is distinct within the averaged waveform of EEG when the number chosen by the subject appears (Fig. 1a). Other averaged signal courses contain no sign of P3 component (Fig. 1b).

Figure 1 shows the result of an experiment. As written in previous paragraph, figure 1a shows signal with P3 wave present (signal has a significant wave in positive numbers – be aware, positive numbers are down to the graph). Part b) shows signal without a presence of P3 wave. Stimuli

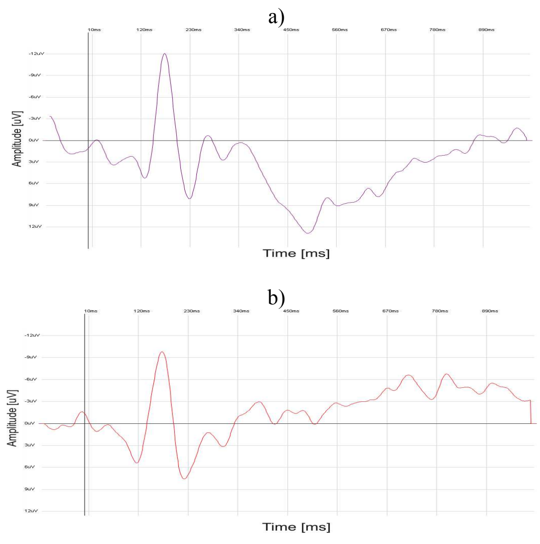

Fig. 1: Result from experiment using P3 wave to detect the selected number by the subject.

J.Coufal, Department Of Applied Sciences, University Of West Bohemia, Pilsen, Czech Republic (jcoufal@kiv.zcu.cz)

M. Mojžíš, Department Of Applied Sciences, University Of West Bohemia, Pilsen, Czech Republic (mojzis.@kiv.zcu.cz)

(number) evoke signal with the presence of P3 in case the number is exactly the one, subject has selected in his/her mind. It means, we are able to tell the number according to readings like from Figure 1.

B. *Real life simulation*

1) *Virtual Battlefield Simulator 2*

Driving experiments demand specialized authentic real life simulation. We are using military simulator Virtual Battlefield System 2 [5] (VBS2) developed by Bohemia Interactive. The system is used by the Australian Defense Force to simulate real time combat simulations.

VBS2 contains simple point and click scenario editor with maps and various objects and vehicles ready to use. When using predefined objects, the simple scenario is easy to master.

Creating a scenario can be summarized in few steps.

1. The map is selected according to needs of experiments. It resembles real environment.
2. Vehicles, player and optional AI characters and additional objects are inserted and positioned.
3. Triggers are placed into the map at locations where particular actions are required. For example triggers allow creating synchronization impulses when the player clicks the button.
4. It is possible to control the day time and weather conditions of the simulation. It is opening the new dimension for creating scenarios – an experiment can be moved from a day light to the storm or night by the simple click.

VBS2 editor offers following useful features:

- It is possible to select a type of vehicle the subject is driving; even planes and helicopters can be used. Movement on foot is also available.
- Additional objects, such as obstacles, inserted to the scenario approach the experiment closer to the reality. Other AI driven characters and animals with specified behavior model can be easily inserted to the map.
- Movement trajectory can be pinpointed by waypoints inserted positioned into the map. Settings at each waypoint specify the behavior of AI (if the AI goes straight or avoids any obstacles). AI controlled objects can be assign into formation. It is useful for example for simulation driving in convoy or simulating the traffic-jam.
- Displaying information message or playing an audio signal when particular event occurs.
- There are advanced possibilities to control every aspect of the scenario with its integrated scripting language. For example it allows a communication with other programs.

It is possible to involve artificial intelligence for making the experiment more realistic - cars, actors acting according to script, but driven by AI. A scenario sometimes takes much more than 20 minutes. If we use scripting for controlling for example cars on the road, we will need long script to control it. But, we can use AI controlled driver in the car. In this case, scripting is replaced by selecting few waypoints on the maps for navigating the AI driver. In this case the simulation will be more realistic, because every time the simulation will be slightly different – just because of the ambiguity in the behavior of AI.

Using the artificial intelligence could provide advanced

We can implement and use the possibility to control the simulation from another computer. This can be used for remote supervision of the experiment.

2) *A-Drive driver*

EEG recording requires a synchronization of stimuli time in the simulation with the time in the recording device. VBS2 is not able to communicate directly via parallel port. It is the reason why we have created special driver allowing us to send a synchronization marker from the simulator to EEG recorder.

The driver simulates virtual disc drive. If some program accesses a file on it, it sends the synchronization impulse through the parallel port – a byte sent to port is a number given as a file name of the accessed file.

A-Drive can be used by any program – not only by VBS2 or programs from our framework.

There is a problem that the operating system caches the content of accessed file and doesn't attempt to read from the virtual drive. The problem was resolved by changing the file name with every access. Appending a unique suffix to the filename will provide sufficient solution for this problem.

A-Drive allows us to send synchronization markers when the stimuli occur in scenario player or in the simulation. This marker is saved together with raw EEG data and during the phase of processing the markers is used for detection of events within the EEG data. Marker is composed from description (type of stimuli) and time of stimuli occurrence.

C. *Recording*

We use a state-of-the-art EEG recording device called BrainAmp DC. The most important feature of the device is an availability of 16-bit binary input array for synchronization markers.

The device includes a battery pack with enough energy for up to 20 hours allowing us to conduct experiments outside the laboratory environment.

D. *Online communication, feedback*

The BrainAmp device is supplied with its own software allowing us to read data recorded from the EEG device online. It is possible to visualize the signal and apply simple or sophisticated filters on the incoming signal.

The acquired data can be immediately passed to the recognition software. Our colleagues are working on analysis methods and their modules are going to provide feedback data. We can use the data to alter a course of the scenario.

When experimenting with the simple artificial scenarios the choice of presented stimuli can be different. If a particular stimulus evokes no response, it is not desired to present it again. Such element allows is to assume and evaluate usefulness of the experiment while it is still conducted. The on-going research in the area will be built on results of our teams studying methods of signal processing.

III. Experiment

There are studies (i.e. [2]) describing connections between level of vigilance and event related potentials. Our experiment consists in car driving simulation while the brain activity is recorded. In order to cause the attention decline as quickly as possible, the simulated road is straight and most of the time there are no additional distractions to the driver.

The monotonous driving is regularly interrupted with an obstacle appearing in front of the car. Recorded brain response in moment when the obstacle appears and difference among such responses in various points of the experiment are subject of further analysis.

A. Design of experiment

Tested subject is driving a vehicle on the straight road. There is a minimum of distracting objects, but the scene is as real as possible.

Once in a randomly chosen interval an obstacle appears twenty meters in front of the car. The subject is instructed to press the button on his/her control device when the obstacle is spotted. After clicking the button, the obstacle vanishes and driver is able to continue unobstructed.

To keep the simulation running without difficulties, some additional attributes needs to be included:

- Driver is automatically relocated to his starting point when he/she reaches the designated end of the road. Because of that it is possible to have straight road without turns. If the starting and ending point on the road are precisely positioned, the subject doesn't recognize his/her instant relocation. When subject come close to an invisible end of the road marker, distance and heading of the vehicle are measured relatively to the invisible marker and the vehicle is positioned to the starting point in the same distance and in the same heading.
- There is possibility for the player to get out of the vehicle and walk instead. This undesirable feature has to be disabled in the scenario.
- Automatic repair of the car and immortality of the player in the simulation in case of accident.

B. Communication with EEG, Markers

There are events in the simulation that need to be synchronized with EEG recording. We use synchronization impulses in following actions:

- Every 15 seconds of the simulation
- When subject clicks the button. This is the first possible monitored variable.
- When obstacle appears on the screen. This is a start reference time for measurement other variables.

Synchronization marker connected with appearing obstacle changes its ID during the experiment because we need to evaluate the difference between ERP reactions in the response during the experiment progress. The ID increases when the subject passes fifteen obstacles. When the obstacles appear in 50-70 seconds long intervals, it makes 15 minutes of experiment per for a block of impulses with same ID. It means that subject's vigilance level is monitored and compared in fifteen minutes long blocks.

C. Possible variables

The experiment is focusing on three possible variables.

First of them is an interval between point when the obstacle appears and clicking the button. This reaction time is indicated as the main variable *Rt*. The P3 response latency and amplitude difference are assigned to every sample of reaction time - variable *Rt*.

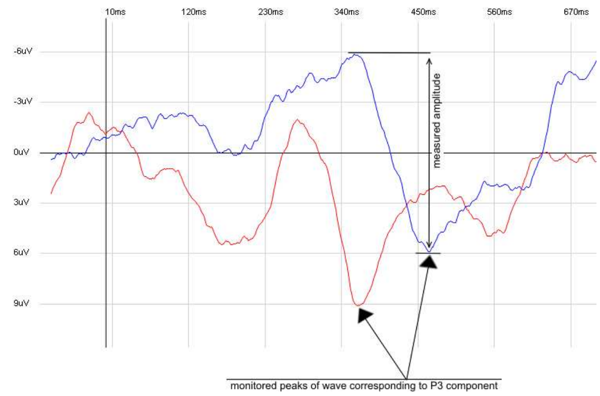

Fig. 2: Variables within the EEG averaged signal an experiment is focusing on.

Second one is an interval between the obstacle showing and the peak of corresponding P3 component - the brain response to the obstacle recognition. The third observed variable is the difference between the peak of P3 component and the preceding peak. Mentioned variables are highlighted on Fig.2. One can see the difference between the latency of similar waves between two different signals. This latency shift will be discussed in conclusion.

D. Further experiment modifications

An improved experiment will fully use possibilities of online communication between the simulation and the EEG recording device. Scenario will include the element of feedback. Mentioned variables in section III.B will be passed to the processing software [6]. The algorithm from [3] could be used for the detection the presence of P3 component.

The result foreshadowed feedback will cause possible alteration of the simulation/scenario:

- Modification of interval between obstacles showing up.
- Audible signalization to driver.
- Turning the radio on or off.

IV. RESULTS

Relation between the reaction time of clicking the button and reaction time of brain response in a form of P3 component wave is shown on figure 3. The latency of monitored peak seems to be increasing with the increasing reaction time. Graph shows the dependence of P3 wave latency and reaction time to the stimuli of the subject.

P3 corresponding component wave appears to be sensitive to the level of tiredness and the level of vigilance. State of vigilance can be tightly linked with boredom and stereotype.

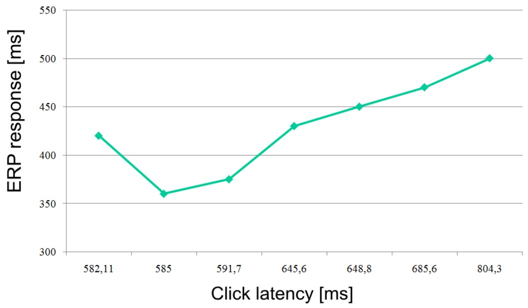

Fig. 3: P3 component wave peak latency

More experiments are going to be done to support the idea – results will be presented in paper dealing specifically with this subject. But, we believe using a latency shift could be used in our future vigilance level detector for drivers.

Post experimental interviews with subjects were conducted. They stated they ran into stereotype and felt the prolonging reaction time themselves. Drivers in real life suggested that simulation was not making them feel the potential danger of life-threatening accident. Thereby their level of vigilance dropped more quickly than in a real car.

Figure 4 shows results of difference between peaks – detailed information about variable in III.B. The [2] study suggests the amplitude of P3 peek should be decreasing. According to the Fig.4 not a big decrease of amplitude is present. Amplitude has a slight tendency to decrease with increasing reaction times (decreasing state of vigilance). According to our measurements the difference is too small and we can't confirm the result from [2]. Because of the small difference of amplitude between states of vigilance, no future use of this attribute is planned.

V. CONCLUSION

Technical challenges were worked out as well as the programming ones. The simulation framework proved itself as suitable tools for both simple and more complex experiments. Simulation software VBS2 included into our framework is definitely worth its reasonable price.

A model experiment in section III proved again the usefulness of the framework and placed basics for the future work:

- Watching and improving the driver's attention level experiments.
- Analysis and treatment of post traumatic conditions of soldiers experiencing combat missions – running the simulation of their combat encounter while their brain activity is being recorded.

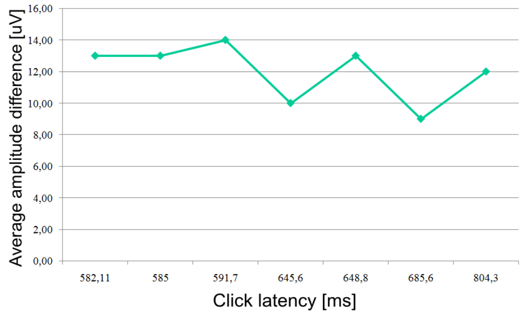

Fig. 4: Average P3 component amplitude difference

Simulation environment will help us to perform more realistic and more sophisticated scenarios in the future. It will help us to extract the main features and patterns within the EEG signal and hopefully will lead to the prototype of vigilance level detector.

The second contribution will be in medical area – a communication with disabled patients. These people can't move and speak, but their intellect is intact. Our framework could help them to communicate with the world.

VI. REFERENCES

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